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VR-001

Vintage Radio Application Note

RECONDITIONING AND MODERNIZING THE HEATHKIT HP-23 AC POWER SUPPLY

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SECTION I - INTRODUCTION AND OVERVIEW

This paper is a vintage radio technical document that describes the reconditioning, modification, and modernization of a Heathkit HP-23B AC power supply. This unit was designed by Heathkit back in the early 1960s to provide the necessary supply voltages for fixed- station AC operation of Heathkit SB- and HW-series HF amateur transceivers and other equipment. This paper is also applicable to the HP-23, HP-23A and HP-23C variants of this power supply. (See Appendix A for a discussion of the feature differences among these various models.)

I procured this unit on Ebay and found it to be in fair condition. Although the unit was functional and structurally sound, it required significant reconditioning, modification, and modernization to make it a reliable power supply in “like-new” operational condition. This paper describes this process in detail along with the necessary supporting technical background.

Although this project did not pose any major technical challenges and was not particularly difficult, it is my hope that the enhanced technical detail provided will be helpful to other vintage radio afficionados interested in refurbishing the HP-23 and other power supplies with similar issues.

Also, visit my N6DC vintage radio website at www.rdfproducts.com/n6dc.htm for possible revisions to this paper as well as other vintage radio technical articles.

**** DANGER ****

The Heathkit HP-23 AC power supply contains dangerous high voltages that can be ***lethal if contacted****. Those intending to work on this power supply should be well-versed in working on equipment with high voltages present and be completely familiar with all necessary safety precautions. Those unfamiliar with these safety precautions or inexperienced in working on equipment containing high voltages should not open the unit.*

SECTION II - SUMMARY CIRCUIT DESCRIPTION

Referring to the schematic of Figure 1, the HP-23B circuitry is very conventional and straightforward. The unit accepts AC main input voltages of 120/240 VAC @50-60 Hz. The selection for 120/240 VAC operation is made by wiring the two T1 primary windings either in parallel (for 120 VAC mains) or series (for 240 VAC mains). The specified input voltage ranges are 105-125 and 210-250 VAC, respectively. Specified power consumption for the maximum rated loads is 350 watts.

The HP-23B supplies three separate unregulated DC voltage outputs (in addition to a 12.6 VAC @5.5 ampere filament voltage output). These DC output voltages are as follows:

<u>High Voltage</u> - The high voltage output is generated by a full-wave voltage doubler. Its rated output is +820 VDC no-load and +700 VDC @250 mA.

<u>Low Voltage</u> - The low voltage output is generated by a half-wave voltage doubler. Its rated output is +350 VDC no-load and +300 VDC @150 mA (with a 100 mA load on the high voltage supply). This low voltage output can be reduced (for appropriate applications) by selecting the lower voltage tap on the T1 power transformer secondary via S1. With the lower voltage tap selected, the rated output is +275 VDC no-load and +250 VDC @100 mA (with a 100 mA load on the high voltage supply).

<u>Bias Voltage</u> - The bias voltage output is generated by a half-wave rectifier. This is a negative voltage rated at -130 VDC no-load and -100 VDC @20 mA.

Capacitive input filters are used for all three DC voltages. The low-voltage supply also employs an additional series 6H filter choke (L1) followed by an additional shunt filter capacitor for improved AC ripple reduction.

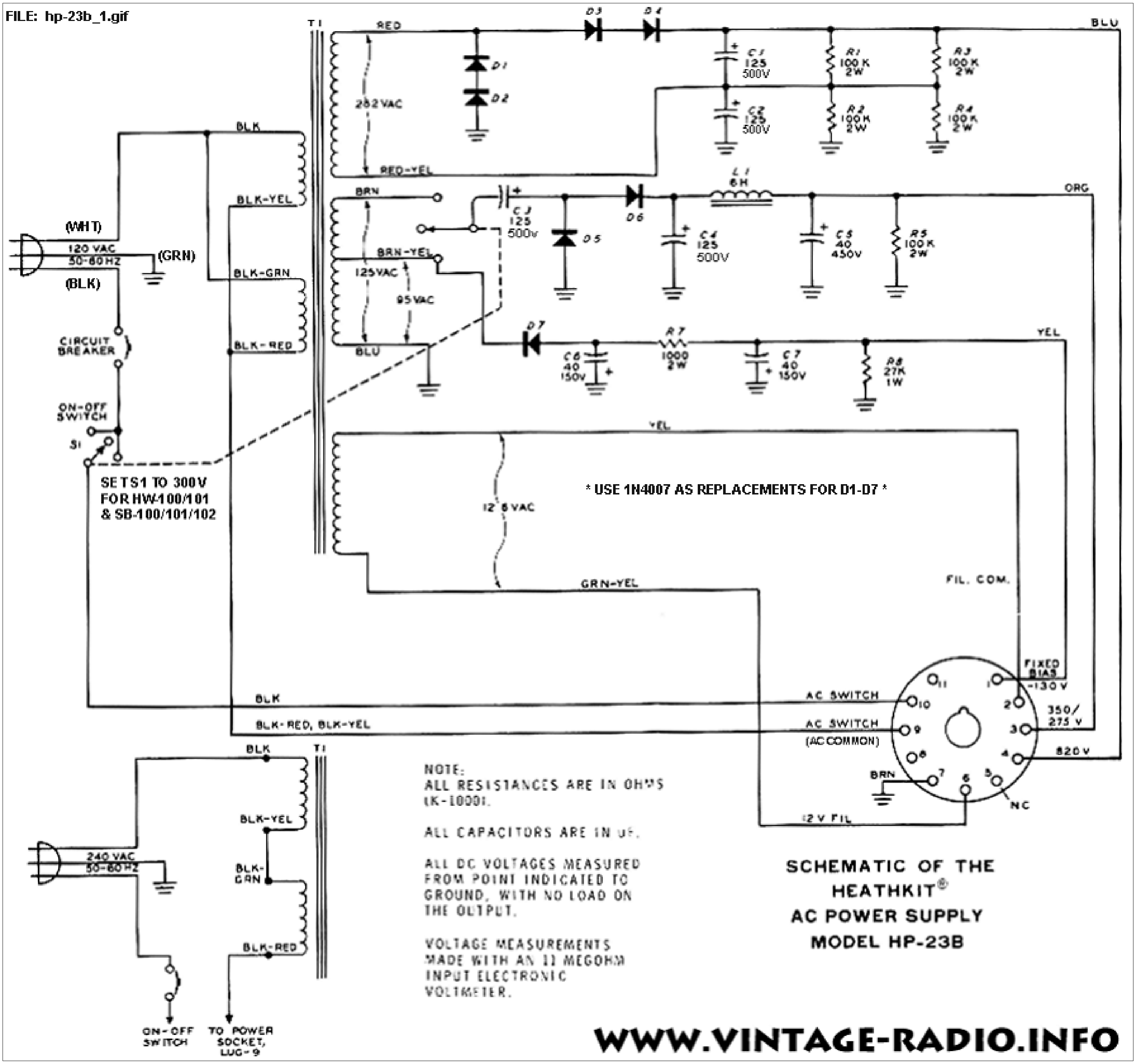


Figure 1 - Heathkit HP-23B AC Power Supply Schematic

SECTION III - AC LINE CORD REPLACEMENT AND COSMETICS

A. AC LINE CORD REPLACEMENT

As stated above, the HP-23B I procured on Ebay was functional and structurally sound, but somewhat shop-worn and very aged. Figures 2 and 3 illustrate the unit with its top and bottom covers removed.

Although not shown in Figures 2 and 3, the unit as originally received had a 2-wire AC power cord which was not secured by a chassis strain relief. As per the schematic of Figure 1, the HP-23B was designed with a 3-wire grounded power cord for safety secured to the chassis by a plastic strain relief.

Figure 2 - HP-23B w/Top Cover Removed

Since the HP-23B is not double-insulated, it requires a 3-wire grounded power cord to minimize shock hazard. Be sure that the green safety ground wire is securely connected to the chassis.

It is also important that the AC power cord be securely strain-relieved so that it won't be inadvertently pulled loose.

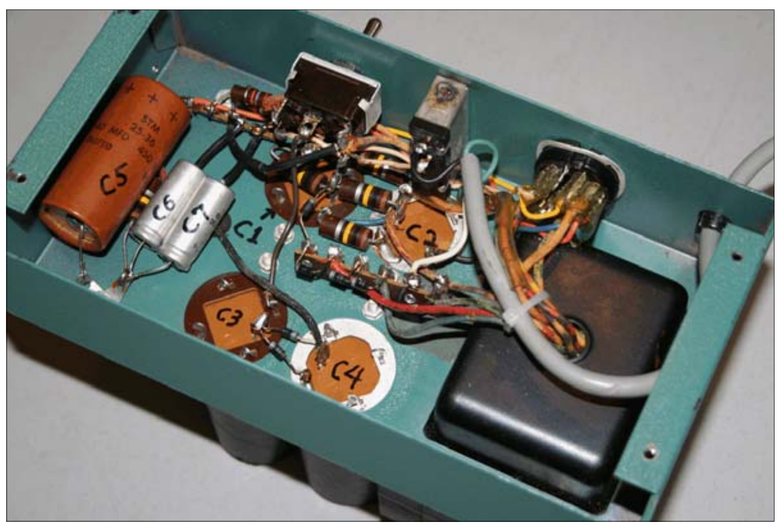


Figure 3 - HP-23B w/Bottom Cover Removed

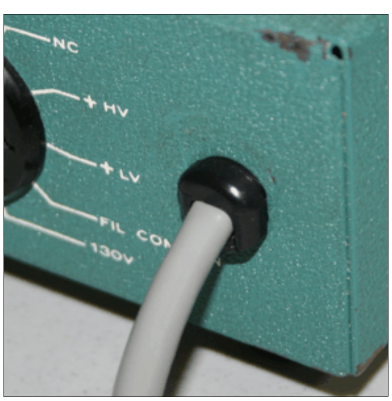


Figure 4 - Strain Relief Detail

To correct this problem in my unit, I used a plastic snap-in Heyco power cord strain relief specifically designed to fit the HP-23B power cord entry hole cut-out (see Figure 4 detail). Fortunately, I already had this part in my engineering stock and the necessary tool to install it.

On a related safety note, inspect the three power cord wires to confirm that they are wired correctly. These three wires should be color-coded and routed as follows (for 115 VAC U.S. AC mains):

BLK - The black wire is the "hot" side of the 115 VAC AC line input. *Verify that this wire is connected to the circuit breaker (and from there to the On-Off switch) as per the schematic in Figure 1*.

WHT - The white wire is the "neutral" side of the 115 VAC AC line input. *Verify that this wire is connected to the T1 transformer primary winding as per the schematic in Figure 1*.

GRN - The green wire is the safety ground wire of the 115 VAC AC line input. *Verify that this wire is connected directly to the HP-23B chassis*.

It is extremely important that the safety ground be connected and that the black wire be routed to the circuit breaker and the On-Off switch. Disconnecting the safety ground or switching the neutral (white) side of the AC power is dangerous and can create a lethal electrical shock hazard.

B. COSMETICS

Although the unit looked its age, no cosmetic restoration effort was made aside from general cleaning. Since my intent was to install this unit inside a Heathkit SB-600 speaker (and thus be completely concealed from view), I saw no reason to invest any effort into cosmetic restoration.

Even if the unit is not mounted inside a speaker cabinet, it would likely be mounted somewhere out of sight where cosmetics would not be an issue.

Although the unit was assembled reasonably well, it did have some solder balls, solder splashes, and other debris lodged in the chassis. These were all scraped out as part of the cleaning process.

SECTION IV - SILICON RECTIFIER DIODE REPLACEMENT

A. DIODE REPLACEMENT

The HP-23B rectifiers (D1-D7 from Figure 1) are all 1960s-vintage 1N2071 silicon diodes. These diodes are rated at 600 PIV (peak inverse voltage) with a maximum average forward current rating of 750 mA. Although these are old diodes, they are fully adequate for this application. Even so, being 40+ years old and with newer and better diodes available at very low cost, it seemed prudent to replace them.

Although there are many modern silicon rectifier diodes available to replace the 1N2071, the 1N4007 is a particularly good choice in that it is widely used, readily available, and very inexpensive. Rated at 1,000 PIV with a maximum average forward current rating of 1.0 A, the 1N4007 is superior to the 1N2071 in all respects. Being very similar in size to the 1N2071, the 1N4007 is thus an excellent choice for a fit/form/function replacement for the 1N2071. The 1N4007 can be purchased in small quantities from Digi-Key Corp., Jameco Electronics, and Mouser Electronics. I purchased mine from Digi-Key Corp. (P/N 1N4007FSCT-ND) along with replacement electrolytic capacitors as discussed in Section V.

B. PLACING DIODES IN SERIES

As per the schematic of Figure 1, the full-wave voltage doubler employs series diode strings (D1/D2 and D3/D4) in each leg to increase the PIV ratings. To put some numbers on this, the required rectifier PIV rating for a full-wave voltage doubler is given by the following equation:

$$PIV = 2.82\ Erms \qquad (1)$$

where PIV is the maximum peak inverse voltage and Erms is the power transformer RMS secondary voltage. For a nominal T1 high-voltage secondary winding output of 282 VAC (RMS), the maximum rectifier PIV would be 2.82 x 282 = 795 volts. Since this is far in excess of the 1N2071 600 PIV rating, the Heathkit engineers correctly decided to employ two series diodes in each leg for a total nominal rectifier PIV rating of 1,200 volts.

Although at first glance it might seem that the 1,000 PIV rating of the 1N4007 replacement diodes would eliminate the need for two series diodes, this would be marginal design practice. To explain, since the HP-23B rated input voltage is 105-125 VAC (the standard design range for most U.S.-built electrical equipment), we have to assume that the nominal 282 VAC T1 high-voltage secondary output is specified at 115 VAC (the design center voltage for electrical appliances designed for 105-125 VAC operation). If the AC line voltage soars to the 125 VAC high end of this range, however, then the maximum rectifier PIV would be about 864 volts. Although this would still be within the 1N4007 1,000 PIV rating, the margin of safety would be a little thin for conservative design standards. Thus, even with the higher 1N4007 PIV rating, two series diodes should still be used in each voltage doubler leg.

C. SERIES RECTIFIER DIODE REVERSE VOLTAGE ISSUES

Although I have always given the Heathkit engineers high marks for their circuit designs, I have to offer an (amicable) criticism of their practice of omitting shunt voltage equalizing resistors in their series rectifier diode strings (this topic is discussed in more depth in Section IV-D below). In a paper I recently read on Heathkit upgrades for the SB-200 linear amplifier, this same topic was addressed.

As it happens, the SB-200 employs a similar full-wave voltage doubler circuit that employs the same 1N2071 silicon rectifier diodes. Since the SB-200 requires a +2,400 VDC plate supply, however, eight diodes are employed in each leg to obtain the necessary PIV rating. However, no shunt voltage equalizing resistors are employed.

The author of this paper tactfully addresses this questionable Heathkit design practice as “remarkable”, but then goes on to say that with modern diodes this practice is acceptable. Once again, I have to offer an amicable disagreement.

To get back to the basics on this subject, the salient issue is the silicon rectifier diode back resistance. If we place two 1,000 PIV diodes in series to effectively increase the total PIV rating to 2,000 volts, our implicit assumption is that both diodes have nearly the same back resistance. If this is not the case, there will be “voltage hogging”. To explain, if one of the diodes has (for example) twice the back resistance of the other, then that diode with the higher back resistance will drop 2/3 (rather than ½) of the total reverse voltage. With simple arithmetic, we can see that the total effective PIV rating of these two series diodes would then be only 1,500 rather than 2,000 volts (i.e., with 1,500 reverse volts applied across the series pair, the higher back resistance diode will see its maximum rated 1,000 PIV).

To resolve this matter, we need a better understanding of the characteristics of diode back resistance. Unfortunately, diode back resistance is not directly specified in the 1N4007 diode data sheet. The diode specification most closely related to back resistance is the reverse (leakage) current. The “typical” reverse current for a 1N4007 at its maximum 1,000 volts reverse voltage at 25°C is given as 0.05 microamperes (which corresponds to a 20,000 megohm back resistance).

However, this same data sheet lists the “maximum” reverse current for this same diode as 10 microamperes (which corresponds to a far lower 100 megohm back resistance). This in itself is a huge variation, but it even gets worse. At 100°C, the “typical” and “maximum” numbers are given as 1.0 and 50 microamperes, respectively, corresponding to back resistances of 1,000 megohms and 20 megohms, respectively.

Clearly, diode back resistance is an uncontrolled parameter that is all over the place, varying both from unit to unit and over temperature. Given the above numbers, it seems amazing that Heathkit’s practice of placing these diodes in series without shunt voltage equalizing resistors could ever have worked. Equally clearly, the problem cannot be solved simply by substituting modern diodes since back resistance is still an uncontrolled and unspecified diode characteristic. I have to think that what pulled Heathkit through on this (aside from a generous dose of luck) was that most of the diodes supplied with their kits must have come from the same production batch.

D. EQUALIZING SERIES RECTIFIER DIODE REVERSE VOLTAGE

The issues associated with the highly variable back resistances of series diodes have been well-known for many years along with a mature and time-proven solution. Essentially, the remedy is to place shunt "swamping" resistors of the same value across each diode in the series string. If this resistor value is much lower than the diode back resistance, then the effective back resistance is essentially the value of this resistor and the voltage will divide nearly equally across each diode/resistor shunt pair.

Although there is likely no truly "optimum" value for this shunt resistor, the 1974 ARRL Radio Amateur's Handbook in its chapter on AC operated power supplies provides the following rule-of-thumb:

$$Rs = PIV \times 500 \qquad (2)$$

where Rs is the required value of shunt resistance and PIV is the diode rated peak inverse voltage. Essentially then, the author recommends using 500 ohms of resistance per diode PIV rating. For a 1N4007 diode rated at 1,000 PIV, the required resistor value would be 500,000 ohms. A 470,000 ohm resistor is thus selected as a good-match standard value.

Again referring to the HP-23B schematic of Figure 1, the 820 volt open-circuit high-voltage is dropped across four rectifier diodes. If 470,000 ohm voltage equalizing resistors are placed across each diode, then the voltage across each 470,000 ohm resistor is 820/4 = 205 volts. The resulting power dissipation in each of these resistors can then be computed by Ohm's Law as E x E/R = 205 x 205/470,000 = 0.089 watts.

Purely from the standpoint of power dissipation, we could use 1/8 watt 5% carbon film resistors. However, resistors also have maximum voltage ratings and it would be unsafe to use a 1/8 watt resistor for this high-voltage application. 1/4 watt 5% carbon film resistors have a rated maximum working voltage of 250 VDC which would probably be adequate. However, it is better to use ½ watt 5% carbon film resistors with their higher rated maximum working voltage of 350 VDC. The modified diode section of the full-wave voltage doubler is illustrated in Figure 5.

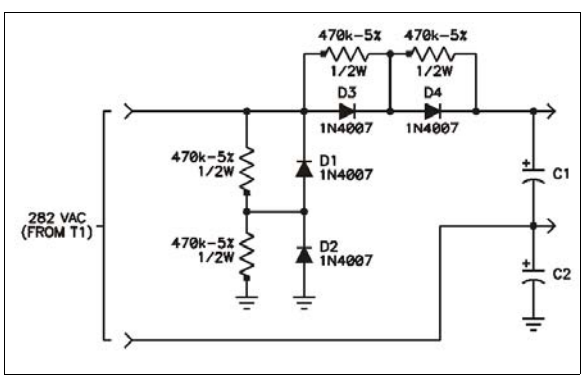


Figure 5 - Full-Wave Voltage Doubler Modified to Include 1N4007 Silicon Diodes and Shunt Voltage Equalizing Resistors

SECTION V - ELECTROLYTIC CAPACITOR REPLACEMENT

A. OVERVIEW

Electrolytic capacitors (especially high-voltage ones) are likely not to be reliable after 40+ years of service. Although the electrolytic capacitors in my HP-23B were functional, I decided to replace them for this reason.

Of all the HP-23B restoration tasks, replacing the seven electrolytic capacitors turned out to be the most difficult and time consuming. Although high-voltage electrolytic capacitors are still available, there are no longer any direct fit/form/function replacements for the original 1960s-vintage electrolytic capacitors employed in the HP-23B. As a result, adaptations must be made to accommodate the different sizes and footprints of modern electrolytic capacitors. On the positive side, modern electrolytic capacitors are much smaller, better performing, and more reliable than their 1960s-vintage predecessors. Since electrolytic capacitors have service lives that are much shorter than nearly all other components aside from vacuum tubes and dial lights, I chose premium-grade replacements.

In the following paragraphs, the important characteristics of high-voltage electrolytic capacitors are discussed, followed by identification of specific modern substitutes for the obsolete originals. Suggestions are then made as to how to install these modern substitutes in the HP-23B.

B. IMPORTANT CHARACTERISTICS OF ELECTROLYTIC CAPACITORS

1. Capacitance and Voltage Rating - Replacement electrolytic capacitors should have capacitances and voltage ratings equal to or greater than the originals.

2. Service Life - The service life of electrolytic capacitors is typically in the order of thousands of hours, which surprisingly is only somewhat better than that of vacuum receiving tubes. Service life is highly dependent upon operating temperature, applied voltage, and applied ripple current. When operated conservatively, electrolytic capacitors last far longer than when they are operated near their maximum ratings.

3. Temperature Rating - The original electrolytic capacitors employed in the HP-23B (and most non-military electronic equipment built in the 1960s) are rated for operation up to +85°C. Keeping in mind that the service life of electrolytic capacitors is typically in the order of thousands of hours and that this service life degrades at higher temperatures, I recommend that premium grade capacitors rated for operation up to +105°C be used for longest service life.

4. ESR (Equivalent Series Resistance) - Since electrolytic capacitors dissipate a certain percentage of the charge applied to them into heat, they are characterized as having an equivalent series resistance. This ESR is frequency sensitive, but is mostly constant over the frequency range of interest (under 1,000 Hz) for high-voltage power supplies. Low ESRs are desirable for good performance and long life.

5. AC Ripple Current - Electrolytic capacitors employed as power supply filters are subject to AC ripple current as a consequence of the fact that there is always some AC ripple voltage across them. Since this ripple current flows through the capacitor ESR, heat is generated that shortens capacitor life. It is therefore important that electrolytic capacitors be selected both for high ripple current capacity and low ESR.

C. REPLACEMENTS FOR C1-C4 (125 uF/500 V)

C1-C4 are the tall 125 uF/500 V electrolytic capacitors visible on the HP-23B chassis top-side (see Figure 2). As per the schematic of Figure 1, C1/C2 are used in the high-voltage supply while C3/C4 are used in the low-voltage supply. Since the high-voltage supply imposes the most demanding requirements on these capacitors, we will focus primarily on C1/C2.

A vendor search to locate a 125 uF/500 V replacement electrolytic capacitor was unsuccessful. However, a premium grade 220 uF/500V manufactured by Vishay (P/N MAL219390101E3) was available from Digi-Key Corp. (P/N 4569PHBK-ND). The relevant specifications for this capacitor are as follows:

Temperature Range:	-25°C to +105°C
Rated ESR @ 100 Hz:	0.9 ohms
Rated Ripple Current (100 Hz/105°C):	1.75 amperes

The rated service life is dependent upon a number of variables, but was very favorable compared to other capacitors that were also considered.

To determine the suitability of this capacitor for the application at hand, we must first calculate the overall impedance of this capacitor, which comprises the 0.9 ohm ESR in series with the capacitive reactance at the 120 Hz ripple frequency (for the full-wave voltage doubler). First, we compute the capacitive reactance:

$$\begin{aligned} Xc &= 1/(2 \times \pi \times F \times C) \\ &= 6.03 \text{ ohms} \end{aligned} \tag{3}$$

where Xc is the capacitive reactance, π is 3.14159, F is 120 Hz, and C is 220 uF.

Next, the total impedance is found by vectorially adding Xc and the ESR as follows:

$$\begin{aligned} Z &= \text{Square Root } (Xc \times Xc + ESR \times ESR) \\ &= \text{Square Root } (6.03 \times 6.03 + 0.9 \times 0.9) \\ &= 6.10 \text{ ohms} \end{aligned} \tag{4}$$

According to the HP-23B specifications, the high-voltage ripple is rated at 1% under a 250 mA (presumably typical) load. Since the high-voltage DC output under a 250 mA load is specified as 700 volts, 1% ripple corresponds to 7 volts RMS (based on the commonly-accepted definition of ripple percentage). Given this to be the case, and given that only half of this 7 volt RMS ripple voltage (Vr) will appear across each capacitor (since C1/C2 are in series), the approximate ripple current is as follows:

$$\begin{aligned} Ir &= Vr/Z \\ &= 3.5/6.10 \\ &= 0.574 \text{ amperes} \end{aligned} \qquad (5)$$

where Ir is the RMS ripple current, Vr is the RMS ripple voltage, and Z is the capacitor total impedance as defined in equation (4). Since 0.575 amperes is well below the 1.75 ampere capacitor ripple current rating, we can expect long capacitor service life.

The reason that equation (5) is an approximation is that the ripple voltage has a “sawtooth” rather than sinusoidal characteristic. Since a sawtooth waveform has odd-order harmonics (e.g., at 360 Hz, 600 Hz, 840 Hz, etc.), these harmonics result in additional ripple current since the capacitive reactance Xc as defined in equation (3) progressively diminishes at these higher frequencies. However, the magnitude of these harmonics also progressively diminishes as they increase in order. To account for the additional ripple current contributed by these harmonics we can add 15% or so to the result of equation (5), but even with this addition the ripple current is still very comfortably within the capacitor 1.75 ampere rating.

In reality, the above computation overstates ripple current Ir since the substitution of the larger capacitor (220 uF versus 125 uF) substantially reduces the ripple voltage Vr. As a result, the margin of safety is further improved.

Since ripple voltage Vr across C3/C4 used in the low-voltage supply is even lower, this same capacitor can be used with an even greater margin of safety.

Figure 6 is a photo of the modern 220 uF/500 V replacement capacitor (left) alongside the original 125 uF/500 V unit (right). This picture is worth a thousand words on the topic of improvements in electrolytic capacitor technology since the 1960s.

In general, there is no downside to using replacement filter capacitors with higher capacitance than the originals provided that good quality units are used with adequate ripple current ratings as discussed above. Although larger filter capacitors result in more surge current when the power supply is turned on, modern silicon power diodes (e.g., the 1N4007) have very high surge current ratings. The advantage of higher capacitance units, of course, is lower ripple voltage.

Figure 6 - Electrolytic Capacitors - Then & Now

D. MOUNTING C1/C2/C3/C4

Although the 220 uF/500 V capacitors selected to replace C1/C2/C3/C4 offer great performance and reliability, they did not fit the HP-23B chassis holes that were punched for these capacitors. It was thus necessary to fabricate capacitor mounts to handle this.

The most convenient available solution was to simply mount these capacitors on perforated prototyping boards as per Figures 7 and 8 and then mount these boards onto the chassis topside.

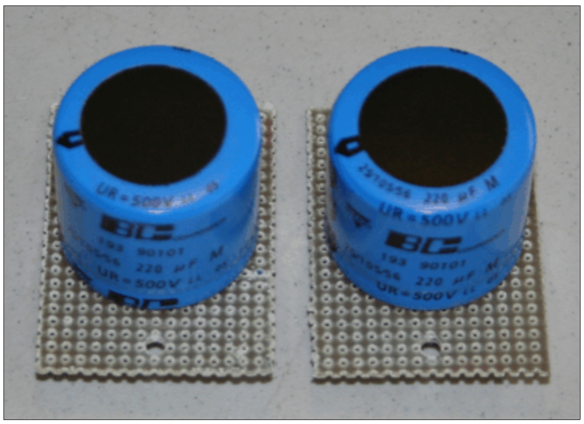


Figure 7 - Capacitor Mounts (top)

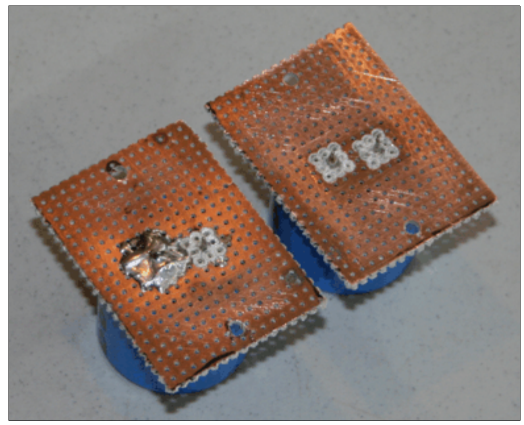


Figure 8 - Capacitor Mounts (bottom)

The perforated prototyping board material on-hand had holes drilled on a 0.1" grid and had copper-clad on one side. Since copper clad had to be cleared away from the non-grounded capacitor leads, it would have been better to have used board material with no copper clad on either side. The cut board dimensions are 2.2" x 1.6".

The capacitors employ a “snap-in” lead configuration. To accommodate this mounting configuration, board holes were drilled out with a #52 drill bit (slightly larger than 1/16") to provide a tight lead fit. The capacitors were mounted close to the center of the boards.

Additional holes were drilled at the ends of each board to accommodate the #6 mounting screws used to secure the original capacitor brackets to the matching chassis holes.

E. REPLACEMENTS FOR C5-C7 (40 uF)

As per the schematic of Figure 1, C5 is a 40 uF/450 V electrolytic used as the final output filter capacitor for the low-voltage power supply. Similarly, C6 and C7 are 40 uF/150 V electrolytics used to filter the -130 V bias supply output. As per Figure 3, all three of these capacitors are axial lead types.

The demands placed on C5-C7 are far more modest than those placed on C1-C4 discussed above. Since C5 follows the 6 H filter choke used in the low-voltage supply, ripple current is low. Since C6 and C7 filter the low-ripple -130 V bias supply output, they likewise are subject to only modest ripple current.

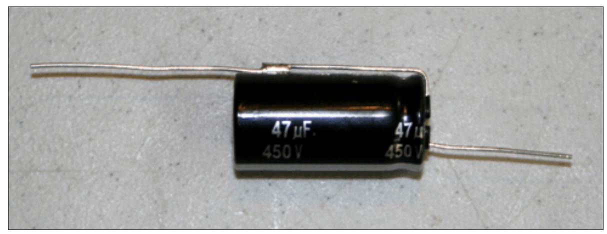
Despite the relatively modest demands placed on C5-C7, I still wanted to replace these with premium grade units selected using same high standards as for C1-C4.

A vendor search found a suitable high-quality 47 uF/450 V replacement for C5 manufactured by Panasonic (P/N EEUEE2W470) and available from Digi-Key Corp. (P/N P13677-ND). The relevant specifications for this capacitor are as follows:

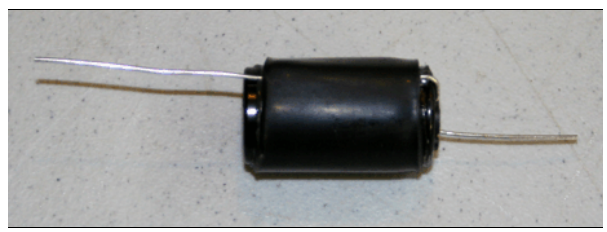
Temperature Range:	-25°C to +105°C
Rated ESR @ 120 Hz:	6.8 ohms
Rated Ripple Current (120 Hz/105°C):	0.42 amperes

Given the modest price and small size of this C5 replacement, I decided to also use this same capacitor to replace C6 and C7 as well (even though C6 and C7 require only 150 V capacitors).

A small difficulty emerged in that axial lead high-voltage electrolytic capacitors of the type originally employed for C5-C7 are hard to find (probably as a result of the fact that modern electrolytics are designed almost exclusively for PC board mounting rather than for point-to-point wiring). Since the selected replacement capacitors have radial leads, adaptations had to be made to facilitate more convenient installation.



<u>Figure 9</u> - Adapting Radial Lead Capacitor (1)


<u>Figure 10</u> - Adapting Radial Lead Capacitor (2)

As per Figure 9, one of the leads was bent back (positioned close to the capacitor body) and extended in length by soldering an extension lead (#20 or #22 bus wire works well for this purpose). This extended lead was then secured to the capacitor body (and electrically insulated) using heat-shrink tubing as illustrated in Figure 10. Good quality electrical tape can also be used for this purpose.

F. <u>RESISTORS</u>

Although a discussion of the HP-23B resistors might seem outside the purview of this discussion of its electrolytic capacitors, replacing the capacitors also presents an opportunity tp check these resistors. More specifically, significant disassembly of the HP-23B is required to replace its capacitors. As a result, most of the resistors will have at least one lead disconnected during this process so it is easy to check their values with an ohmmeter.

Although resistors are not usually considered as high-maintenance components prone to failure, the resistors used in the HP-23B are all power resistors and have thus been subjected to thermal stress. Also, these resistors are all carbon composition types, which are significantly less stable in value than the more modern carbon film types.

The resistors in my HP-23B all measured on the high side of their nominal values, in some cases having drifted outside the 10% tolerance specification. However, the values had not changed enough to warrant replacing any of them.

The high-voltage supply bleeder resistors (R1-R4; 100k/2W) are the most critical. Although a modest upward change in their values is of no great concern, it is important that their values track with each other reasonably well.

To explain, if the parallel value of R1/R2 is significantly different than the parallel value of R3/R4, there will be an unequal voltage division across C1 and C2 (“voltage hogging”). As a result, voltage appearing across one of these two capacitors might come close to or exceed its 500 V rating. To deal with this issue in my HP-23B, I regrouped these resistors so that the total resistance value of each leg was nearly the same.

Any resistor that is excessively out of tolerance (i.e., by more than 20% of its nominal value) should be replaced. Similarly, resistors that appear burned or “cooked” should also be replaced. On the positive side, resistors employed in extensively used 40+ year old equipment are fully aged and will likely not drift in value much further.

SECTION VI - PHOTOS OF FULLY RECONDITIONED HP-23B AND VENDOR NOTES

A. CHASSIS PHOTOS

Figure 11 is an underside photo of the fully reconditioned HP-23B (see Figure 3 shot prior to reconditioning for comparison). Note that C5-C7 are staked-down to the chassis using RTV. (RTV is a form of silicone sealant). I used Permatex Part 66B (now sold as Permatex #80050) which is non-corrosive and available in many hardware and auto supply stores. Other similar products are also suitable. Note also the new 1N4007 rectifier diodes with their added shunt voltage equalizing resistors. Finally, note that cable ties are used as appropriate to secure wires and cables together.

Figure 12 is a topside photo of this same unit (see Figure 2 shot prior to reconditioning for comparison). Note the replacement capacitors for C1-C4 and their mounts.

B. PARTS VENDORS

As discussed above, I purchased the necessary parts from Digi-Key Corp. since they have an excellent selection of capacitors. Other parts vendors with good parts selections and reasonable minimum order requirements are Jameco Electronics and Mouser Electronics. Contact information is as follows:

Digi-Key Corp. - www.digikey.com
Jameco Electronics - www.jameco.com
Mouser Electronics - www.mouser.com

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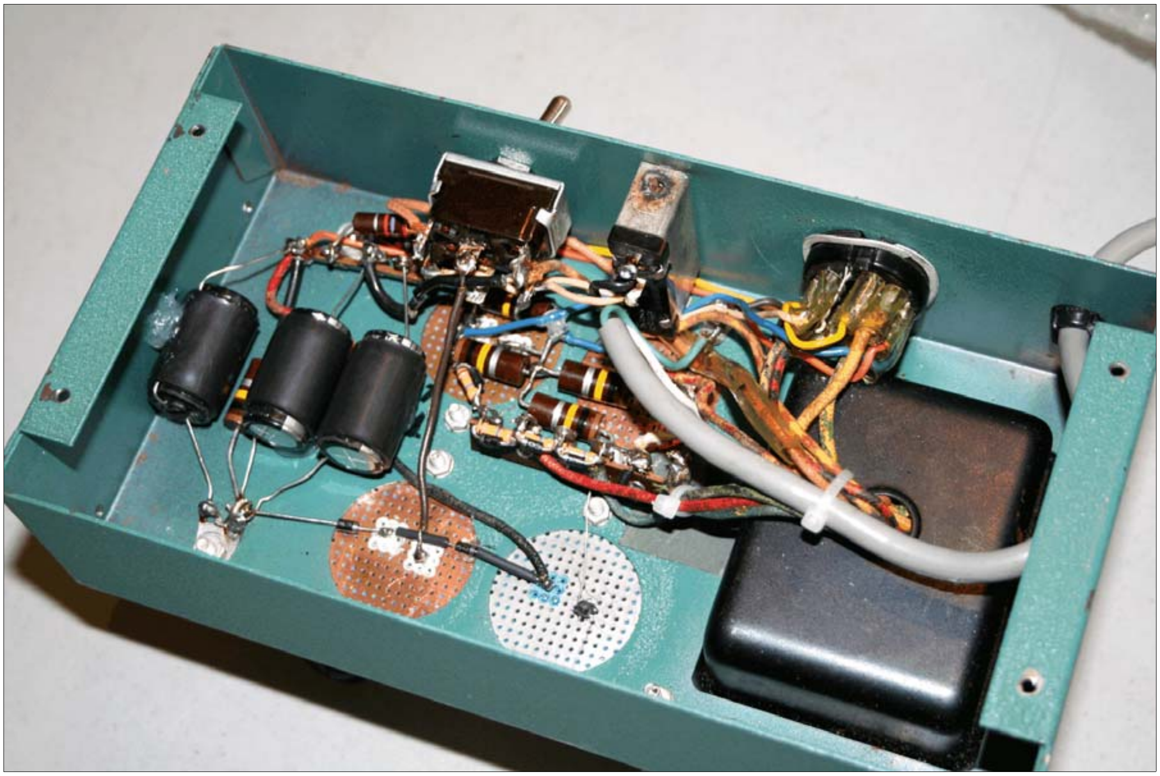


Figure 11 - **Underside Photo of Fully Reconditioned HP-23B**

Figure 12 - **Topside Photo of Fully Reconditioned HP-23B**

APPENDIX A - MODEL VARIATIONS (HP-23/HP-23A/HP-23B/HP-23C/PS-23)

Since the HP-23 series power supply was in production for at least 15 years beginning in 1963, it is not surprising that there were changes (in both the design and the corresponding model suffix) during this period. The most important and significant change was from the original HP-23 to the HP-23A.

The original HP-23 was designed exclusively for 115 VAC operation (and thus was inconvenient to operate in Europe and other areas with 220-240 VAC power mains). This shortcoming was corrected in the HP-23A which employed a new power transformer having two 115 VAC primaries that could be wired either in series for 220-240 VAC mains or in parallel for 110-120 VAC mains.

The remaining changes are summarized as follows:

Pilot Lamp - The original HP-23 had a neon pilot lamp to indicate that the unit was powered-up. This feature was discontinued in all successor models.

Circuit Breaker (vs. fuse) - The original HP-23 had a 3 ampere fused AC power plug, whereas all the successor models employed a manual resettable circuit breaker.

Center-Tapped Filament Winding (6.3 VAC) - The HP-23 and HP-23A employed a center-tapped 12.6 VAC transformer filament winding to provide a 6.3 VAC filament output. This 6.3 VAC tap was eliminated in the HP-23B/C models (presumably since as the 1960s progressed, the newer compatible Heathkit transceivers required 12.6 VAC filament voltage only).

Adjustable Negative Bias Output - Although all of the HP-23 series models had a fixed -130 VDC negative bias output, the HP-23 and HP-23A additionally had an adjustable -40 to -80 VDC negative bias output as well. This feature was eliminated in the HP-23B/C models.

On/Off Switch - The HP-23 and HP-23A/B models had an On/Off switch. This feature was eliminated in the HP-23C.

Selectable Low-Voltage Supply - While all HP-23 series models had selectable low-voltage DC outputs (+250/+300 VDC), the HP-23A/B models employed a 3-position (On-Off-On) double pole AC power switch that also selected the appropriate tap on the power transformer low-voltage secondary. With these models, the left/right most positions respectively selected +250/+300 VDC low-voltage outputs with the center position being AC OFF (see Figures 2 & 12). The HP-23 and HP-23C models, in contrast required that this selection be done by means of a hard-wired jumper.

In the final years of production, the HP-23 model number was apparently changed to “PS-23". This appears to be a renamed version of the HP-23C with no substantive changes in features or performance.

For a convenient comparison of these Heathkit 23 series power supplies, go to the chart at this link (or see the abbreviated version in Table I below):

http://webusa.us/OHP/PAGES/COMPARISONS.htm

It is interesting to note that aside from adding the dual power transformer primary windings to allow both 115/230 VAC operation and eliminating the fused AC power plug, the overall trend following the HP-23A model (the most “feature-rich”) was to “strip-down” features to reduce production costs. Fortunately, these deleted features were relatively minor ones that did not significantly affect the unit’s versatility (and had no effect whatsoever on the unit’s core performance or reliability).

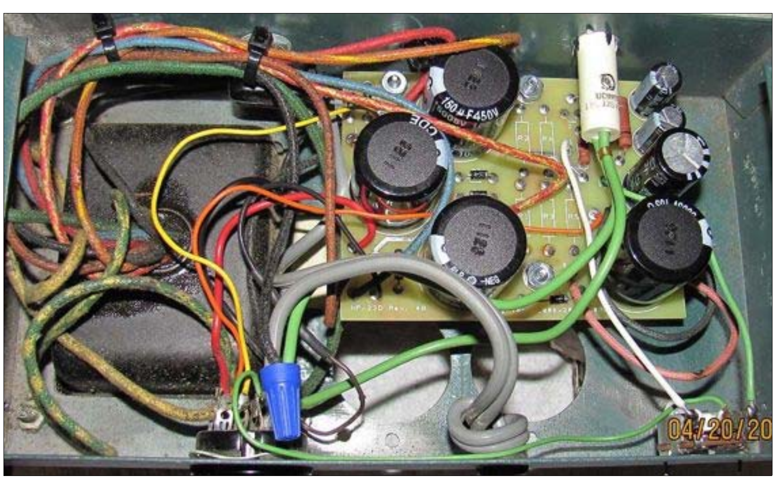
More specifically, the pilot lamp was mostly ornamental and served no useful purpose since these HP-23 series supplies were mostly located out of the operator’s view. This was especially true for their dominant application as AC power supplies for the SB-100/HW-100 series transceivers where they were typically mounted inside the SB-600 speaker cabinet.

The 6.3 VAC filament voltage output was similarly unnecessary. As discussed above, the predominant application of the HP-23 series supplies was for use with Heathkit equipment that required 12.6 VAC filament voltage only. Similarly, the adjustable -40 to -80 VDC negative bias output was not required in the contemporary (60s/70s) Heathkit equipment .

The On/Off switch was likewise unnecessary since it was far more convenient to power up the supply remotely via the associated Heathkit transceiver On/Off switch via interface socket pins 9 & 10 (labeled “AC SWITCH” as per the Figure 1 schematic). Although eliminating the On/Off switch also eliminated the ability to switch-select the +250/+300 VDC low-voltage supply output (thus requiring the operator to make this selection during kit assembly via a hard-wired jumper), this was no practical inconvenience since this jumper was “set and forget” for any given Heathkit transceiver.

So although the HP-23C/PS-23 final versions were stripped-down as compared to the feature-rich HP-23A, these production economies were of no practical consequence. Fortunately for Heathkit, there was apparently no resulting market push-back.

The reader will notice mention of an “HP-23D” at the above link. This is actually a kit (sold by “OldHeathkitParts”/K8GNZ at the above link) comprising a PC board and better and more modern resistors, capacitors and diodes. This PC board then mounts inside the HP-23 series chassis (all models including the PS-23) as per Figure 13. This kit does not add any new features, but does provide a convenient means of refurbishing these units with modern and more reliable components.



<u>Figure 13</u> - “OldHeathkitParts” PC Board Retrofit for HP-23

TABLE I - HP-23 MODEL COMPARISON

MODEL	AC INPUT	PILOT LAMP	ON/OFF SW	FILAMENTS	BIAS	LV TAP	PROTECTION
HP-23	115 Only	Yes	Yes	6.3 & 12.6	Fixed & Adj	Hard-Wired	Fuse Plug
HP-23A	115/230	No	Yes	6.3 & 12.6	Fixed & Adj	Switched	Circuit Breaker
HP-23B	115/230	No	Yes	12.6 Only	Fixed Only	Switched	Circuit Breaker
HP-23C	115/230	No	No	12.6 Only	Fixed Only	Hard-Wired	Circuit Breaker
PS-23	115/230	No	No	12.6 Only	Fixed Only	Hard-Wired	Circuit Breaker

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