Heathkit of the Month #094:
by Bob Eckweiler, AF6C

[ELECTRONIC TEST EQUIPMENT

Heathkit IP-27
Regulated Low Voltage Power Supply.

Figure 1: Heathkit IP-27 Regulated LV Power Supply. (See Figure 5 for detailed view.)

Introduction:

A Lambda dual low voltage power supply with two independent current limited outputs, each rated at 0 - 20 VDC and 0 - 1.7 amps, supplies power for most low-voltage projects on this bench. Some years ago a used Heathkit IP-27 Power Supply was purchased at a local garage sale to supplement the Lambda supply. It ended up on the shelf without so much as being given a "once-over", where it sat until recently. Finally it's being checked out and getting some respect; it is the subject of this month's Heathkit article. See **Figure 1**.

That IP-27 included the original manual and inside the manual was the bill of sale. It was originally purchased from the Heathkit store on Ball Road in Anaheim on November 18th 1972. It cost $91 plus CA tax (4.9% back then.) The factory catalog price at the time was $79.95 and UPS shipping (16 lbs.) was $3.80 to 92667[1] zip code.

Important IP-27 Service Bulletin:

In 1973 Heathkit made an important modification to the IP-27 due to the frequent failure of the pass transistors resulting from rapidly switching the **COARSE VOLTAGE** switch. The modification is documented in Heathkit service bulletin IP-27-1 (dated June 24, 1973), and service centers were told to modify any Heathkit IP-27s returned for service. If you have an IP-27 check that the modification has been done. If not, it is easy to do and parts are readily available. (See the sidebar for more details).

The IP-27 Regulated Low Voltage Power Supply:

The IP-27 was released in 1967, too late to make that year's main catalog. In the 1968 factory catalog (610-68) it was marked as "New". It's initial price was $76.95.

The IP-27 is a styling change and circuit upgrade to the IP-20. New to the IP-27, now in the "New Look"[2] style with its beige paint and "low-boy" clamshell cabinet, is a zener diode regulated bias supply replacing the 0B2 gas regulator tube, a new power transformer that can be wired for 120 or 240 VAC operation, and two neon lamps that indicate whether the meter is reading voltage or current. The lineup of transistors were also updated. With the exceptions noted above, the IP-20 and IP-27 have identical circuitry; thus it is surprising to see a few significant differences between their specifications. Perhaps the IP-20 was specified with some added optimism, or perhaps a typo? **Table I** shows the specifications of the two units side-by-side.

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

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

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Specification	IP-20 Regulated LV Power Supply	IP-27 Regulated LV Power Supply
Voltage Range:	+ 0.5 Volts to +50 Volts	
Current Range:	0 to 1.5 Amps	
Load Regulation:	± 15 millivolts no load to full load for output of 0.5 to 50 volts.	
Line Regulation:	Less than **0.005%** change **105 to 125 VAC** line voltage	Less than **0.05%** change with **5% change** in line voltage
Ripple & Noise:	less than **150** millivolts	**250** millivolts maximum
Transient Response:	> 25 microseconds	
Output Impedance:	Less than **0.1 Ω** DC to 10 kHz, >0.5 Ω above 10 kHz	Less than **0.075** Ω DC to 10 kHz, >0.3 Ω above 10 kHz
Meter Ranges (A)	Four Ranges: 50 ma, 150 ma, 500 ma, 1.5 amps full scale	
Meter Ranges (V)	Three Ranges: 5, 15 and 50 volts full scale	
AC Power:	105 - 125 VAC 50/60 Hz **125** W at full load Two wire line cord.	105 - 125 VAC or 210 - 250 VAC 50/60 Hz **135** W at full load. Three wire line cord.
Dimensions:	9-1/2 H x 6-1/2 W x 11" D	5-1/8 H x 13-1/4 W x 9" D
Net Weight:	11 lbs. (13 lbs. shipping wt,)	12 lbs. (16 lbs. shipping wt.)

TABLE I Heathkit IP-20 vs. IP-27 Specifications

IP-27 Front Panel Controls:

The IP-27 **COARSE VOLTAGE** switch adjusts the output voltage between 0.5 and 50 volts in ten coarse steps: 0.5 V to 5 V for the first step followed by nine 5 volt steps, the last being 45 to 50 V. An eleventh position, fully counterclockwise, is the **AC OFF** position. The meter range automatically changes with the COARSE VOLTAGE setting: Five volts full-scale for the first range, 15 volts full-scale for the second and third range and 50 volts full-scale. for the remaining ranges. The meter scales and switch nomenclature are color-coded to aid selection. A **FINE** VOLTAGE potentiometer allows adjustment over the selected coarse range.

The IP-27 **COARSE CURRENT** switch selects the maximum current that can be drawn from the power supply. The four switch positions are: 0 – 50 ma, 0 – 150 ma, 0 -– 500 ma and 0 – 1.5 amps. The meter range automatically changes with the COARSE CURRENT setting and again the switch nomenclature is color coded with the proper meter scale. A **FINE** CURRENT potentiometer allows adjustment over the selected range.

The remaining items on the front panel are:

- The 3-1/2" meter with two scales: 0 – 15 in black and 0 – 50 in red.
- The meter rocker switch marked **CURRENT** to the left and **VOLTAGE** to the right
- A neon lamp above the CURRENT controls that lights to indicate the meter is in the CURRENT position.
- A neon lamp above the VOLTAGE controls that lights to indicate the meter is in the VOLTAGE position.

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- A toggle switch marked **DC ON** (up) and **RESET-STANDBY** (down) controls the application of power to the supply's output terminals. It also resets the overload relay should an overload have occurred.
- Three binding posts arranged in a triangle on 3/4" centers. They are marked (L to R):
  - **–** (Negative output terminal)
  - ⏚ (Chassis Ground) The power supply output is totally isolated from ground.
  - **+** (Positive output terminal)

IP-27 Rear Panel:

The IP-27 rear panel contains three screwdriver adjustable controls and a slide switch; these are used for calibration. Also mounted on the rear panel are three TO-5 power transistors, with insulating covers, and two line cord retainers that the power cord can be wound on for storage - a nice touch. The line cord exits the rear panel through a line cord strain relief grommet.

One of the three rear panel adjustments is located at the left (as viewed from the rear) below the two output transistors that mount on an aluminum heatsink. This is the **DC REGULATION** control. Under the current limiting transistor near the right side of the rear panel are the remaining two adjustments, located side-by-side. The left adjustment is the **VOLTAGE CALIBRATE (ADJUST FOR 50 VOLT OUTPUT)** control. To its right is the **ZENER CURRENT (ADJUST FOR 5 ma)** control. To the left of the current limiting transistor is a recessed **METER** toggle switch. This switch remains in the **NORMAL** position except during calibration. Then it is moved up to the **ZENER CURRENT** position and the meter reads the reference voltage zener current so it can be set properly. Adjustment of the IP-27 is well documented in the manual.

IP-27 Service Bulletin No: IP-27-1 (6/24/73)

Heathkit required that this modification be done on any IP-27 that came to a repair shop for service. It involves the addition of two wires and two components: a 56 volt zener diode and a 0.015 µf 600 V capacitor. A PDF copy of the service bulletin is available at:

http://www.w6ze.org/Heathkit/TN/SB-IP27-1.pdf

Has my IP-27 been modified or not?:

To see if your kit has already been modified, remove the bottom cover (four screws). Orient the chassis so it is upside down and the rear is facing you. In the front righthand corner is a four lug terminal strip (designated CA in the manual). This is the terminal strip closest to the corner with the output binding posts. Terminal 1 (closest to the front panel) has a black wire and the negative end of two electrolytic capacitor connected to it. In an unmodified IP-27 the two inner terminals (2 and 3) have nothing connected to them.

Continued…

Figure shows an unmodified IP-27. Note terminals 2 and 4 of CA are unused.

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Circuit Description:

The IP-27 manual has a good circuit description chapter so this section will be brief. A schematic of the IP-27 is available online[3].

Power Source:

The power transformer has three secondary windings, the top winding (on the schematic) produces about 9 volts at low current; this is a bias source for the current limiter. The middle winding is multi-tapped and produces the voltage that is regulated and appears at the output. The multi-tap limits the voltage drop across the regulating transistors at the lower voltage settings, reducing heat and wasted energy. The third winding produces 170 Vac for the reference source. This reference is accurately known and is compared to the output voltage by the regulating circuit that then corrects the output voltage.

Reference Voltage Source:

The 170 Vac voltage is rectified and regulated in three stages by zener diodes, first to 110 volts, then to 68 volts and finally to 56 volts. R3 (ZENER CURRENT ADJ.) allows the current through the final zener diode to be set to the optimum point for temperature compensation. R14 (VOLTAGE CALIBRATE) sets the top of the divider chain to 50 volts. The chain, composed of R33 through R50 and the FINE VOLTAGE pot provide a fixed 2000 Ω load to the reference supply. The voltage at the wiper of the pot can be adjusted over a six volt range below the maximum voltage set by the COARSE VOLTAGE switch.

Current Limiter:

Germanium transistor Q1 is normally biased on by the current limiter bias source. A resistor network consists of R5 control (FINE CURRENT) and R7, R8, R10, R11 and R12; this network is different for each of the four current ranges. The load current passes through the network and a voltage is developed at the FINE CURRENT pot wiper. In each current range, near the full CW position, and the load drawing maximum current, about 0.4 volts with respect to the emitter of Q1 appears. Q1 has an emitter to base drop of about 0.2 volts so the voltage across D7, connected to the wiper sums to 0.6 volts and the diode starts conducting, stealing bias from Q1, causing it to limit the current passing through it. As the pot is moved CCW less current is required to reach the 0.4 volt level, causing the current to limit at a lower value.

Voltage Regulator:

The error detector transistor Q2 provides voltage to amplifier Q3, which, in turn provides bias to Q4 and Q5 which are effectively in parallel; the small Q4 and Q5 emitter re-

Service Bulletin cont….

A modified IP-27 will have a diode and capacitor connected between terminals 2 and 3 and a jumper between terminals 1 and 2.

Parts for the Modification:

The service bulletin gives Heathkit part numbers for the diode and capacitor. Unfortunately, these parts are no longer available, but good substitutes exist:

A substitute for the 56-13 diode is DigiKey 1N4758AFS-ND (ON Semiconductor 56V 5% 1W zener diode DO41 package - 25¢)

A substitute for the 27-107 capacitor is DigiKey EF6153-ND (Panasonic ECQ-6153KF 0.015 µf 630 V metallized polyester film radial capacitor ±10% - 41¢)

You will also need some #22 insulated wire, (use solid in keeping with Heathkit custom!)

A step-by-step set of instructions (à la Heathkit manual) is available at:

http://www.w6ze.org/Heathkit/TN/SB-IP27-1A.pdf

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sistors, force the transistors to share the load even if their parameters vary. Q2 varies its drive level depending on any error between the reference voltage and the actual voltage. Should the output voltage rise too high the error detector reduces the drive and the voltage drops, and vice-versa. Some positive feedback is provided to the error detector through R23 (D.C. REGULATION) and R24. This helps keep the voltage from dropping between no lad and full load. It is normally set to perform best at 15 volts output. This results in less than a 15 mV change between no load and full load across the full voltage range of the instrument. The D.C. REGULATION control can be adjusted to keep any specific voltage constant from no load to full load. Just remember to set it back when you are done or the regulation will suffer at one extreme or the other.

Meter Circuit:

The IP-27 comes with a 1 milliamp meter. with an internal resistance of 50 Ω. Normally it can be switched to measure the output voltage or output current. The ZENER CURRENT switch on the rear panel also allows setting the reference zener diode current for best accuracy over its temperature range..

Three voltage ranges exist. The coarse voltage switch selects the correct range. In the 0.5 to 5 V position R53 (4,950 Ω 1%) is in series with the meter. It, along with the 50 Ω internal to the meter, results in 1 ma flowing in the meter at a voltage of 5 V. In the next two meter positions R54 (10K Ω 1%) is added in series with R53 and the meter, resulting in 15K Ω total. Now, 15 volts drives the meter to full-scale. Finally, for the remainder of the ranges R55 is added in (an additional 35K Ω 1%) resulting in 50K Ω total and the meter reads 50 volts full-scale.

	Meter Range			
	50 ma	150 ma	500 ma	1.5 A
R Series Leg* Ω :	147.0	149.0	149.7	149.9
R Shunt Leg Ω :	3.0	1.0	0.3	0.1
R Total Ω :	2.9400	0.9933	0.2994	0.0999
I (Full scale) A :	0.05	0.15	0.50	1.50
V Total (Volts) :	0.147	0.149	0.1497	0.1499
I Meter leg (mA) :	1.0	1.0	1.0	1.0
I Shunt leg (mA) :	49	149	499	1,499

* Includes 50 Ω meter resistance

TABLE II: Meter Current Calculations

When measuring current, R17 through R21 form a series – shunt 1% resistor network that includes the meter resistance. **Figure 2** shows the basic circuit (in this case the values when in the 500 mA full-scale range). **Table II** shows the calculations for each of the four ranges.

When the ZENER CURRENT switch on the rear panel is on, the zener current is measured in the same manner, with R32 (10 Ω)

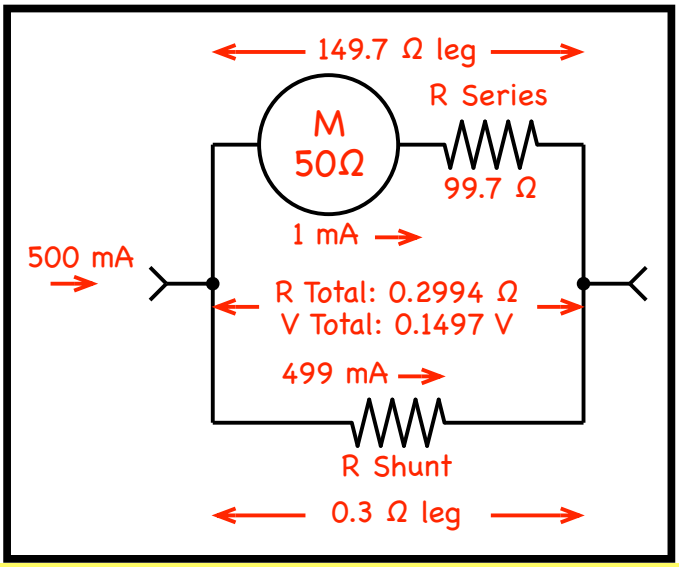

Figure 2: Basic current meter circuit when in the COARSE CURRENT switch is in the 500 mA full-scale position. (See Table II)

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and the meter resistance forming the series leg and R13 forming the parallel leg. The meter reads the zener current with 5 mA full scale on the meter.

With the ZENER CURRENT switch in the NORMAL position, the current or voltage function of the meter is selected by the meter rocker switch below the meter. This switch also selects one of two neon lamps that indicate the meter is reading either current (amber) or voltage (red). These lamps are above the COARSE CURRENT and COARSE VOLTAGE switches respectively.

It is worth noting that about 2 mA of the current read on the meter is consumed internally and is not part of the external current used. Current readings should be adjusted accordingly when on the 50 mA and possibly on the 150 ma ranges in critical situations.

IP-27 Construction:

Figure 3 and **Figure 4** are photographs of the top and bottom of the IP-27 respectively with the clamshell covers removed. Note how the power transformer is part of the chassis structure and mounted to allow a low overall height. Also note how the front panel is mounted separate from the chassis.

The IP-27 uses five transistors. Three are TO-5 power transistors and mount using sockets with the rear panel as a heat sink. They are covered with insulating cases since

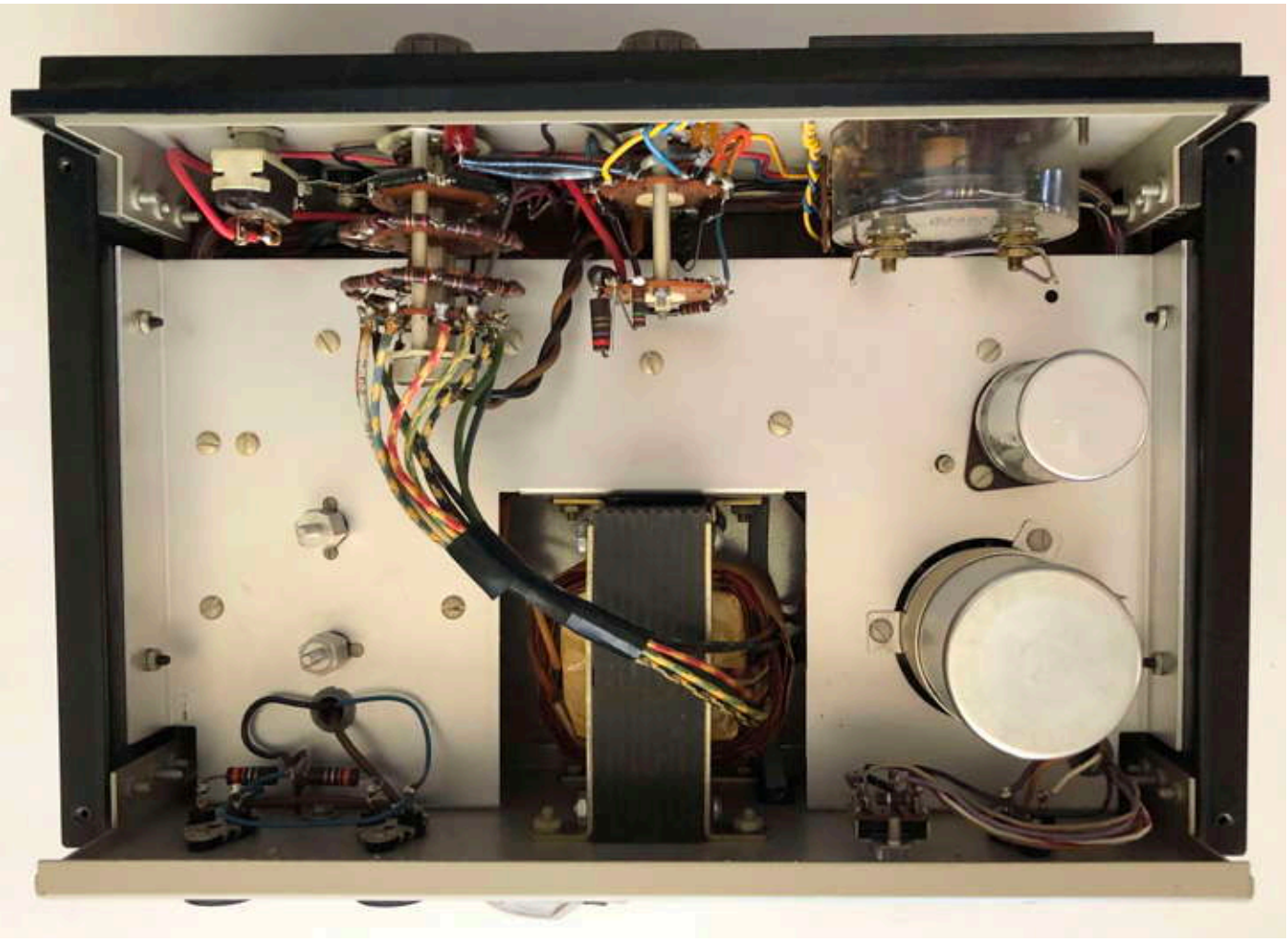

Figure 3: Top View of The Heathkit IP-27 Regulated LV Power Supply

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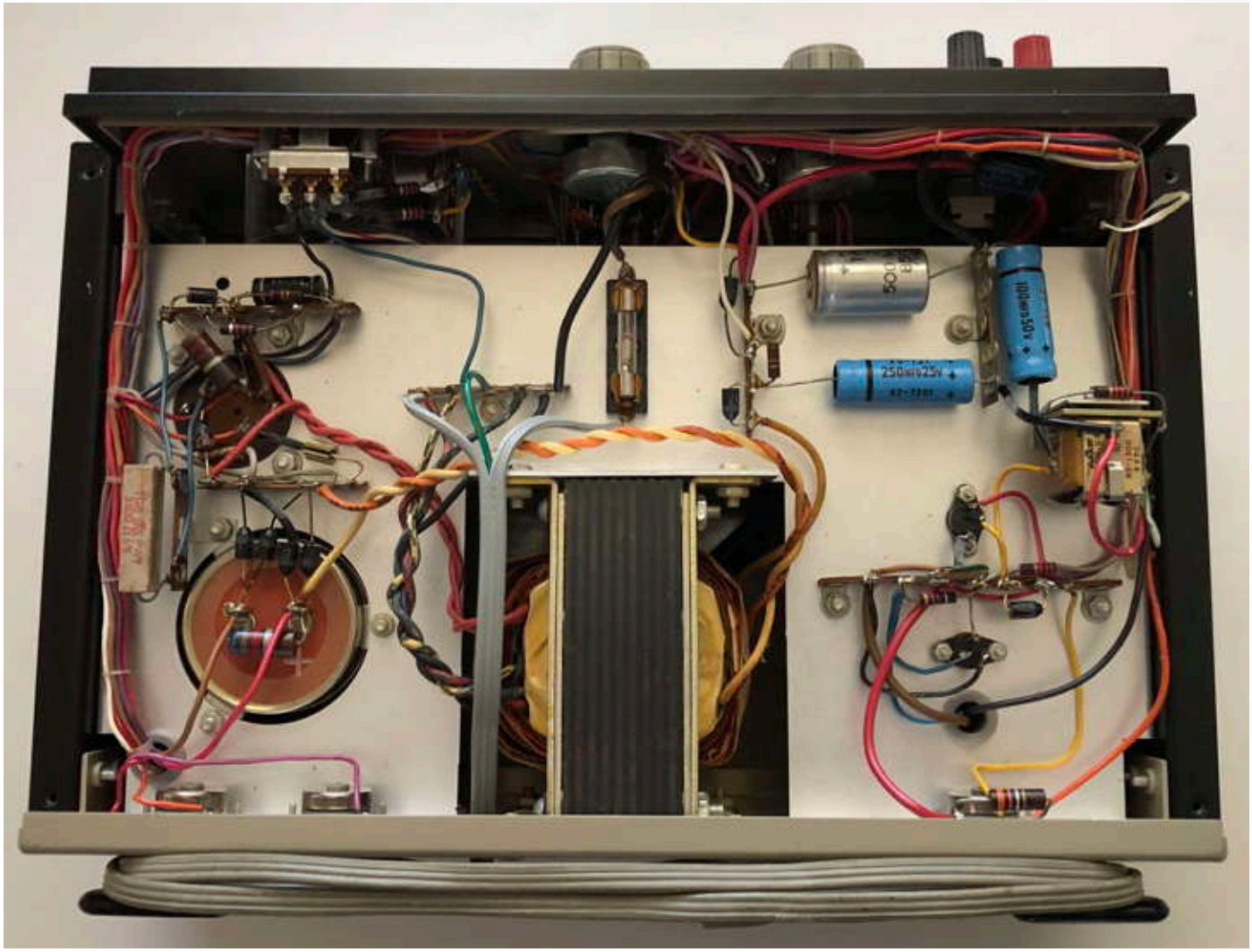

Figure 4: Bottom View of The Heathkit IP-27 Regulated LV Power Supply

their metal case is not at chassis potential. The remaining two transistors are internal.

The top view (Figure 3) shows an uncluttered layout. The two smaller transistors mount atop the chassis on the left. They have a hexagonal case with a stud for heat dissipation. The two large electrolytic capacitors are on the right. The smaller of the two is a three section electrolytic (100 µF @ 250V / 40 µF @ 250 V, 40 µF @ 200 V) that filters the reference supply. The other capacitor is a single 3,000 µF 75 V electrolytic that provides filtering for the main power supply. The two-deck COARSE CURRENT switch is above the power transformer. To its left is the four-deck COARSE VOLTAGE switch, and to the left of that is the RESET-STANDBY switch.

The bottom view (Figure 4) shows the component wiring for the reference voltage source in the upper left, the fuse holder center, above the transformer, and AC voltage selection wiring terminal strip to the right of the fuse holder. On the far right center is the overload relay, above it is CA, the terminal strip mentioned in the service modification, and below it is the regulator wiring including the sockets for the two small transistors. The three calibration potentiometers can be seen along the back edge at the bottom (two to the left and one to the right).

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Figure 5: Front View of The Heathkit IP-27 Regulated LV Power Supply

Closing Comments:

Inspection of the IP-27 shows it still needs to have the modification added. Parts are in queue for ordering. More disheartening, a deposit on the inside of the bottom clamshell reveals possible leaky capacitor residue. After an examination, it appears the leakage is coming from the three-section can capacitor. Since it is shorter than most can capacitors it may be hard to replace, and may either have to be re-stuffed or new capacitors will be installed under the chassis.

The builder of this kit did an excellent job with soldering and lead dress. Internally, everything looks clean and neat. The outside clamshells are a little scuffed up and worth painting if a reasonably matching paint can be found. Those horrible stick-on rubber feet have migrated off their base pads and are beginning to turn into goo. I see these stick-on bumpers in the local hardware store; those are sold by 3M, I'd like to know if they are the same as Heathkit uses? I'll pick some up to replace these, but why have 30 year stick-on feet used by Heathkit on kits like the HD-1420 and HD-1424 turned to goo, when their 70 year old thru-hole feet (V-4A and others) are still doing their job?

73, from AF6C

Notes:

1. 92667 is the Zip Code for a southern section of the City of Orange back in the early 70's. It is now 92869
2. In his book ***Heathkit Test Equipment Products*** author Chuck Penson WA7ZZE defines the six styles that the Heathkit line of test equipment went through over the years. See page iv for the list and description of the styles.
3. www.w6ze.org/Heathkit/Sch/IP-27-Sch.jpg

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

Thanks - AF6C