

Heathkit of the Month #114:
by Bob Eckweiler, AF6C



AMATEUR RADIO - SWL – and –
ELECTRONIC TEST EQUIPMENT

Heathkit IP-2715
Battery Eliminator

Introduction:

The Heathkit IP-2715 (Figure 1) is a 12-volt battery eliminator that can also function as a power supply for ham equipment requiring well regulated 13.8 VDC. Heathkit sold three power supplies, designed for the SB-104(A) and HW-104(A): the HP-1144 (circa 1974 -- 1978), the HP-1144A (circa 1978 - 1979 and the PS-1144 (circa 1979 - 1982). They share a lot of common circuitry and parts with the IP-2715, including the power transformer, bridge rectifier, filter capacitors, and partially the pass transistors and regulator IC^{1,2,3}.

The IP-2715 Battery Eliminator:

The IP-2715 was introduced in the Spring 1976 catalog (#808) for \$134.95 (see Figure 2), and remained in the catalog until 1984 when it was replaced by the IP-2760. At the end it was selling for \$169.95, the same price as the IP-2760 was at its introduction. The specifications for the IP-2715 are shown in Table I.

There are only three controls for the IP-2715. They are located along the bottom third of the front panel and are (L to R) the **VOLT-**

Heathkit IP-2715 Battery Eliminator



Figure 1: Heathkit IP-2715 Battery Eliminator

AGE ADJUST potentiometer, the **POWER** toggle switch marked **OFF - ON**, and the **LOAD** toggle switch marked **STBY - NORM**. To the right of the **LOAD** switch are the red and black output binding posts marked with a **+** and **-** sign respectively. The upper two-

Specifications for the Heathkit IP-2715
Variable Isolated AC Supply:
From Heath Manual 595-1845-06

Output Voltage:	Variable from approximately 9 to 15 VDC.
Output Current:	20 amperes intermittent , 12 amperes continuous.
Output Ripple:	Less than 1% at full load.
Output Regulation:	Less than 2% variation from no load to full load.
Power Requirement:	110 to 130 VAC, 7 amps; or 220 to 260 VAC, 3.5 amps 50/60 Hz maximum
Fuses:	7 ampere, 3AG, slow-blow primary. 20-ampere, 3AG, output.
Maximum Continuous Operation:	See chart on page 2
Net Weight:	26 lbs. (9.7 kg.)
Overall Dimensions:	5 ¼" H x 11" W x 11" D (13.34 cm x 27.9 cm x 27.9 cm)

TABLE I

Here is a link to the index of Heathkit of the Month (HotM) articles:

http://www.w6ze.org/Heathkit/Heathkit_Index.html

1. Notes begin on page 11

IP-2715 Power Supply/Battery Eliminator

\$134⁹⁵

Provides variable 9-15 volt output capable of 12 amps continuous, 20 amps intermittent

Heavy-duty supply is the one you NEED for reliable Ham and CB radio servicing, any high-current 12-volt use. Features negligible ripple; excellent regulation from no load to full load. Has double heat sinks with 4 output transistors, extra-large transformer for steady smooth power.

Kit IP-2715, Shpg. wt. 31 lbs. **134.95**

IP-2715 SPECIFICATIONS

Output Voltage: variable from 9-15 VDC. Output Current: 12 amps continuous, 20 amps intermittent (per derating curve in manual). Ripple: less than 1% at full load. Regulation: less than 2% variation from no load to full load. Fuses: 7A, 3 AG slow-blow primary; 20A, 3 AG output. Power Requirements: 110-130 VAC, 7A or 220-260 VAC, 3.5 A, 60/50 Hz. Dimensions: 5 1/4" H x 11" W x 11" D.

New

Ideal for 2-way Radio Servicing, High-Current 12-Volt Applications



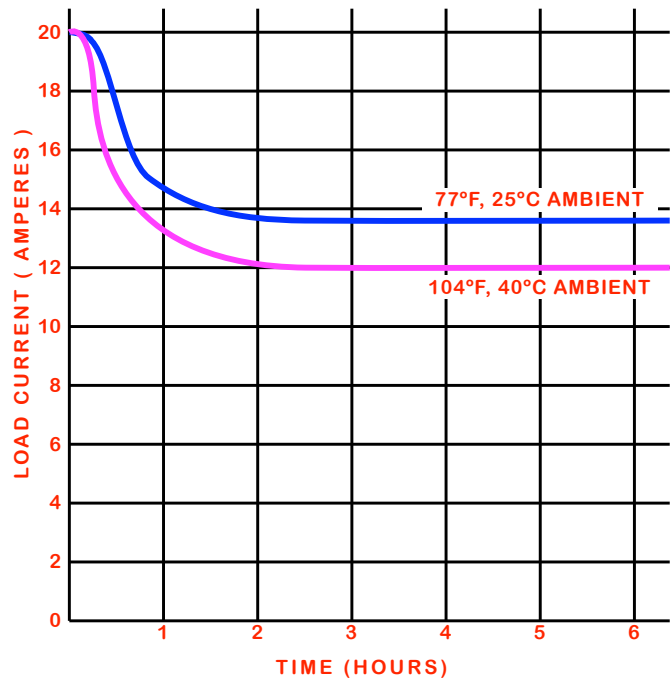
Kit

Figure 2: The IP-2715 announcement from the Spring 1976 Heathkit catalog #808

thirds of the front panel contains the two monitoring meters. On the left is a **0 to 15 D.C. VOLTS** meter. The scale has numbered marks every 3 volts with mid-tick-marks every volt and minor tick marks every 1/2 volt. On the right is a **0 - 25 D.C. AMPERES** meter. The scale has numbered tick marks every 5 amperes with minor tick marks every ampere.

The rear panel accommodates the 3-wire line cord, with its strain relief, at the lower right, a fuse holder for the load fuse (F2) at the upper left and the TO-3⁴ power transistor, Q2, that drives the four output transistors, at the upper middle-right. Q2 is covered with a plastic insulator to prevent shorts since its case is above ground potential. While the load fuse is mounted on the rear panel for quick changing, the main 7 amp power fuse (a 3 1/2 amp fuse if wired for 240 VAC.) is mounted internally in a clip-type fuse holder.

Each side panel contains a heavy heatsink that accommodates two TO-3 transistors. Q5 and Q6 mount on the left-side heatsink, and Q3 and Q4 mount on the right-side heatsink.



NOTE: This chart should be used to determine the maximum length of continuous operation at a given load current and ambient temperature. The battery eliminator must be allowed to cool an equal length of time before you do additional testing to prevent damage due to thermal overload.

Figure 3: This chart is recreated from the manual and shows the Maximum Continuous Operation.

Like Q2, these transistors are covered with an insulator to protect from shorts⁵. There are two plastic handles bolted to the top panel for easy carrying and four heavy-duty rubber feet on the chassis bottom.

The IP-2715 can supply a well regulated DC voltage adjustable from approximately 9 to 15 VDC. Regulation is better than 2% from no load to full load, and ripple is under 1%. Allowed output current is 20 amperes intermittent service and up to 12 amperes continuous when the ambient temperature is at or below 40°C (104°F). At 25°C (77°F) it can supply 13.5 amperes continuously. The derating curve chart is shown in **Figure 3**.

Operating the IP-2715:

Operation is quite simple. The battery eliminator is plugged into 50 or 60 Hz AC power of the proper voltage. With the LOAD switch in STBY, the POWER switch is switched ON. The desired voltage between 9 and 15 volts is set using the VOLTAGE ADJUST potentiometer.

The device to be powered is connected to the binding posts on the front panel. Heath provided a 6', 12-gauge, 2-wire cable with ¼" spade lugs to fit the posts. The other end of the cable can be wired to suit the user; the IP-2715 doesn't provide remote voltage sensing capability. Once the device is connected, the LOAD switch is switched to NORM to apply power. Should excess current be drawn, the 20 amp fuse will blow. Access to this fuse is on the rear panel using a standard panel mount fuse holder. Replace the fuse with a 20 amp 3AG fuse. Do not use a slow-blow type. The IP-2715 does not provide any over voltage protection.

The Early IP-2715 Circuit:

The original IP-2715 circuit is based on the four pin Fairchild 78MGT4 voltage regulator IC (442-626). This chip is also used in the

HP-1144A power supply, where it replaced the obsolete (and hard to find) six-pin MFC6030 regulator chip (442-48) used in the earlier HP-1144. Late in the production run of the IP-2715 the 78MGT4 IC itself became obsolete, and Heathkit redesigned the circuit to use the inexpensive LM317T (442-708) sourced by many manufacturers and readily available, even today.

Figure 4 (page 8) shows the schematic of the early IP-2715⁶. The power transformer (54-848) has dual primary windings and can be wired for 120 or 240 volt input. The output is about 20 VAC. This voltage is rectified by a Motorola MDA990-2 (57-88) sealed high-current full-wave bridge rectifier and filtered by two paralleled computer grade 10,000 μ F electrolytic capacitors (25-263). The approximately 28 VDC output is fed to the four main pass transistors that control the output voltage. The four transistors are in parallel, collector to collector, base to base, and emitter to emitter, except in each emitter lead is a small resistance. This resistance is made up of four 0.33 Ω 5 watt resistors in parallel resulting in a resistance of about 0.09 Ω ⁷ at 20 watts. These resistors force the transistors to better share the load. The parallel emitters are then connected through the output fuse, ammeter, and LOAD switch SW2, to the output binding posts. C7, a 0.1 μ F mylar capacitor across the binding posts, adds extra high frequency filtering.

The regulator circuit is mostly contained on a circuit board (85-1752-1) that mounts with standoffs to the rear panel. A transistor socket mounted to the foil side of the circuit board plugs into the leads of transistor Q2 a 2N3055 (417-215) which is mounted on the rear panel. The circuit board is outlined by dashes on the schematic. Four leads connect to the circuit board, using connectors. They

**SCHEMATIC OF THE
HEATHKIT®
BATTERY ELIMINATOR
MODEL IP-2715**

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Part of 595-1845-01

NOTES:

1. RESISTOR VALUES ARE IN OHMS. RESISTORS ARE 1/2 WATT UNLESS OTHERWISE SPECIFIED.
2. CAPACITOR VALUES ARE IN μ F.
3. THIS SYMBOL INDICATES CONNECTIONS TO THE CIRCUIT BOARD
4. THIS SYMBOL INDICATES NO LOAD DC VOLTAGES MEASURED FROM POINT INDICATED TO GROUND. VOLTAGES MAY VARY \pm 5% VOLTAGES WERE TAKEN WITH VOLTAGE ADJUST CONTROL FULLY CLOCKWISE UNDER NO LOAD CONDITIONS.

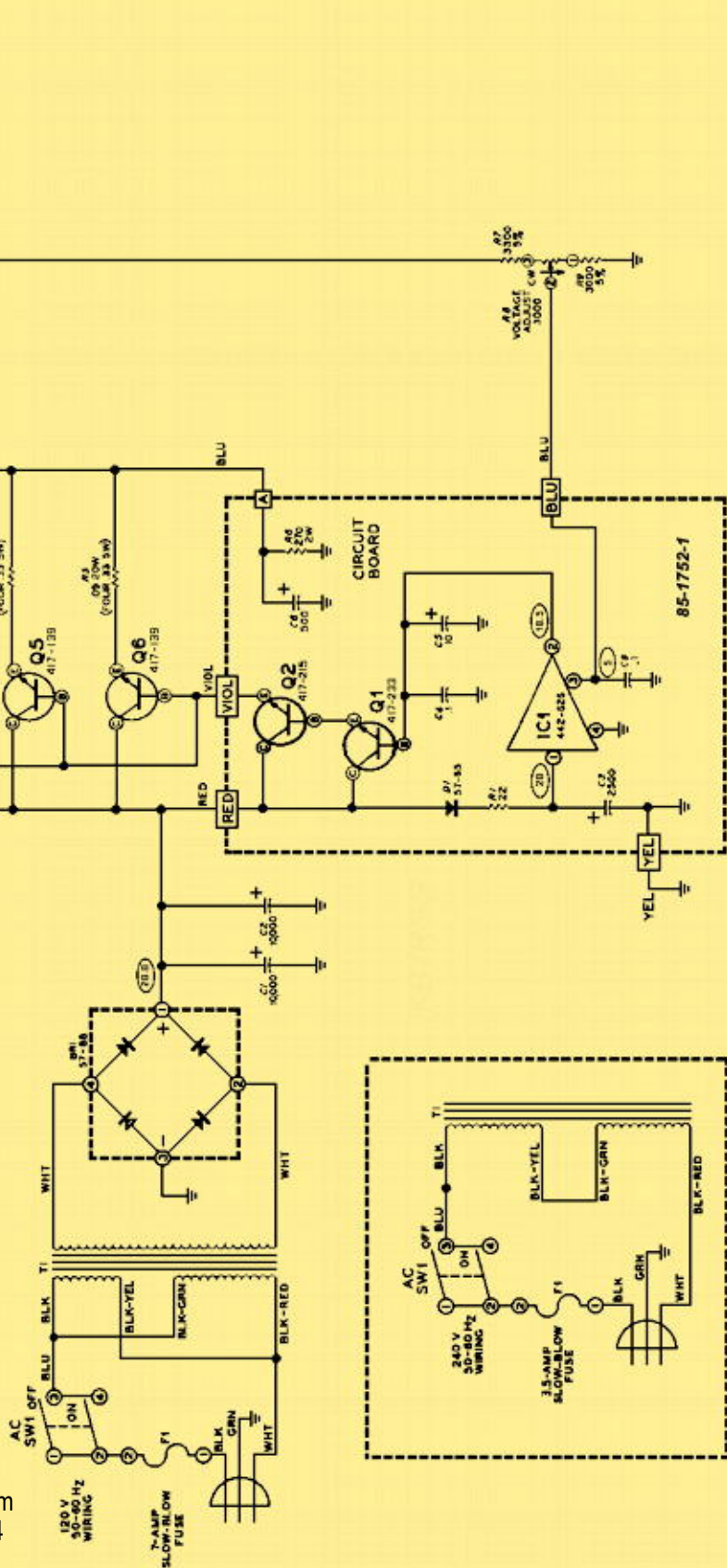
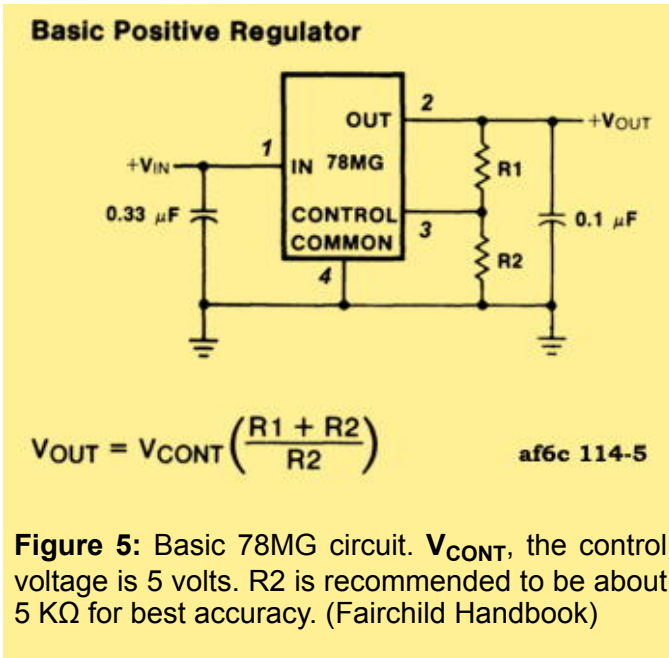


Figure 4: Original schematic of the IP-2715 from Heath manual 595-1845-01 using the 78MGT4 regulator IC (442-626).



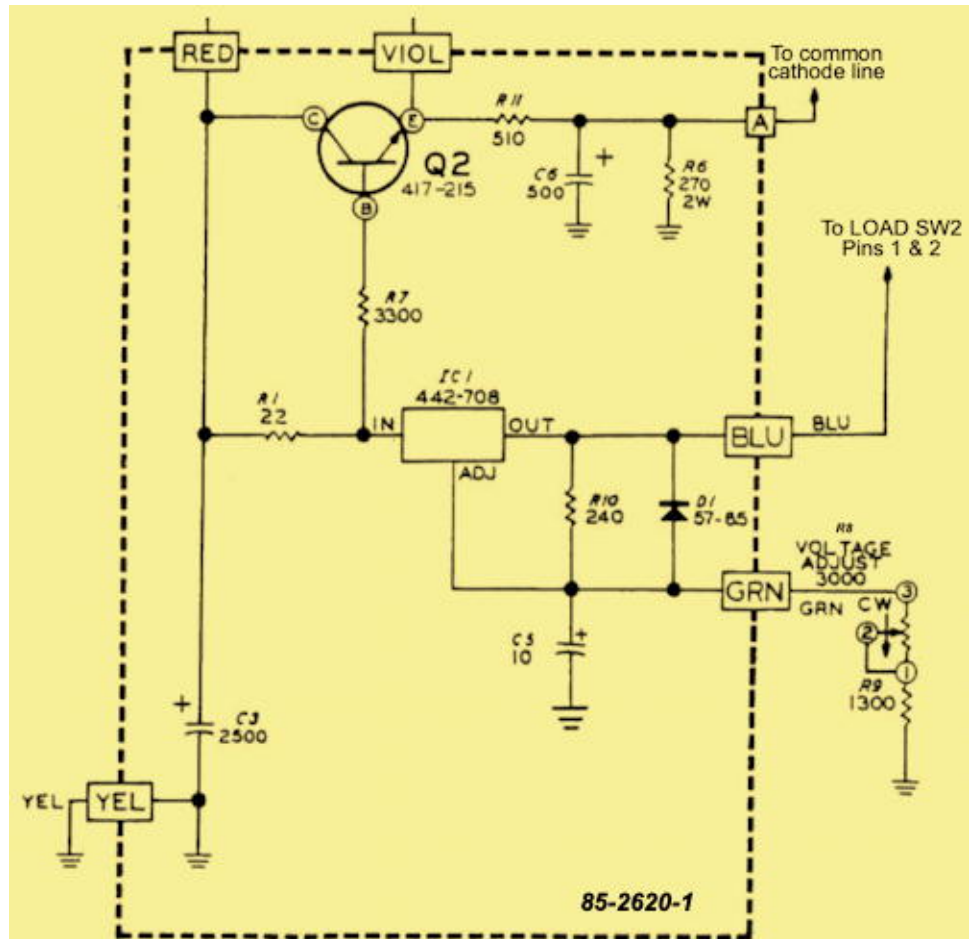
the control pin and pin 4 is ground. The basic regulator circuit is shown in **Figure 5**. The output (pin 2) is driven to a voltage so that the divided voltage at the control terminal (pin 3) equals 5 volts. In the IP-2715 circuit the regulator IC drives a Darlington pair consisting of Q1 and Q2, which in turn drives the four pass transistors to the voltage where the feedback coming in on the BLU terminal equals 5 volts.

The Later IP-2715 Circuit:

Late in the IP-2715 production the 78MGT4 regulator IC became obsolete and Heathkit was forced to update the regulator circuit. In a later manual [595-1845-06] the IC was re-

are coded **YEL**, **RED**, **VIOL** and **BLU**. YEL is ground; RED is 28V power; VIOL is the output to the base of the pass transistors; and BLU is feedback from the output voltage. This feedback is fed through a voltage divider consisting of R7 (3.3 K Ω), the VOLTAGE ADJ. potentiometer R8 (3 K Ω) and R9 (3 K Ω) to ground. The BLU feedback signal to the circuit board is connected to the wiper of the potentiometer R8. A fifth circuit board lead, soldered directly to pad 'A,' connects to the common cathode lead of the four pass transistors after the cathode equalizing resistors.

The regulator IC, IC1 has four pins. Pin 1 is the input, pin 2 is the output, pin 3 is



placed with the common three-pin LM317T regulator. This change required significant modifications to the circuit resulting in a new circuit board (85-2620-1)⁸. The new circuit added an additional terminal **GRN** to isolate the **VOLTAGE ADJUST** control from the **BLU** feedback terminal. The circuit board and adjustment control as it appears in the schematic is shown in **Figure 6**. Note that there is no longer a Q1 or C4 in the circuit. **This schematic includes a critical error.** It shows Q2 as an NPN 2N3055 transistor (417-215) instead of the correct MJ2941 PNP transistor. This transistor is also a TO-3 style transistor and mounts identically to the

2N3055 it replaces. A corrected partial schematic of the regulator board is shown in **Figure 7**.

Using **Figure 6** it is impossible to understand how the circuit works. The error was caught by comparing the parts information with the schematic. Still, the circuit seemed hard to understand until a simple fact came to light. The LM317 has three pins, IN, OUT and ADJ. The sum of the currents for the chip must be zero. However, the ADJ pin current is very small, typically 50 μ A, and if this is ignored since it is small compared to the 10s to 100s of mA for the IN and OUT pins, there is very little error in saying the IN and OUT currents are basically the same.

The LM317 provides a nominal constant 1.25 VDC between the output and the adjust pin. This voltage sets up a current through the 240 Ω resistor R10 of 5.2 mA (the manufacturer recommends a standard 5% value of 240 Ω for this resistor. This current (plus the small current from the adjustment terminal) flow through R8 and R9, which, when added to 1.25 volts, sets the output voltage. The formula is:

$$V_O = V_{REF} (1 + R_2/R_1) + I_{ADJ} R_2$$

Where: V_O = Output Voltage

$$V_{REF} = 1.25 \text{ V}$$

$$R_2 = R_8 + R_9$$

$$R_1 = R_{10} = 240 \Omega$$

$$I_{ADJ} \approx 0.05 \text{ mA}$$

Thus, when the output voltage is lower than the

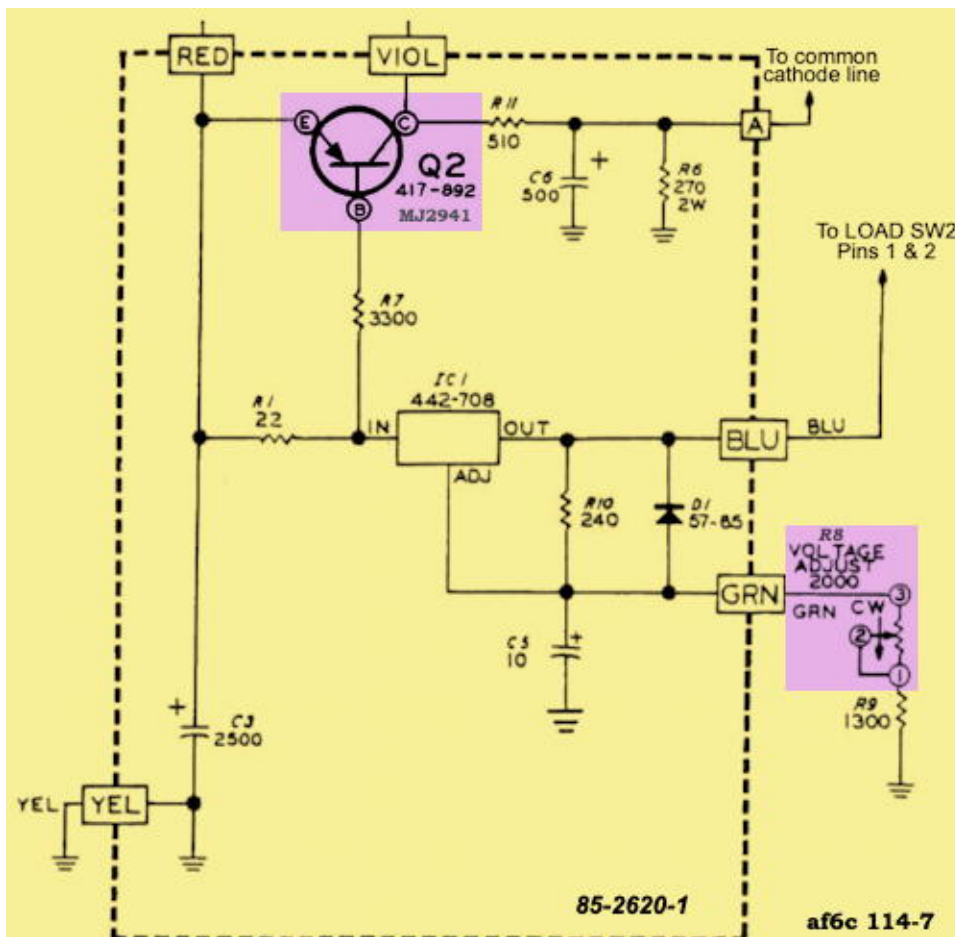


Figure 7: Corrected schematic of Figure 6. Note that Q2 is now a MJ2941 PNP transistor (442-892). Also note that the ADJUST CONTROL is now 2000 Ω (10-269); a correction that evidently came as an addendum to the manual (both are highlighted). Connections to RED, VIOLET and 'A' are as shown on the old schematic (Figure 4).

voltage set for the regulator, IC1 draws more current to raise the voltage, resulting in more current being drawn through the base of Q2 and thus through the four pass transistors, raising the output voltage. Likewise, should the output voltage be too high, IC1 draws less current, reducing the current being drawn through Q2 and lowering the output voltage.

Capacitor C5 improves ripple rejection, and diode D1 protects IC1 should an output short occur. These components are recommended on the LM317 data sheet. The 22 Ω ½ watt R1 can only withstand about 3.3 volts across it which limits the current through R7 to about 800 μA. The MJ2941 has an hFE of 20 to 100. Should it be on the low side, IC1 would need to draw more, but is limited to 150 mA without exceeding the dissipation on R1.

Increasing the wattage of R1 is one of two weaknesses that stands out after the circuit change. The other is the location of the 20 ampere load fuse. Should it open under heavy load IC1 is asked to supply the whole load. It can't and shuts down due to its internal overload circuitry. However, there will still be stress on the chip. The fuse can be moved to a point past the junction of the BLU feedback point, but the fuse will add voltage losses outside the regulation loop. Instead, placing the fuse right after C2, the second filter capacitor, would provide protection without affecting regulation.

Assembling The IP-2715:

Due to the high currents in parts of the battery eliminator Heath supplied some heavy wire and heavy #14 AWG bare buss wire with sleeving for use where needed.

Construction starts with stuffing the small printed circuit board. Then parts are mounted to the chassis including the two heatsinks

with transistors and sockets, and heavy leads are connected to the transistor sockets.

Next, two 20-lug terminal boards are wired, again with heavy buss wire, and then eight 0.33 Ω 5W resistors are soldered to each board. Each board makes up two 0.09Ω emitter resistors which are then mounted to the side panel board. The heavy power transformer is mounted along with the two large filter capacitors, and additional chassis wiring is added.

The rear panel then has the load fuse, printed circuit board and power cord with its strain relief installed and it is attached to the chassis. Wiring between the rear panel and chassis is added, as is the line cord and primary wiring for either 120 or 240 VAC.

Parts are then installed on the front panel including the two meters, toggle switches, voltage control potentiometer and binding posts. Wires are added.

Next, the front panel is attached to the chassis and additional wiring is completed.

IP-2715 RESISTANCE MEASUREMENT TABLE			
#	Measurement	Resistance	Scale
1	Remove Fuse F2 from fuseholder.		
2	Connect negative ohmmeter lead to black banana plug		
3	Either line cord flat prong	Infinite	R x 1M
4	Other line cord flat prong	Infinite	R x 1M
5	Line cord round prong	0	R x 1
6	C1 lug 2	See Note	
7	Fuseholder F2 lug 1	3000 Ω	R x 100
8	Replace Fuse F2 into fuseholder.		
9	Fuseholder F2 lug 1	250 Ω	R x 10
10	Disconnect the ohmmeter from Battery Eliminator.		
	NOTE: Meter should rise slowly as capacitors charge and stop at a high resistance indication.		
TABLE II			

IP-2715 OPERATIONAL CHECKS	
1	Set controls as follows: R8: VOLTAGE ADJUST Fully counterclockwise SW1: POWER switch to OFF SW2: LOAD switch to STBY
2	Plug line cord into a proper AC outlet.
3	Toggle SW1 POWER switch to ON: The DC VOLTMETER (M1) should read approximately 9 volts.
4	Slowly advance VOLTAGE ADJUST: The DC VOLTMETER (M1) should increase to approximately 15 volts when the control reaches its full clockwise position. The DC AMPERE meter(M2) should remain at zero.
5	Place the LOAD switch in the NORM position: Neither meter reading should change.
6	Toggle SW1 POWER switch to OFF: The DC VOLT meter should remain at its voltage position, then slowly move to zero as capacitors C1 and C2 discharge.
TABLE III	

A series of resistance checks are made next (See **Table II**), followed by operational checks (See **Table III**).

Upon successful completion of the checks, plastic handles are attached to the top plate. The blue and white series label is attached to the underside of the top plate and the plate is attached to the chassis using black finished screws.

The IP-2715 and the HP-1144(A) (PS-1144):

As commented earlier, there are a lot of similarities and common parts between the IP-2715 and the HP-1144 series. The original HP-1144 uses an MC6030 6-pin regulator chip. However, most HP-1144 owners updated their power supplies to the ‘A’ version using the upgrade kit supplied by Heathkit⁹. It adds crowbar over-voltage protection and the 78MGT4 regulator chip. This chip is used in the early IP-2715s. Since this chip is also now very difficult to find, users owning units in which the chip has failed are looking for an alternative circuit in lieu of trying to obtain a replacement 78MGT4. The circuit of the later IP-2715 should offer a good clue to

making that modification so the power supply uses a common LM317T. Perhaps some enterprising ham will create a modification kit using a new circuit board?

The IP-2760 Battery Eliminator:

When Heath discontinued the IP-2715 they replaced it with the IP-2760. As this article was near completion, Steve - N8FH sent a schematic and parts list for the IP-2760. The two units are very similar, but with some significant changes. The power transformer was changed. The PS-1144 had been discontinued, and the PS-9000 was being manufactured, so Heath used the transformer (54-971) currently in that power supply for the IP-2760. Some changes were made to the regulating circuit, though the circuit board remains the same except for new silk-screening. The two weaknesses in the circuit that were mentioned earlier have been corrected. R1 is now a 1-watt resistor, and F2, the 20 A load fuse, has been moved in the circuit to just after the large filter capacitors. The unit sits on a new chassis, but the rear panel, front panel and top panel are the same, the latter two sporting new style paint and thus a new part dash number.

The IP-2760 Circuit:

Other than the relocation in the circuit of the 20 ampere fuse, and changes due to the new transformer, the circuit, external to the printed circuit board, is identical. **Figure 8** shows a partial schematic of the IP-2760 regulator circuit board. With only one 1.0 μF tantalum capacitor (C4) added, and a few components changing value, the circuit is close to the later IP-2715 circuit. C4 actually mounts across the B and E pins of the the Q2 transistor socket. The regulator chip remains a three-lead LM317T.

The transformer in the earlier IP-2715 has a secondary voltage of 20 VAC with no center-

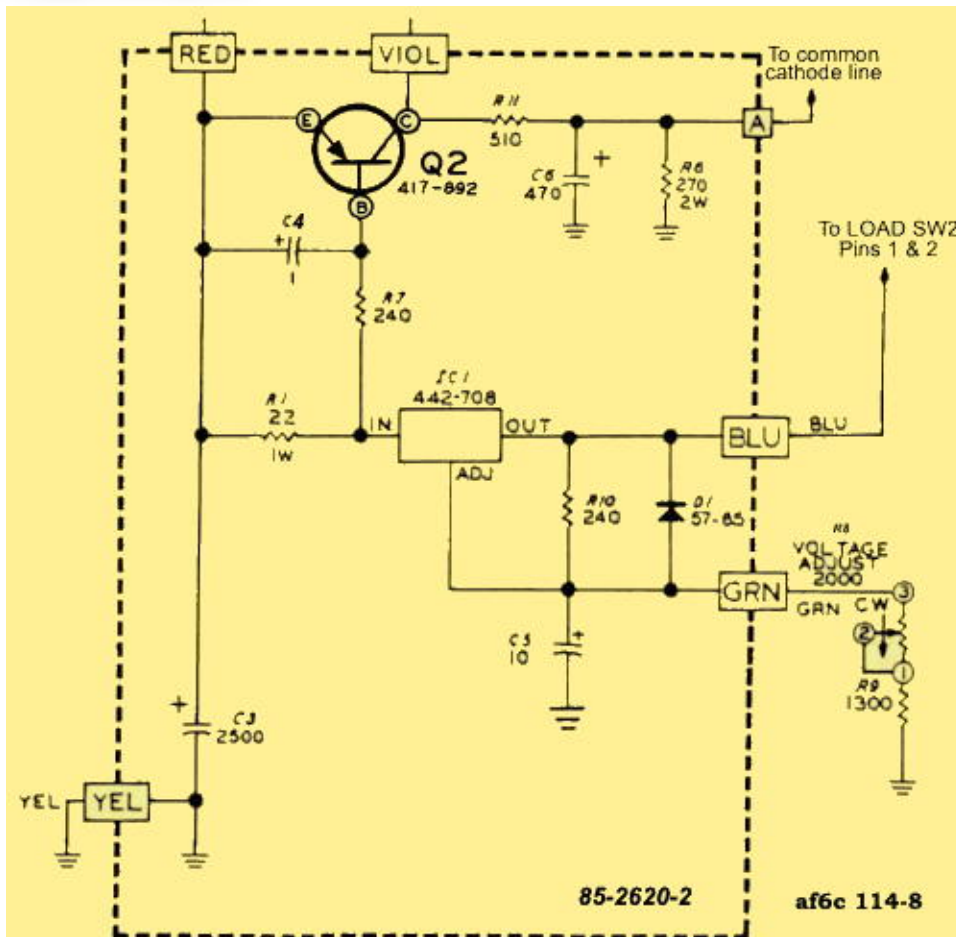


Figure 8: The regulator circuit of the IP-2760. R1 has been increased to 1-watt, C4 has been added. R7 has been changed to increase drive to Q2, and C6 has changed from 500 to 470 μF, likely do to a parts procurement issue as 500 μF is no longer a standard value.

feedback loop. C4, which was removed during the regulator circuit change in the IP-2715, is now used to add stability to the loop.

Restoring an IP-2715:

Last year the author picked up a rather battered IP-2715. This unit uses the older 78MGT4 chip, and, after checking the two large 10,000 μF capacitors, it was a pleasant surprise to find the unit powers up and functions properly. The VOLTAGE ADJUST control is a little noisy, and under examination it was found that the Sterling 0 - 25 A ammeter had been replaced with an Emico 0 - 20 A meter. Also, evidently one of the 40411 pass transistors must have failed and was replaced with a 2N3055. A replacement 40411 should be easy to find.

tap. However the transformer used in the IP-2760 has a secondary voltage of 38.4 VAC with a center tap. Thus the rectifier circuit has been changed from full-wave bridge rectification to full wave center-tap rectification, with the center-tap of the transformer grounded. The IP-2760 still uses the same bridge rectifier part, but only two of the diodes are used; terminal 3 is no longer connected to ground. The modified secondary circuit is shown in **Figure 9**. This figure also shows the new location of the LOAD fuse (F2).

The biggest change is the lowering of the resistance of R7 from 3300Ω to 240Ω, tightening the

This unit was in heavy use by a commercial manufacturer and, as shown in **Figure 10**, (which was taken prior to any cleanup) is cosmetically poor. The plastic handles have been replaced with metal ones (unfortunately of a different size so new holes had been made. A cigarette lighter jack was added on the top. Also, the front and top panels have a lot of the paint and nomenclature worn off.

What's needed to clean up the unit is a replacement front and top panel (preferably with handles) and possibly the Sterling 0 - 25 amp meter. Has someone parted out an IP-2715 to repair an HP-1144 series power

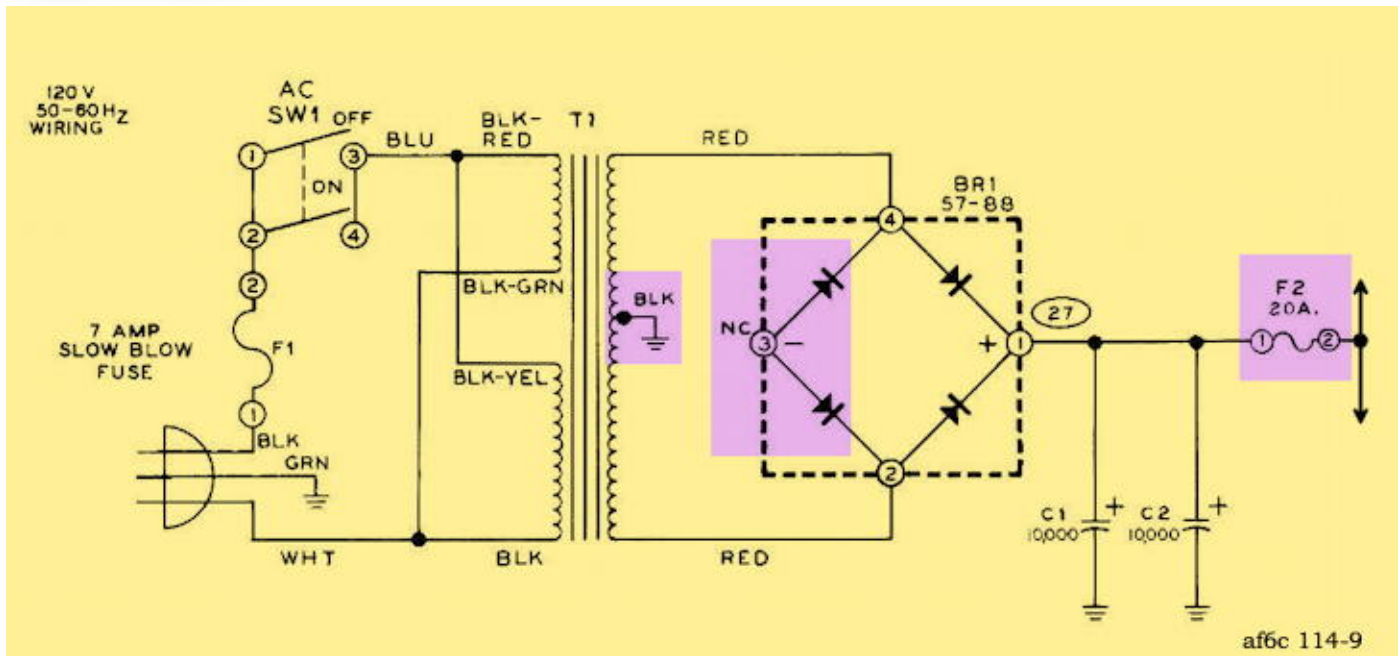


Figure 9: Highlighted are the changes to the rectifier circuit in the IP-2760 required to accept the new 54-971 transformer. Half of BR1 is no longer used (highlighted). Also highlighted is the new location of fuse F2.



Figure 10: The author's IP-2715 as it was when it arrived to the workbench. Dirt, grime and the cigarette lighter receptacle have since been removed, and the unit is working electrically.

supply and still has the carcass? If so the author would be interested in purchasing the needed parts¹⁰. Contact him using the link in the lower right corner of the pale yellow box on the last page of the article.

Summary:

Having a paper manual for any Heath product you own is worthwhile. Lately I've been purchasing them from the vintage manuals

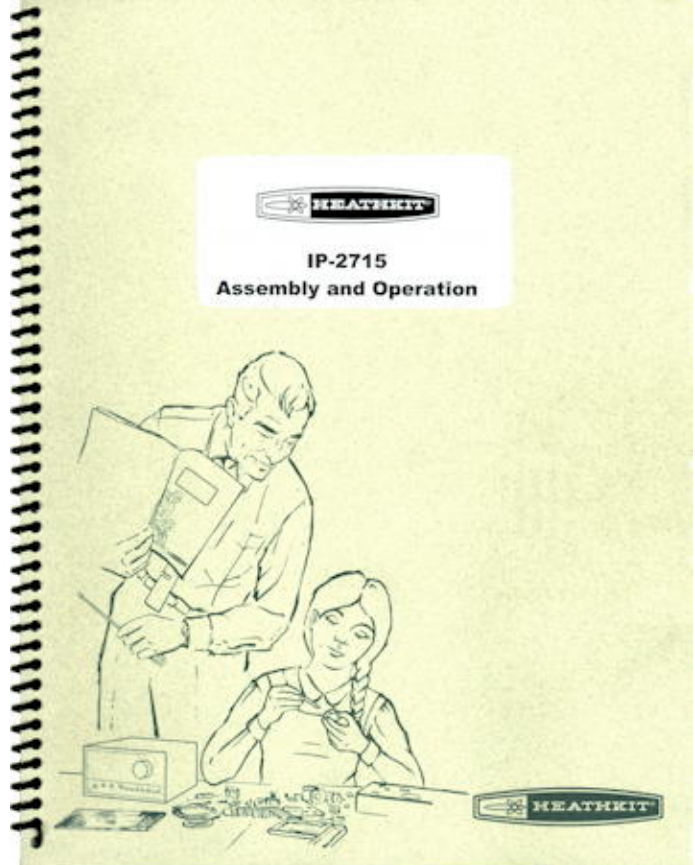


Figure 11: Reproduction of the IP-2715 manual cover from Don Peterson and heathkit.com's vintage manual section. Note neat spiral binding.

page provided by Don Peterson and linked on the new Heathkit website home page. It is there that a manual for the IP-2715 was ordered. (<https://www.heathkit.com>).

When the purchased IP-2715 manual arrived it was a real surprise. It was a late version [595-1845-06] (**Figure 11**). This was the first the author was aware of any change to a new regulator chip. One now has to wonder if the late PS-1144 may also have been updated; though the feeling is no as the timeline is a bit early.

So far all manuals received from Don have been clean, complete and nicely spiral-bound with Heathkit covers - with one exception: I ordered a manual for the GD-1110 Fireball Pinball Game to help write HotM #106¹¹ and while it arrived in very good shape complete with the thick illustration booklet, one page of the manual (page 45) was blank. Also pictorials 6-1 and 6-2 were missing. They are separate from the Illustration Booklet. They come "...folded inside the manual." Happily, enough information was provided in the GD-1110 manual to complete the article so I never pursued the missing page or pictorials. Even with that one incident I'd still recommend Don's manuals.

I'd like to thank Steve Gladstein - N8FH, Chuck Penson - WA7ZZE, Santos e Silva and Gerhard Wagner - DF1DA for all their help and support for this and many of the other HotM articles. As this article was nearing completion Steve provided the parts list and schematic for the IP-2760, which replaced the IP-2715. This allowed the brief discussion of the IP-2760 added to the article.

Update on IP-5220 Isolation Transformer:

Steve - N8FH peeked inside his IP-5220 and confirms the variable autotransformer is made by Staco of Dayton, OH.

73, from AF6C 

Notes:

1. The HP-1144 uses the older MFC6030 regulator IC. The HP-1144A uses the same IC as, all but the latest IP-2715, the 78MGT4.
2. The HP-1144 uses the same pass transistors as the IP-2715, the RCA 40411. The HP-1144A uses the Motorola MJ802 pass transistor. The IP-2715 uses four pass transistors while the HP-1144 uses two.
3. The mod kit 830-33 that updates the HP-1144 to the A version changes regulator IC from the MFC6020 to the 78MGT4 and the two pass transistors to the MJ802.



4. TO-3 is the transistor style:
5. All five TO-3 transistors mount using thermal compound for good heat transfer.
6. Figure 4 schematic is taken from manual 595-1845-01.
7. Heath rounded 0.0825 up to 0.09 assuming added lead resistance.
8. Heathkit 85-xxxx circuit boards without an ending dash # are un-silkscreened boards. the dash # signifies the silkscreening. If the silkscreening changes the dash# is incremented. Should the actual copper tracings be changed a new 85-xxxx number is used.
9. **Modification Kit for the Heathkit HP-1144 Power Supply** - Model 830-33: (http://www.w6ze.org/Heathkit/Mods/Mod_830-33.zip)
10. Parts needed (one each except as noted). Parts are listed in order of need:
 1. 203-1849-1 Front panel
 2. 205-1657-1 Top plate
 3. 211-15 Plastic handle (2 ea.)
 4. 407-722 Meter 0-25 amperes
 5. 417-139 40411 Transistor.
11. https://www.w6ze.org/Heathkit/Heathkit_106%20GD1110.pdf

Remember if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.

This article is copyright 2022, and originally appeared in the October issue of 'RF', the newsletter of the Orange County Amateur Radio Club - W6ZE.

Thanks - AF6C

Revision Sheet:

A: The wrong image was used for Figure 6. It has been corrected. The old image already had the corrections added to the schematic. Some small typos & punctuation were corrected.