Heathkit of the Month #127:
by Bob Eckweiler, AF6C

ELECTRONIC TEST EQUIPMENT

Heathkit IP-18
1 - 15 VDC Regulated Power Supply

Introduction:

The IP-18 (**Figure 1**) supplies a well regulated 1 to 15 volts DC at up to a 500 mA continuous load; it was introduced in 1969 at $19.95 (**Figure 2**). While inexpensive, this supply provides some advanced features, and to keep the cost low, leaves out some others. Since the IP-18 is still seen around a lot, many must have been sold. The IP-18 continued in production until 1977. It was selling for $24.95 when it was replaced with the equally priced IP-2728 **(Figure 3)**. The IP-2728 appears to be almost identical to the IP-18 circuit-wise[1], with only changes in styling and a few components; a fuse has been added. The IP-2728 remained in production until 1990. In the spring 1990 catalog the IP-2728 was listed, without an accompanying picture, priced at $49.95. In the summer catalog it was shown, with its picture, but instead of a price, were the words *"Sorry, no longer available."* **(Figure 4).** The IP-18 specifications are given in **Table I.**

Here is a link to the index of Heathkit of the Month (HotM) articles:
http://www.w6ze.org/Heathkit/Heathkit_Index.html

Figure 1: The author's IP-18 sporting a newly painted top cabinet shell.

Heathkit IP-18 Controls and Connections:

The IP-18 front and rear panel layout is shown in **Table II**. The **VOLTAGE** control sets

New Low Cost Heathkit 1-15 VDC Solid-State Power Supply . . .
Ideal For Transistor Circuitry Experimentation & Servicing

• Voltage regulated • Adjustable current limiting Output up to 500 mA continuous at 1-15 v. • AC and DC programming • "Floating" output for either + or — ground • All silicon transistors • Circuit board construction • Compact fit-anywhere size • So low in cost you can afford one for positive supply, one for negative supply

THE IDEAL POWER SUPPLY FOR ANYONE WORKING WITH TRANSISTORS. Whether you work in a laboratory designing transistor circuits, enjoy experimenting with solid-state circuits in your home workshop or service transistor equipment, the new Heathkit IP-18 is the power supply for you. Here in one compact design is a solid-state supply with voltage regulation, adjustable current limiting, AC or DC programming, and the correct output voltages, all at a remarkably low cost.

Kit IP-18, 5 lbs. **$19.95**

IP-18 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 50mV change 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 microseconds. **Output impedance:** .5 ohm or less to 100 kHz. **Power requirements:** 105-125 or 210-250 VAC, 50/60 Hz, 15 watts at full load. **Dimensions:** 5⅛" W x 4⅜" H x 5¾" D. **Net weight:** 3¾ lbs. **Programming:** AC or DC, 5000 ohm input resistance.

Figure 2: Early ad for the IP-18 from the 1969 main catalog.

1. Notes begin on page 19.

Figure 3: The newly styled Heathkit IP-2728 that replaced the IP-18 in 1977.

Figure 4: The last Heathkit IP-2728 ad appeared in the summer 1990 catalog, page 86.

the maximum voltage the supply will provide, and the **CURRENT** control sets the maximum current the power supply will provide.

Heathkit IP-18 Features:

The constant current feature of the IP-18 is a feature not often found in inexpensive power supplies. You can limit the current the supply will provide with the CURRENT control. Even the more expensive IP-2718 doesn't have this feature, though it does have fixed current limiting for circuit protection. A second feature is the output is isolated from chassis ground so you can series multiple power supplies. A convenient green binding post is provided so you can select which lead, if any, you want to reference to chassis ground. The chassis is connected to earth ground through its 3-wire AC power cord. A third feature is the ability to program the output voltage with either an AC or DC voltage. More on this feature later.

Heathkit IP-18 - What's Missing:

The IP-18 has a lot of features for a $20 power supply, even back in 1969. It comes with some drawbacks too. Missing, and almost crucial, are meters. Most all power supplies with constant current capability come with not just a voltmeter but also a separate ammeter. These expensive components are

IP-18 SPECIFICATIONS

Voltage Control	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 500 mA.
Transient Response:	25 μs
Output Impedance:	0.5 Ω or less to 100 kHz
Power Requirements:	105 – 125 or 210 – 250 VAC 50/60 Hz, 15 watts full load.
Dimensions:	5-½" wide x 4-⅜" high x 5-¾" deep.
Net Weight:	3-¼ lbs.

TABLE I

missing on the IP-18. The early IP-18 power supplies came with a scale on the VOLTAGE control, but it must have been inaccurate as it was dropped shortly after production began (**Figure 5**) [2]. The CURRENT control never had anything but a circular arrow showing **MIN** and **MAX**. An external meter, or better two meters, are worth having available when using the IP-18, depending on your use. A simple VOM or two should be adequate.

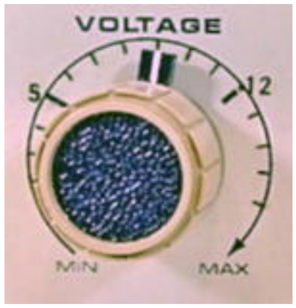


Figure 5 See Text

IP-18 Circuit Description:

A schematic (**Figure 8**) is shown on page 14. The IP-18 uses five diodes, four transistors (including one FET transistor), and one neon bulb that is used only for power on indication. **Table III** lists these components and some of their pertinent specifications. The IP-18 circuit can be split into five parts. The power supply, the reference supply, the voltage regulator circuit, the current regulator circuit and the output filtering. Let's examine them:

IP-18 FRONT PANEL ITEMS	
Row - Top (Left -to-Right):	
VOLTAGE	Potentiometer 5KΩ
Circular Arrow **MIN** (full CCW), (**MAX** full CW)	
CURRENT	Potentiometer 100Ω
Circular Arrow **MIN** (full CCW), (**MAX** full CW)	
Row - Bottom (Left -to-Right):	
Pilot Lamp	Neon (NE-2H)
Output Binding Posts (3) in a triangle (¾" centers)	
–	Black (Negative)
(Gnd. symbol)	Green (Chassis Ground)
+	Red (Positive)
Power Switch	SPST slide switch **ON OFF**
IP-18 REAR PANEL ITEMS	
Row - Top (Left -to-Right):	
Transistor (Q3)	Insulated (cabinet for heatsink)
PROGRAMMING - EXTERNAL VOLTAGE CONTROL	
Terminal strip	screw type, 3-terminals
Terminals 1 - 2	**AC** (Jumpered for normal operation.)
Terminals 2 - 3	**– DC +**
Row - Bottom (Far Right):	
Power cord exit	Three-wire with strain relief.
(*Bold items in table are printed nomenclature.*)	

TABLE II

Power Supply & Reference Supply:

It seems a little strange to talk about a power supply's power supply, but we'll press on! The power transformer has two primary windings that allow the IP-18 to be wired for 120 or 240 volt line voltage. The primary may be fused [3] and has an NE-2H neon bulb for a pilot lamp. The neon lamp and its current limiting resistor (R8) wired across one winding of the transformer primary so it sees about 120 volts independently of the primary voltage the supply is wired for.

There are two secondary windings. One is 40 VAC center-tapped, rectified by two hard-to-find CER100 diodes [4]. The circuit is a common full-wave rectifier, discussed here many times, and uses a pi RC filter. It produces about 25 volts [5] DC. The second winding is 30 volts, and produces a regulated 20 VDC. Rectification is half-wave by another CER100 diode, and regulation is provided by a VR20 1-watt zener diode (D4). This voltage is the reference for the voltage regulator circuit. It produces a negative voltage between 0 and minus 16.7 volts, depending on the position of R4, the VOLTAGE control. The positive lead of the reference power supply is tied to the output voltage of the IP-18, so the voltage at the wiper of R4 varies from the output voltage to 16.7 volts below the output voltage.

IP-18 ACTIVE COMPONENTS

D1, D2, D3	CER100	Rectifier Diode
(57-29)	100V PRV 750 mA	
(Substitute):	1N2002	Rectifier Diode
(57-65)	100 PRV 1000 mA	
D4	VR20	Zener Diode
(56-45)	20 V, 1 Watt (Sarkes Tarzian)	
(Substitute):	1N4747A	Zener Diode
(56-45 new)	20V, 12.5 mA 1 Watt	
D5	1N191	Germanium Diode
(56-26)	90 PRV, 5 mA	
(Substitute):	ECG109	Germanium Diode
	75 PRV	
PL-1	NE-2H	Neon Lamp
(412-15)	95 / 65 V ¼ watt, R series 30K	
(Substitute):	C2A	Neon Lamp
	Identical specs.	
Q1	2N4304	JFET TO-5
(417-140)	$V_{GS(off)}$ –10 V, I_{DSS} 0.5 mA	
Q2	2N3566	NPN Transistor TO-5
(417-109)	40 V_{CEO}, 100 mA, 800mW, 20 MHz	
Q3	2N3055	NPN Transistor TO-3
(417-162)	60 V_{CEO}, 115 W, HFE = 20 Min	
Q4, Q5	2N3393	NPN Transistor TO-92
(417-118)	25 V_{CEO}, 825 mW, 500 mA	

TABLE III

Voltage Regulator Circuit:

Q1, a 2N4304 field effect transistor is wired as a current source, sourcing about 425 µA to the base of Q2. Q2 and Q3 are wired as a Darlington pair with a typical overall current gain of 6,000. Q3 is a pass transistor that controls the output voltage of the supply. With Q4 and Q5 cutoff, all the current from the constant current source biases the Darlington pair on, allowing maximum voltage output. However, the reference power supply is connected between the supply output and the base of Q4. Let's assume the VOLTAGE control is set so the reference supply is at 10 volts. If the power supply output is greater than 10 volts (plus the small voltage drop due to Q4 and D1) [6] Q4 will begin to conduct, routing part of the constant current to the negative side of the power output, in turn reducing the current available to Q2 and Q3 causing them to reduce the output voltage. Likewise, if the output voltage is lower than the set voltage, Q4 draws less current and the voltage rises. So the output voltage is regulated to a voltage slightly higher than the voltages by the VOLUME control. That is why the minimum voltage is specified as 1V.

Current Regulator Circuit:

R6, the CURRENT control is a 100 Ω potentiometer in series with R7 (0.51 Ω) in the output lead. As long and the combined drop between R6 and R7 is below about 0.6 volts Q5 remains cutoff. However, if the current through these resistors exceeds that voltage, Q5 will start to conduct, also routing some of the constant current away from Q2 and Q3 causing the voltage to drop, and keep the output current steady. With R6 set to MAX (0 Ω) The maximum current will be somewhere near 1 amp due to the resistance of R7 as well as other stray resistances. The minimum current that can be set is less than 10 mA.

The Output Circuit:

There are only two components in this circuit. The first R9 is a 3.3 KΩ bleeder resistor across plus and minus output terminals. It sets a minimum load for the regulator circuit. The second is C4, a 100 µf electrolytic capacitor, also across the output terminals. It is probably there to add some additional low frequency filtering. however this capacitor is a current source and is beyond the current regulator. Thus, if the power is on and a device is connected across it, the device will initially see a higher voltage that causes a current surge before the current settles down to the correct operating current.

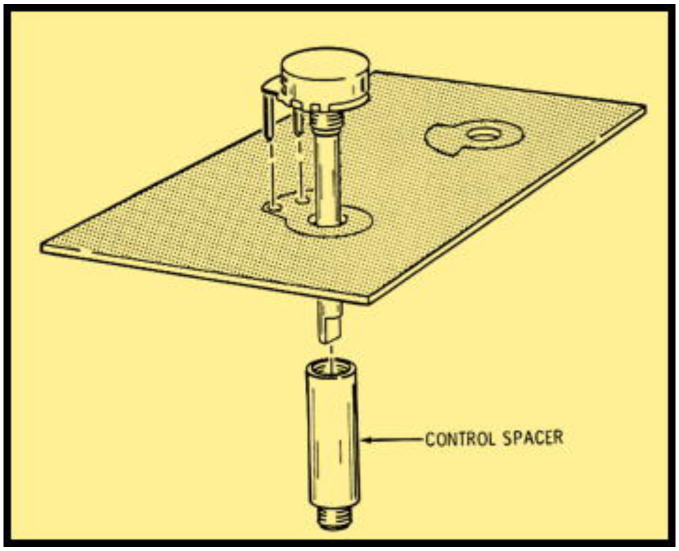


Figure 6: Long shaft controls and control spacers allow the circuit board to mount to the front panel.

IP-18 Assembly:
Most of the components in this kit mount on a single circuit board, including the two controls. The controls have long shafts and a control spacer (see **Figure 6**) is used for mounting. External parts that mount directly to the chassis are the three binding posts, the neon lamp lens, the power slide switch, the three-screw programming terminal strip, the power cord with strain relief and Q3, which uses the chassis as a heatsink. Q3 is socketed and has a protective insulated cover since its case is at 25 volts. Internally, the circuit board is mounted vertically using the two control spacers and an 'L' bracket (see **Figure 7**). The transformer mounts directly to the chassis bottom with #8 hardware. All the transformer leads terminate at the circuit board, as do the line cord hot and neutral leads. Selection of the line voltage is done with jumpers on the circuit board.

The IP-18 Operation:
The VOLTAGE and CURRENT controls set the maximum voltage and current the supply will output. If the IP-18 contained meters you would set the VOLTAGE control with the voltmeter and then short the output and set the CURRENT control using the ammeter. It is always best to start with the CURRENT control near minimum when setting the current. You can still do this with an external VOM meter. As long as the set current is not exceeded, the voltage will remain constant; this is considered the voltage mode. As soon as the current is exceeded, the voltage will decrease as needed and the current will remain constant; this is considered the current mode. It is all governed by Ohm's law and the resistance of the load.

In the following discussion there are three graphs **(Figures 9, 10 and 11)** that illustrate the power supply output under three different conditions. The data plots in cyan (light blue) show the output current; they are plotted against the vertical axis on the left at 31.25 mA per division. The data plots in violet show the output voltage; they are plotted against the vertical axis scale on the right at 1 V per

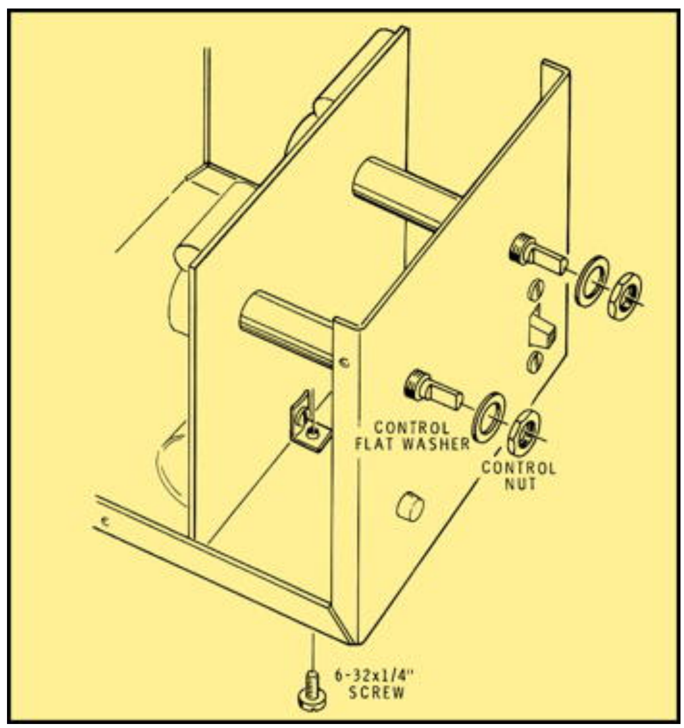


Figure 7: Installing the circuit board to the front panel and chassis bottom.

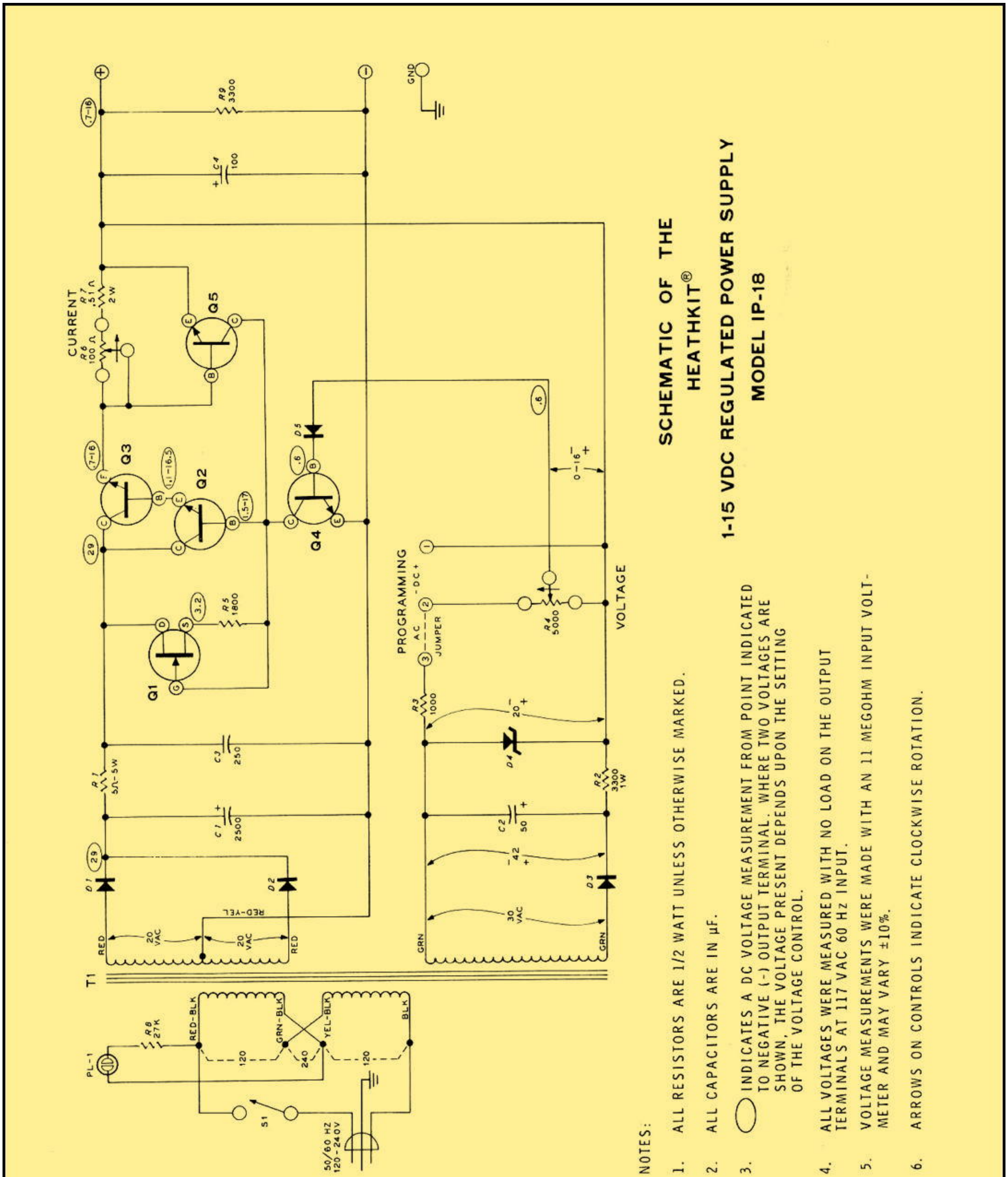


Figure 8: A schematic of the IP-18 from the Heathkit manual [595-983-01] Dated June 20, 1969

division. Remember that the IP-18 is specified to output between 1 volt and 15 volts and 10 mA to 500 mA. However, in the first two examples the minimum current that can work with 1 V and 40 Ω is 25 mA.

Current Control:

Figure 9 is a graph illustrating the action of the CURRENT control. The VOLTAGE control is set for 10 V, and then a 40 Ω load is placed across the output of the power supply. Initially the CURRENT control is set at 500 mA, near maximum. At this point 10 volts is being applied across the load and the current is 250 mA by Ohm's law:

$$I = \frac{E}{R} = \frac{10V}{40\Omega} = 250mA$$

As the CURRENT control is decreased from 500 mA to 250 mA, both the voltage and actual current remain 10 V and 250 mA. Once the CURRENT control decreases past 250 mA it takes control of the output and the voltage begins to drop linearly with the current. The current controls the voltage by Ohm's law. When the CURRENT control reaches near minimum the current reaches 25 mA and the voltage is then 1V:

$$E = IR = 25mA(40\Omega) = 1V$$

When the current is above the knee in the graph the voltage remains constant; when it drops below the knee the voltage is reduced due to current limiting. The location of the knee depends upon the load resistance and the setting of the VOLTAGE control, and is easily calculated with Ohm's law.

Voltage Control:

Figure 10 is a graph illustrating the action of the VOLTAGE control. The CURRENT control is set for 250 mA, and then a 40 Ω load is placed across the output of the power supply.

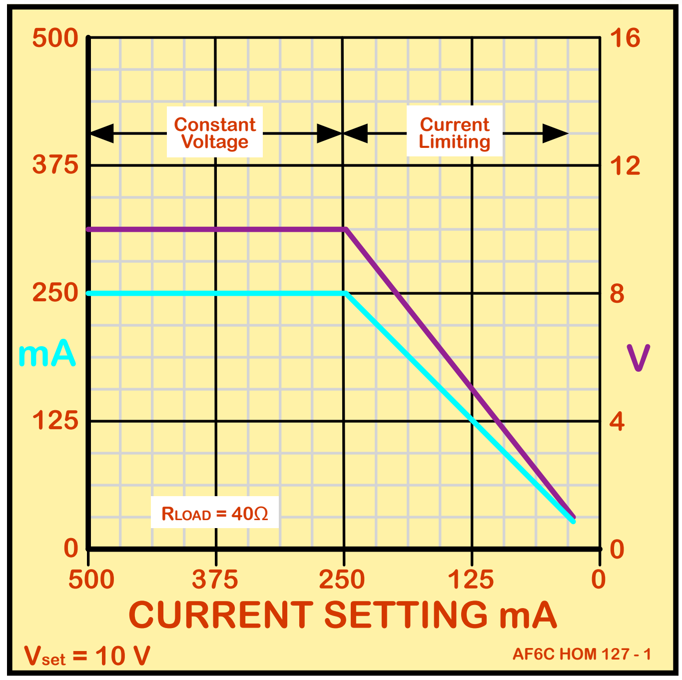


Figure 9: A Graph showing the functioning of the CURRENT Control with a fixed load and fixed VOLTAGE control setting. (Constant Voltage mode).

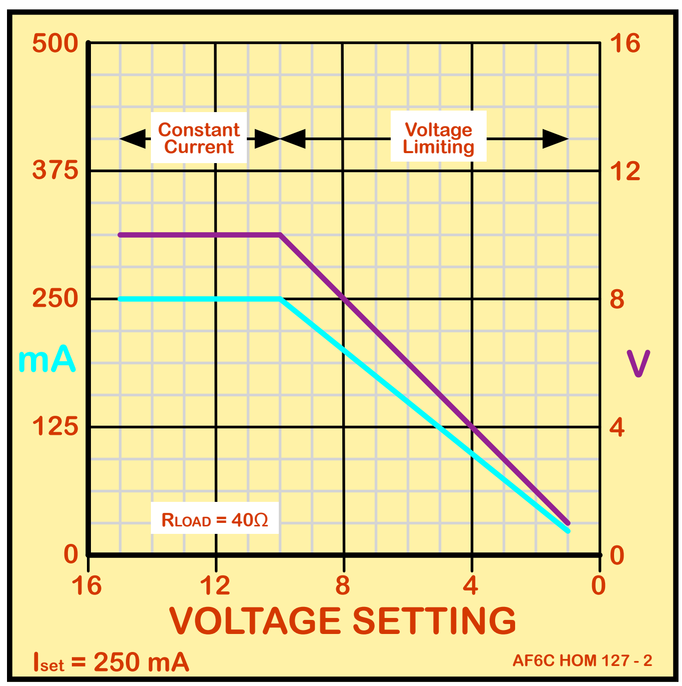


Figure 10: A graph showing the functioning of the VOLTAGE Control with a fixed load and fixed CURRENT control setting. (Constant Current mode).

Initially the VOLTAGE control is set at 15 V, near maximum. At this point 10 volts is being applied across the load and the current is 250 mA by Ohm's law:

$$E = IR = 250mA(40\Omega) = 10V$$

As the VOLTAGE control is decreased from 15 V to 10 V both the current and actual voltage remain 250 mA and 10 V. Once the VOLTAGE control decreases past 10 V it takes control of the output and the current begins to drop linearly with the voltage. The voltage controls the current by Ohm's law. When the VOLTAGE control reaches near minimum the voltage reaches 1 V and the current is then 25 mA:

$$I = \frac{E}{R} = \frac{1V}{40\Omega} = 25mA$$

When the voltage is above the knee in the graph the current remains constant; when it drops below the knee the current is reduced due to voltage limiting. The location of the knee depends upon the load resistance and the setting of the CURRENT control, and is easily calculated with Ohm's law.

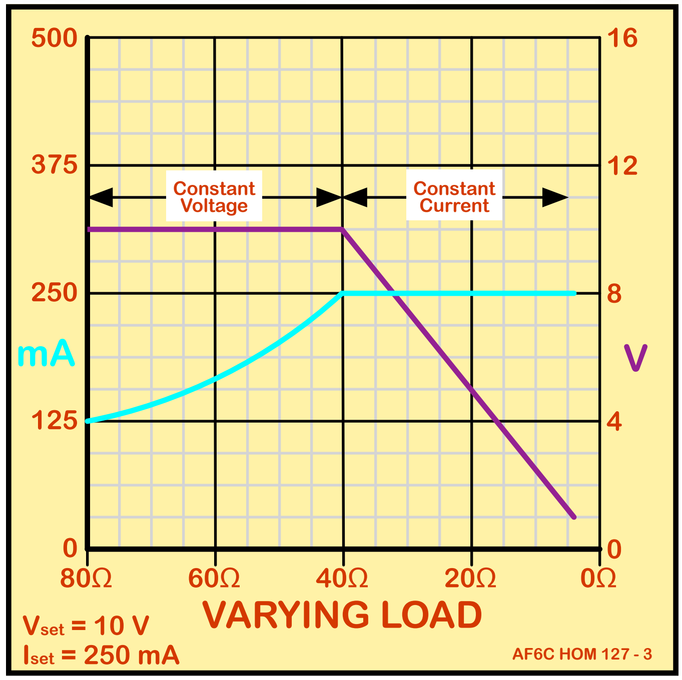


Figure 11: A graph showing the result of changing the load with fixed VOLTAGE and CURRENT control settings.

IP-18 Remote Programming:
The output voltage can be programmed externally by applying an appropriate voltage to the three-screw terminal strip on the rear of the IP-18 (**Figure 12**). Either AC or DC programming may be used. There is a jumper

FIGURE 12: A view of the rear of the IP-18 showing the programming terminal strip. Insulated transistor is on the left and the power cord exit is on the right.

<u>Varying Load</u>:
In the two previous sections the fixed load of 40 Ω was used for convenience, but what happens when the load changes dynamically? **Figure 11** shows the power supply operation, with the VOLTAGE and CURRENT controls set to 10 V and 250 mA respectively, for a load that is varying between 80Ω and 5Ω. Between 80Ω and 40Ω the voltage stays constant at its set voltage, but the current rises from 125 to 250 mA. It is not a straight line but a reciprocal curve, that, if were to continue, would become asymptotical to the 0Ω vertical axis. At 40Ω the current now reaches its set value and it remains constant while the voltage decreases linearly down to a minimum of approximately one volt. or less.

across the AC terminals on the **PROGRAMMING (EXTERNAL VOLTAGE CONTROL)** terminal strip that is required for normal operation. It is removed when either AC or DC remote programming is used.

DC Remote Programming:

With the jumper removed, a DC programming voltage can be applied to the DC terminals. Be sure to observe polarity and do not exceed 16 volts. The input impedance across the DC terminals is 5 KΩ. The programming voltage should not be referenced to ground. With the VOLTAGE control at MAX the output of the IP-18 will be the same as the input voltage, less a small drop due to the base drop of Q4. The VOLTAGE control can then be used to proportionally control the output voltage. For example, with the VOLTAGE control halfway between MAX and MIN the output voltage will be half of the programming voltage. When finished using the programming voltage, be sure to replace the jumper across the AC terminals on the terminal strip.

AC Remote Programming:

AC remote programming is a bit esoteric. It allows placing an AC voltage on top of the DC output voltage. The sum of the DC and AC voltage should not exceed 16 volts or go negative. To maintain the DC reference source the AC source should have a low impedance with respect to the 5 KΩ VOLTAGE control. Heath recommends "*…a low impedance transformer secondary.*"

Heath, in the manual, describes the output of the power supply when using AC programming thusly:

"The output voltage from the Power Supply will now be a pulsating 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 pulsating DC output. The CURRENT control operates normally."

Operation With Multiple IP-18s:

Multiple IP-18 Power Supplies may be connected together for higher voltages or currents.

Series Operation:

Since the output of the IP-18 is isolated from chassis ground, two or more of them may be easily connected in series to provide voltages above 15 volts. The current control on each supply should be set identically if current limiting is desired (Figure 13).

Parallel Operation:

Two or more IP-18s may be wired in parallel to supply additional current, though it is a bit more tricky. Before the power supplies are connected in parallel, the voltage of each IP-18 should be separately set to the same desired voltage using an accurate voltmeter, and a resistor (0.1Ω) should be placed in the positive lead of each supply to help them share the load (Figure 14). It seems to me there should be a better way, using the programming terminals on the rear panel, to keep the voltages close to each other?

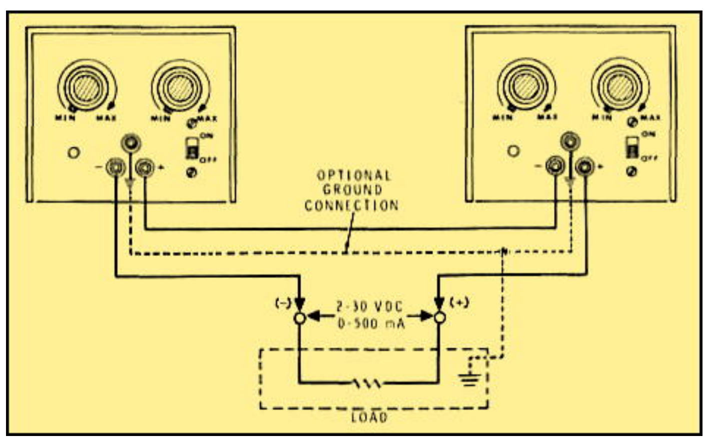


FIGURE 13: An illustration from the manual showing wiring for series operation of multiple IP-18s to get higher current output (See Text).

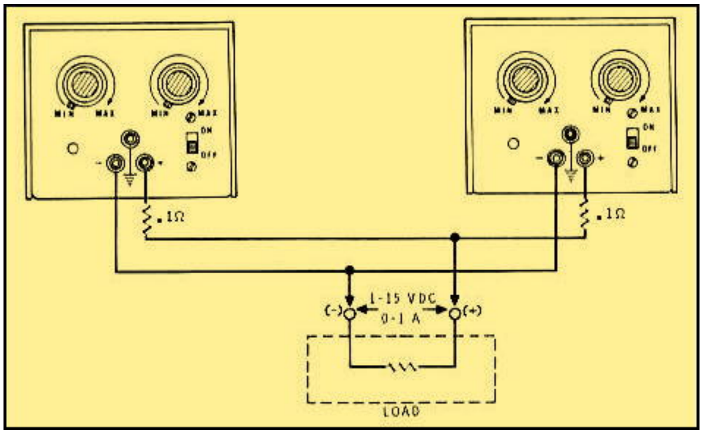


FIGURE 14: An illustration from the manual showing wiring for parallel operation of multiple IP-18s to get higher current output (See Text).

Uses for the IP--18:

This is a handy little power supply for various uses around the shack. It would be so much better if it had at least one built in switchable meter. My test equipment includes a Lambda dual supply, each good for 0 – 20 volts at up to 1.7 amps, and a Heathkit IP-2718 Triple Power Supply (See HotM #108) [7]. Both are useful but hard to move and take up coveted bench space.

My first use of the IP-18 was to power up a Heathkit HD-1424 Active Antenna (See HotM #6) [8]. The active antenna can use an internal 9-V battery, but it was easier to use the IP-18. I tend to remove batteries from infrequently used equipment, for obvious reasons.

Right now it is being used to power an old Motorola transistor AM radio that I want to check out and see if it's viable to fix.

Another possible use is to charge re-chargeable batteries. Many batteries state their maximum recommended charging current and floating charge voltage. If the IP-18 voltage is set for the float voltage and the current is set for the recommended charging current, the power supply will operate in the constant current mode as the battery voltage increases with charge, and then switch to the constant voltage mode at the floating voltage.

Comments:

I purchased the IP-18 at the yearly OCARC auction last October. On examination the supply was found to be received in working condition. An internal check revealed the four electrolytic capacitors to be with in tolerance as to capacitance and leakage. I've added three of the four capacitors to my next purchase list anyway. A cost effective replacement for the 2500 µf 30V **axial** lead capacitor has not been found yet. The price of axial electrolytic capacitors have soared recently. $16+ vs. $3 for a radial lead one (2700 µf 50V).

While the IP-18's chassis is in good shape, its cover had been repainted black and was badly scratched, and the paint, in places was extremely thick. The cover was stripped to bare aluminum and given two coats of Rust-Oleum Satin Oregano. I had planned to use Satin Nutmeg but the local Home Depot was out of stock. You can see the result in **Figure 1**.

Another problem-'in-the-making' on this IP-18 is the VOLTAGE control, which turns stiffly. The problem could be in the control or the control spacer. Removal of the circuit board is required to find out, and that will be done when the capacitors are changed.

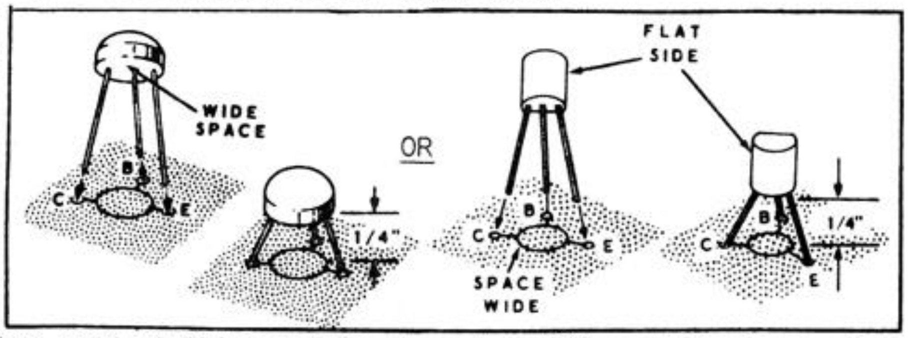
I was recently given a bunch of Heathkit specification sheets that Heath passed out over the years as part of their advertising. I'm in the process of scanning them and putting them up on the site. Most include a schematic which I've tried to reproduce in reasonable resolution. So far I've put up 150 of them and will get around to more as time permits. The site is:
https://www.w6ze.org/Heathkit/HeathSpecSheetsIndex.html

IP-18
1-15 VDC Power Supply

August 29, 1977
BLOWING FUSES

Bulletin No.
IP-18-2

Check for proper installation of Q2 (#417-109).



The transistor used at this position has two different basing configurations; thus, it may be installed incorrectly.

Figure 14: Heath Technical Bulletin IP-18-2

Heath Technical Notes:

I recently obtained the Heath Technical Exchange Bulletins for 1977, and 1982 through 1989. Each comes with a yellow section in the back that is an index of all the technical bulletins published for each kit and the year of the issue that the bulletin was published in. These bulletins are updated by service technicians in the field, as well as Heath engineers and technicians. To my surprise I came across one written by one of our former members, now a silent key, Bob Dillard - K6DNR who had worked at the Heathkit store on Ball Road.

IP-18 Technical Bulletins:

Heath published two service bulletins on the IP-18:

IP18-1 Ripple & Noise Filtering (11/4/70)
2 Blowing Fuses (8/29/77)

I only have access to the second one, which is shown in **Figure 14**. The reference to a fuse caught my attention. On a schematic from a later manual [595-983-04], a fuse is present and a photo accompanying the schematic shows the fuse mounted internally. It also identifies the three rectifier diodes to now be 1N2002 (57-65) diodes.

Notes:

1. Noted changes are mentioned later in the text.
2. Photo courtesy of Chuck Pension - WA7ZZE.
3. An internally mounted fuse was added to the IP-18 sometime during the production run: 3/16 amp slow-blow (⅛ amp for 240V)
4. In later IP-18 production the CER100 was replaced with the (57-65) 1N2002 diode (100 PRV, 1 A).
5. Early IP-18 schematics show Q3 collector voltage as 29 V. Later schematics show the voltage as 25 V,
6. Q4 base emitter drop is about 0.55V and D1, a germanium diode, is about 0.2 V resulting in an offset of around 0.75 volts.
7. Heathkit of the Month (HotM) Heathkit IP-2718 Tri–Power Supply article is available at: https://www.w6ze.org/Heathkit/Heathkit_108%20IP2718.pdf
8. HotM Heathkit HD-1424 Active Antenna article is available at: https://www.w6ze.org/Heathkit/Heathkit_006_HD1424.pdf

73, from AF6C

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 2025, and originally appeared in the February 2025 issue of '**RF**', the newsletter of the Orange County Amateur Radio Club - W6ZE.*

Thanks - AF6C