Heathkit of the Month #108:
by Bob Eckweiler, AF6C

ELECTRONIC TEST EQUIPMENT

Heathkit IP-2718 Tri-Power Supply

Introduction:

If you do any bench work with solid-state devices, a low-voltage power supply is a necessity. More likely, you'll want to have two or three handy. Voltages of 3.3, 3.6, 5, 12 and 15 volts are common for digital circuits. Analog circuits often require positive and negative voltages simultaneously - often ±12, ±15, ±20 or occasionally +15 / –5 volts. A good solution is a multi-output power supply such as the Heathkit IP-2718 Tri-Power Supply, (**Figure 1** and **Figure 8)**.

In HotM #94[1] the IP-27 Regulated Low-Voltage Power Supply was featured. It has a single output capable of 0.5 – 50 volts at up to 1.5 A. It can operate as either a constant voltage or constant current supply – a nice feature if you occasionally charge SLA[2] batteries. On the other hand, the Heathkit IP-2718 offers three totally separate power supplies in a single unit that takes up only about 80% of the workspace of the IP-27. Since the supplies are independent, they can be connected in series, and if properly done, even paralleled for more versatility.

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 12

Figure 1: Heathkit IP-2718 Tri-Power Supply with three outputs of 5 V @ 1.5 A fixed, 0 - 20 V @0.5 A and a second 0 - 20 V @0.5 A. Photo: AF6C

The IP-2718 Tri-Power Supply:

Heathkit first introduced the IP-2718 in the Spring 1976 catalog with an announcement to *"order now for shipment by April 26th 1976"* (see **Figure 2**.) The IP-2718 initially sold for $79.95. It was also available factory wired as the Heath SP-2718 for $140.00. Heath sold numerous units to the government, and likely to schools too. You can still find the SP-2718 manual on a government manual repository site[3]. The kit and factory wired versions remained for sale into 1992, over sixteen years. In the 1992 (229-100) Heath catalog the IP/SP-2718 was listed at $139.95/$200.00, and marked *"Limited Quantities"*.

The IP-2718 Specifications:

Two of the three power supply outputs are variable between 0 and 20 VDC and each is capable of 500 mA maximum current. The third power supply is fixed at 5.0 volts and can supply 1.5 A. None of the power supplies are referenced to chassis ground, so they can each supply either a positive or negative voltage. A separate chassis-ground binding post is provided on the front panel. All outputs are current limited and protected.

The voltage and current for each of the three power supplies can be read on a large, flush mounted, meter with color-coded scales. Selection is by a six-position rotary **METER**

IP-2718 Tri-Output Experimenter Power Supply

$79.95

Three floating outputs can be connected in any combination for a wide variety of output voltage and current capability

Combines 5 VDC fixed output with two 0-20 VDC variable outputs in a single, compact supply ideal for experimenters. The 0-20 variable outputs can be tracked — one will "follow" the other at any specified voltage difference — ideal for analog circuits requiring a + and — voltage. The 5-volt output is useful for digital circuits. All outputs are short-circuit proof, with current limiting. They can be operated independently, in series, or in parallel. Switchable front panel meter monitors all outputs.

Kit IP-2718, Shpg. wt. 12 lbs. 79.95

Assembled SP-2718, Shpg. wt. 12 lbs. 140.00

IP-2718 SPECIFICATIONS

Outputs: 5 volts DC ±5% at 1.5 A. Two 0-20 VDC at 0.5A, continuously adjustable. Regulation: Load: less than 0.1% variation from no load to full load on 20-volt supplies; less than 2% variation from no load to full load on 5-volt supply. Line: less than 0.2% variation for line voltage change of 10 volts on 20 volt supplies; less than 0.15% variation for line voltage change of 10 volts on 5-volt supply. Power Requirement: 100-135 VAC or 200-270 VAC, 60/50 Hz, 100 watts full load. Dimensions: 4½" H x 10¾" W x 9" D.

PLACE ORDERS FOR THESE PRODUCTS NOW FOR SHIPMENT BY APRIL 26, 1976.

New

Offers 3 Output Voltages for Virtually Any Circuit Design

Kit or Assembled

Figure 2: Ad from the Spring 1976 catalog introducing IP-2718 and it's factory built brother the SP-2718.

switch, and the overall accuracy is spec'ed at 5% of full-scale. The meter is not illuminated.

The two variable power supplies can be operated independently or put in "tracking" mode where a single control adjusts both voltages. This can be done with both power supplies being used at the same or opposite polarities.

The specifications of the IP 2718 are summed up in **Table I**.

The IP-2718 Front and Rear Panels:

The front panel controls are well laid-out and easy to use. They are summed up in **Table II**. There are no controls on the rear panel; just a Heyco strain relief for the permanently connected power cord (**Figure 3**). Two power transistors and an IC regulator are mounted on the back panel using it a s a heat sink; all are TO-3 packages and insulated with a plastic transistor insulating cover. On the bottom of the cabinet is a small opening allowing access to a slide switch that selects the line voltage -either 120 or 240 volts AC. The IP-2718 has a 3-wire polarized power cord and protection is via a 1.5 A 3AG fuse internally mounted in a fuse clip.

Figure 3: Rear view of the IP-2718 showing line cord and covers for the 5V IC regulator and two MJ2841 power transistors. Photo: AF6C

IP-2718 SPECIFICATIONS

Outputs:	
5-Volt Supply:	5 volts DC ±5% at 1.5 amps.
'A' Supply:	0 - 20 volts DC at 0.5 amps continuously adjustable.
' B' Supply:	(same a 'A' supply).
Regulation:	**('A' and 'B' supply)**
Load:	Less than 0.1% (20 mV) variation from no load to full load.
Line:	Less than 0.2% (40 mV) for a line voltage change of 10 volts.
Regulation:	**(5 volt supply)**
Load:	Less than 3% (150 mV) variation no load to full load.
Line:	Less than 0.2% (10 mV) for a line voltage change of 10 volts.
Regulation:	**(all supplies)**
Ripple & Noise:	Less than 5 mV RMS.
Current Limiting:	Limiting for each supply fixed slightly above rated current to provide short-circuit protection.
Tracking Range:	2 to 18 volts.
Tracking Error:	Less than 1 volt.
Series Operation:	All three supplies may be operated in series.
Parallel Operation:	'A' and 'B' supplies may be operated in parallel by adding 0.5 Ω current-equalizing resistors (not supplied).
Meter Ranges:	Voltages, 0 - 20 and 0 - 5.5 Current, 0 - 550 mA and 0 - 2 A
Meter Accuracy:	5% of full-scale.
Power Req'm't's:	100 - 135 VAC or 200 - 270 VAC 50/60 Hz, 100 watts at full load.
Fuse:	3AG 1 ½ ampere
Dimensions:	4½' high x 10¾' wide x 9" high.
Net Weight:	10 lbs. (3.73 kg).
Shipping Weight:	12 lbs. (5.45 kg).

(*Data is mostly from the IP-2718 Assembly Manual.*)

TABLE I

IP-2718 FRONT PANEL ITEMS

Row - Top Two thirds (Left -to-Right):

Meter 0–1 mA 50Ω movement (Mercer Electronics)

0 - 20	(Black scale) **0**, **5**, **10**, **15**, **20** Tic marks each div. (total 21)
0 - 5.5	(Red scale) **0**, **1**, **2**, **3**, **4**, **5**, **5.5** 5 tic marks per div.(total 29)
METER:	Switch 6PDT, rotary (from CCW)
5 V - AMPS	0 - 20 scale divided by 10
5 V -VOLTS	0 - 5.5 scale direct
B AMPS	0 - 5.5 scale divided by 10
B VOLTS	0 - 20 scale direct
A AMPS	0 - 5.5 scale divided by 10
A VOLTS	0 - 20 scale direct
VARIABLE OUTPUT VOLTAGE:	
SUPPLY 'A'	Potentiometer 10KΩ
SUPPLY 'B' (inner black knob) with…	
'A' TRACKING 'B' (outer red knob)	
	Dual concentric 10 KΩ pots with clutched coupling
INDEPENDENT ◄ ► TRACKING	
	DPDT Slide sw., centered below & between potentiometer knobs.

Row - Bottom Third (Left -to-Right):

Pilot Lamp	Neon, NE2H
POWER	DPDT Slide Switch **OFF**, **ON**
⏚(Chassis)	Binding post (Green)
5V 1.5 A	
–	Binding post (Black)
+	Binding post (Red)
0 - 20V .5 A OUTPUT 'A'	
–	Binding post (Black)
+	Binding post (Red)
0 - 20V .5 A OUTPUT 'B'	
–	Binding post (Black)
+	Binding post (Red)

(*Bold items in table are printed panel nomenclature.*)

TABLE II

The IP-2718 Operation:
The operation of the Tri-Supply is very simple. When the **POWER** slide switch is turned to **ON**, 5V is available at the **5V 1.5 A** binding posts. Since the supply is isolated you can obtain –5 volts by connecting the +5V binding post to your circuit common. Up to 1.5 amps may be drawn, and if that is exceeded the voltage will begin to drop, protecting the regulating IC[4].

At the same time, voltage is available at the **0 - 20V .5 A OUTPUT 'A'** and **0 - 20V .5 A OUTPUT 'B'** binding posts. With the **MODE** slide-switch in the **INDEPENDENT** position, the OUTPUT 'A' voltage is controlled by the large black **SUPPLY 'A'** knob, and the OUTPUT 'B' voltage is controlled by the outer black concentric **SUPPLY 'B'** knob.

Separate Operation:
The three power supplies can be operated independently as a positive or negative supply. Any one of the two output terminals of each supply may be connected to the chassis terminal.

Tracking Operation:
With the **MODE** switch in the **TRACKING** position OUTPUT 'A' is controlled by the smaller red **'A' TRACKING 'B'** knob that is concentric with the SUPPLY 'B' knob. The concentric controls are clutched together. Turning one turns the other, though they can be moved separately. Thus you can adjust both supplies with one knob and the two will track, keeping whatever offset initially was established, if any.

Series Operation:
Two, or all three power supplies, can be connected in series to obtain voltages up to 25 V, 40 V or 45 V of either polarity. Common can be selected at any of the junctions by connecting that point to your circuit common. This point can also be jumped to the supply's chassis ground (green binding post) if desired.

Parallel Operation:
The 'A' and 'B' power supplies can operate in parallel allowing the current to be increased to 1 ampere. To do this requires two 0.5 Ω resistors to be placed in series with each power supply. Heathkit does not supply these resistors with the instrument. Before making the connection the 'A' and 'B' power supplies should be set to the desired voltage. After the connection the voltages should be adjusted slightly so that each supply is drawing approximately the same current. These resistors help equalize the sharing of the current.

Metering:
The large meter can be switched to read the voltage or current of each of the three supplies. The meter has two scales:

A black 0 - 20 scale to read the 'A' and 'B' supply voltages and the 5 V current (reading the scale as 0 - 2 amperes.)

A red 0 - 5.5 scale to read the 5 V supply voltage and the 'A' and 'B' supply current (reading the scale as 0 - 0.55 amperes.)

The IP-2718 Circuits:
A full schematic of the IP-2718 is available on the web and should be referenced while reading this discussion.[5]

5 V, 1.5 A Supply
A simplified circuit of the 5 V power supply is shown in **Figure 4**. An 18 volt center-tapped winding feeds a full wave rectifier (D1 and D2) followed by C2 a 12,000 µF electrolytic filtering capacitor. The resulting 12.2 volts is fed to IC1, an LM309 5V regulator chip. This integrated circuit was the first of the three terminal voltage regulators used in

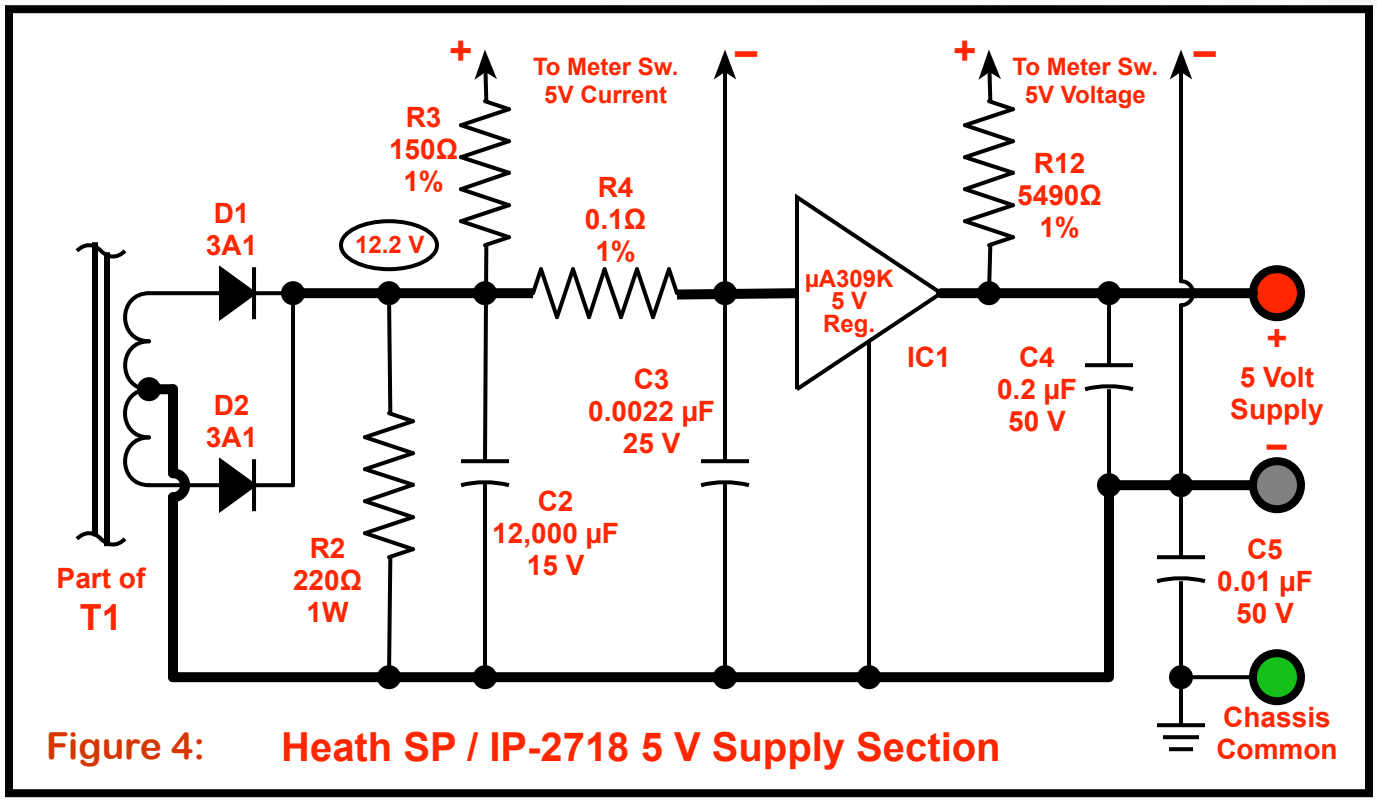

Figure 4: Heath SP / IP-2718 5 V Supply Section

so many simple power supplies. R2 provides bleed current ,C3 prevents instability in the LM309 IC; and C4 lowers the output impedance at high frequencies.

The voltage is monitored across the output terminals by the one mA meter. For a full scale reading of 5.5 volts on the red meter scale, the series resistance to the meter should be 5,500 Ω Since the meter has an internal resistance of 50 Ω, the series resistor should be 5,450 Ω. The closest 1% value is 5490 Ω, which is the value of R12. Any error is insignificant.

The current is monitored across R4, a 0.1 Ω resistor. Assume 2 amperes is flowing through R4; that develops 0.2 volts across R4. The meter, in series with R3, a 150 Ω resistor, is across R4 - a total of 200 Ω. thus when 2 amperes are drawn through R4 1 mA will flow through R3 and the meter resulting in a full-scale reading on the 0 - 20 black scale. There is a slight inaccuracy due to the quiescent current used in the chip, but again this error is insignificant.

0-20 Volt Supplies 'A'and 'B'

The 'A' and 'B' supplies are a lot more complex than the 5 V supply. The two supplies are almost identical so only the 'A' supply will be discussed. On the main schematic the components for the 'A' supply that mount on the circuit board are numbered in the 100's (such as R105, C103 etc.) while the components for the 'B' supply are numbered in the 200's. Parts that mount to the chassis for each have numbers below 100. The major difference between the 'A' and 'B' supplies is that, in the TRACKING mode, control of the power supply is switched from R7, the black 'A'. Supply knob to the concentric small red 'A' Tracking 'B' knob (R8).

'A' SUPPLY Block Diagram:

Figure 5 is a block diagram of the 'A' Supply. Here are the major blocks and their functions:

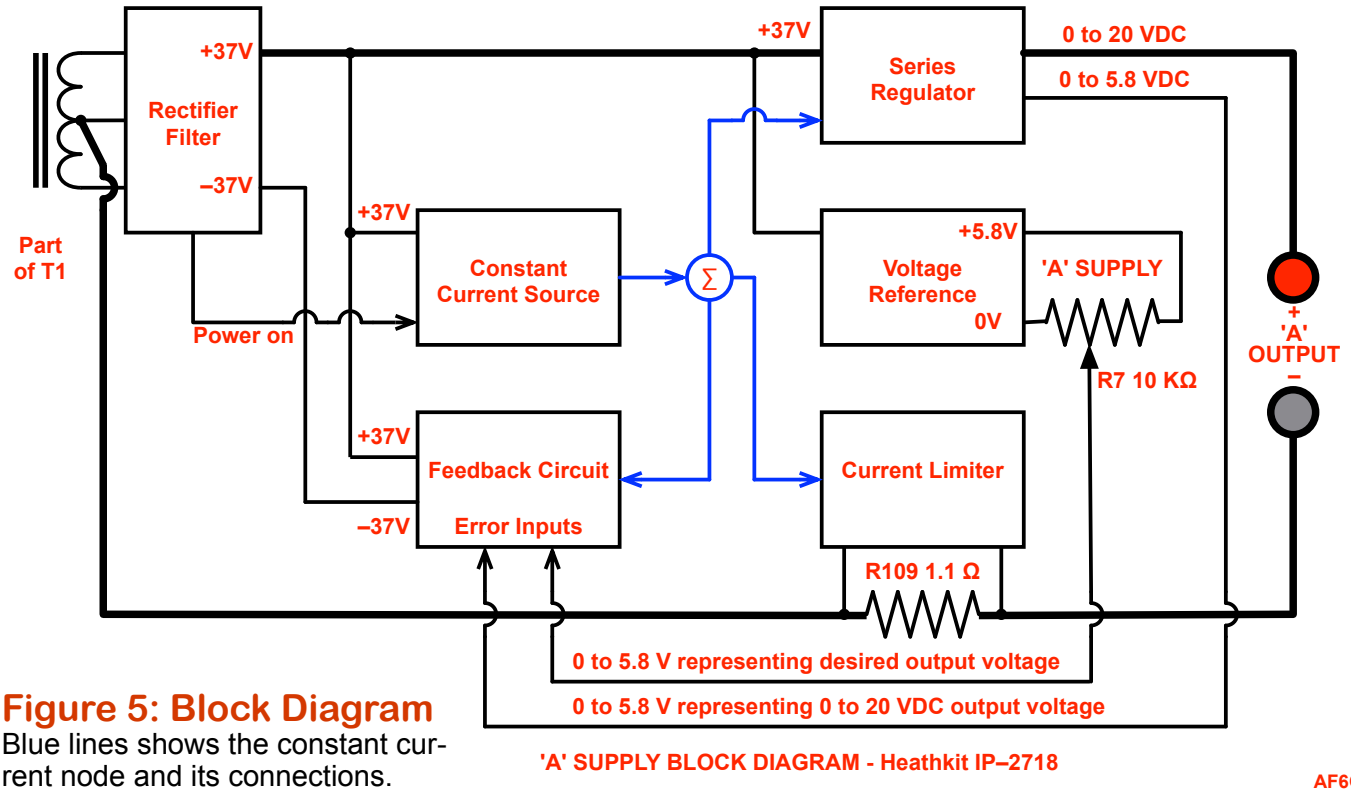

Figure 5: Block Diagram
Blue lines shows the constant current node and its connections.

- **The Rectifier Filter** provides ±37 VDC. It also supplies a power on signal to assure the constant current source runs during startup and and through shutdown.
- **The Series Regulator** sets the output voltage depending on the current it is receiving. It also provides a voltage 0.29 times the actual output voltage to the feedback circuit.
- **The Voltage Reference** provides a stable adjustable voltage that is 0.29 times the desired output voltage. R7 is the front panel control that sets the 'A' supply.
- **The Constant Current Source** provides a stable current (~2.7 mA) to drive the series regulator, setting the output voltage.
- **The Feedback Circuit** compares the difference between the actual voltage and the desired voltage, and draws current from the constant current node to control the series regulator and make these voltages equal.
- **The Current Limiter** monitors the negative current flow via R109. Should the current exceed ½ ampere, the current limiter heavily draws current from the current source to reduce output voltage and protect the series regulator. Under normal operation it draws no current.

A Closer Look at the 'A' Supply Circuit:
For those interested, here is a breakdown of the blocks of the circuit, each with a more detailed description:

<u>The Rectifier Filter</u> (Figure 6A):
The 'A' Supply receives its power from a 58 VCT winding on the power transformer. It is full-wave center-tap rectified by diodes D101 and D102. From that point a power on signal is fed to the constant current circuit (to be

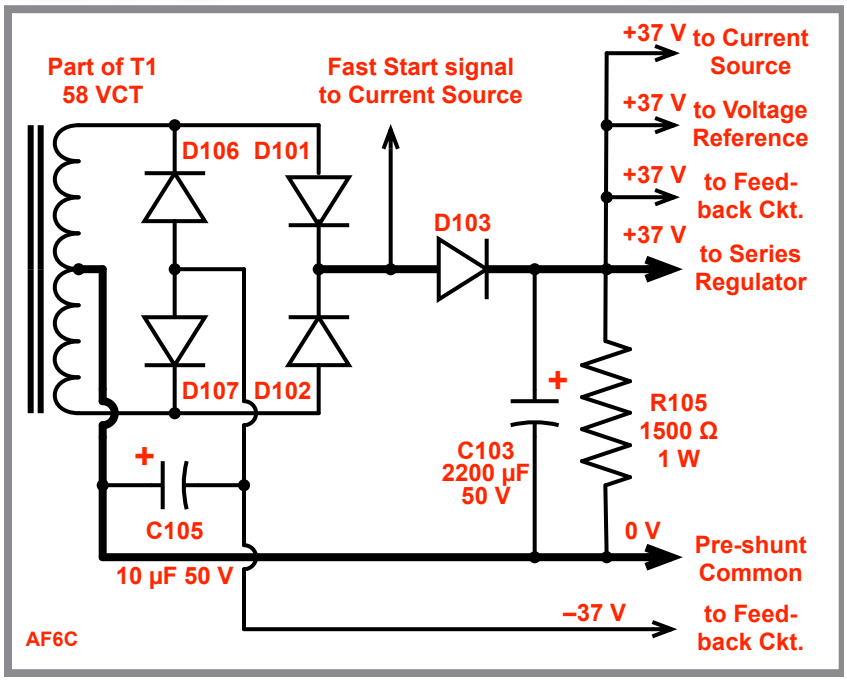

Figure 6A: The Rectifier - Filter circuit with power distribution.

discussed later). The voltage is also fed through an isolation diode D103 and filtered by C103. Resistor R106 bleeds off the charge on C103 when the unit is turned off. The resulting +37 VDC supplies power to the series regulator, the constant current generator, the reference voltage source, and positive voltage to the feedback circuit.

A second pair of diodes, D106 and D107, connected to the 58VCT winding, along with C-105 provides a negative 37 VDC to the feedback amplifier.

Series Regulator (Figure 6B):
Q1, an NPN power transistor is the main series regulator that controls the output voltage. To increase its gain, Q103 is wired to Q1 as a Darlington pair. The 47Ω resistor, R5 adds temperature compensation for Q1 at high temperatures. The voltage at the emitter of Q1 is controlled by its base current. The output voltage appears across output terminals of the 'A' Supply and across voltage divider R123 and R124. The output of the voltage divider is about 0.29 times the actual voltage (At 20 V the divider output is 5.8 volts.) This voltage is sent to the feedback circuit.

Constant Current Generator (Fig. 6C):
To prevent transients while powering the IP-2718 up and down, it is important that the constant current generator and feedback amplifier are operating before the main filter capacitor fully charges, and remain powered through power down. Upon power up a 'fast start' signal, isolated by D103, turns on Q101. Upon power down Q101 remains on while C105 discharges.

When Q101 is conducting ZD104, C102, R102, R104 and Q102 act as a constant current generator; current is drawn through

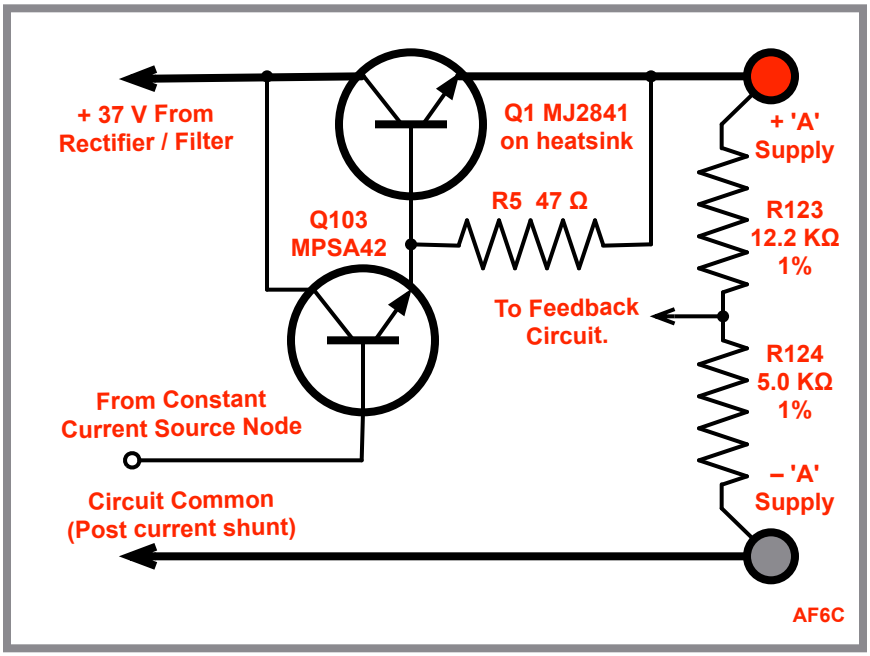

Figure 6B: The Series Regulator Circuit

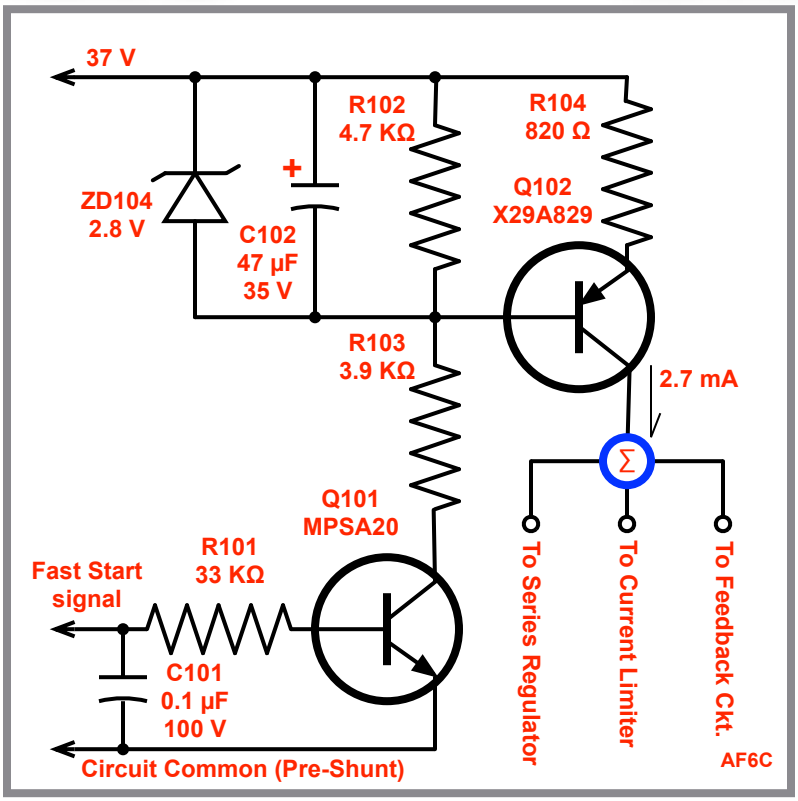

Figure 6C: The Constant Current Source Circuit

ZD104, a 2.8 volt zener. This causes 2.2 volts to drop across R104 resulting in an emitter current of about 2.7 mA. The large current gain (beta) of Q102 assures that the collector current is virtually the same as the emitter current. The resulting collector current is around 2.7 mA. This constant current has three paths it can travel. The first is to the series regulator transistors Q103 and Q1. The more base current Q103 gets the higher the output voltage. Path two is the feedback circuit, and path three is to the current limiting circuit.

The junction of these three paths is called a **Current Node**. 2.7 mA is being delivered to this node by Q102. The current is being fed to the series regulator, and the 2.7 mA is enough to drive it to output more than 20 volts. However, not all the current gets there as the feedback circuit draws from the node to reduce the output to the voltage determined by the reference source (discussed next). Should too much current be drawn from the power supply, the current limiter can also heavily draw current from the node to protect the series regulator.

Reference Source (Figure 6C):

R106 and ZD108 pre-regulate the +37 volt supply down to 12 volts. A second zener regulator (R115 and ZD109) further regulate the voltage down to 6.8 volts. This well regulated voltage is divided down further by R116 and R117. R116 is the 'A' supply calibration pot and is set so the 'A' supply puts out 20.0 volts when the front panel 'A' OUTPUT VOLTAGE control R7 is fully clockwise. This corresponds to about 5.8 volts at the wiper of R116. Thus, R7 outputs 0 – 5.8 volts over its range. This is the voltage reference that sets the desired output voltage.

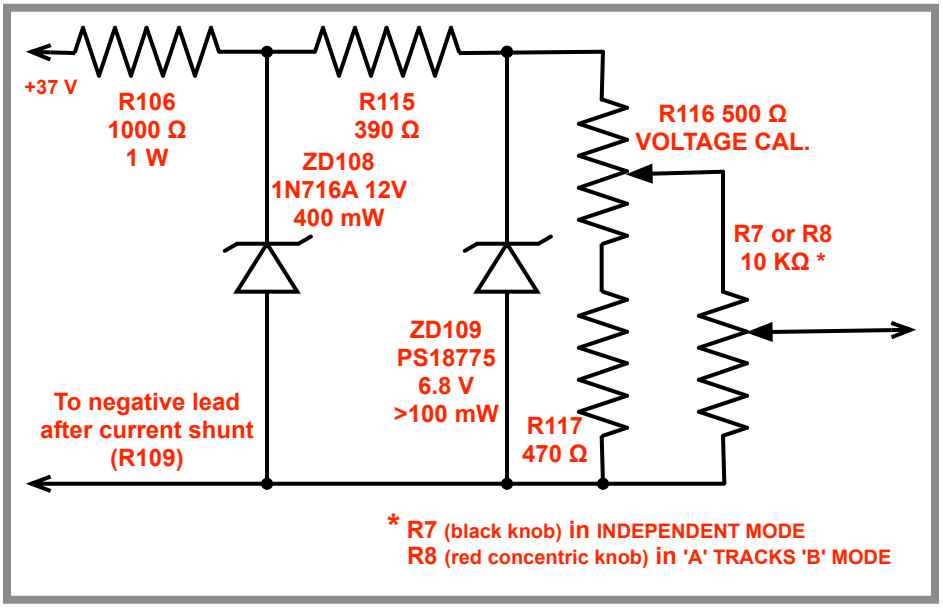

Figure 6D: The Voltage Reference Source Circuit

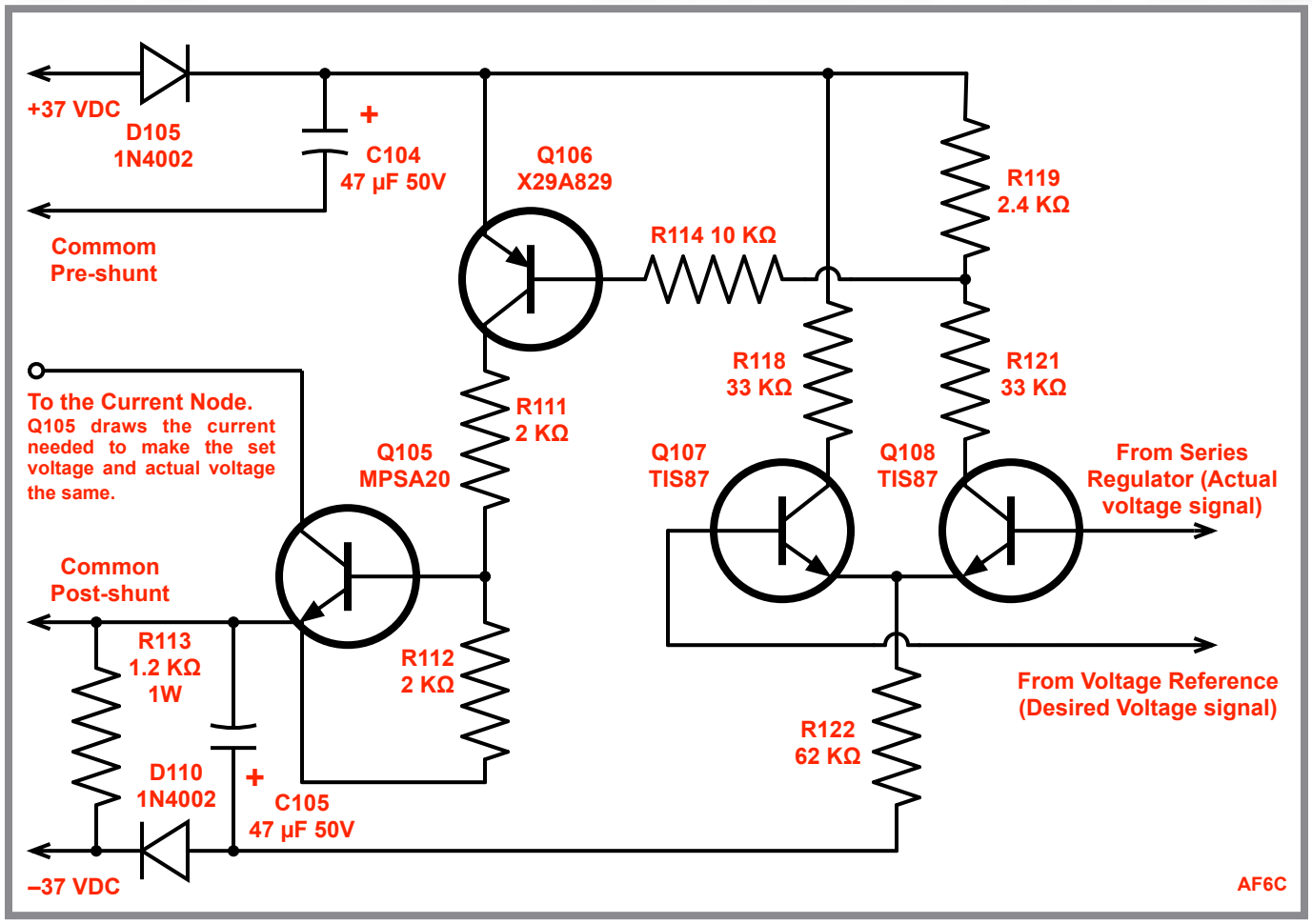

Figure 6E: The Feedback Circuit

Feedback Circuit (Figure 6E):

The feedback circuit consists of an error amplifier (Q107 and Q108), a buffer Q106 and the feedback amplifier Q105. Power for this circuit comes from the plus and minus 37 volt power supplies. D105 with C104 and D110 with C108 isolate the plus and minus power from the main power respectively; the capacitors keep the feedback circuit operational during the shutdown period to prevent transients.

Q107 and Q108 form a differential amplifier. The base of Q107 varies between 0 and +5.8 volts depending on the setting of the front panel 'A' OUTPUT VOLTAGE control, and the base of Q108 varies between 0 and +5.8 volts depending on the actual 0 – 20 volts being output. The emitters are common and range between +5.1 to –0.6. The 62 KΩ emitter resistor ties the emitters to minus 37.5 volts. Thus a fairly constant current of about 0.65 mA flows through the emitter resistor. When the base voltages are equal, the emitter currents, and thus the collector currents, are equal. An error voltage is taken from across R119 that varies with the difference between the two base voltages. It is amplified by Q106 and drives Q105. Responding to the error voltage, Q105 draws more or less current from the current node, allowing more or less current to reach the series regulator base and correcting the output voltage to be the same as the reference setting.

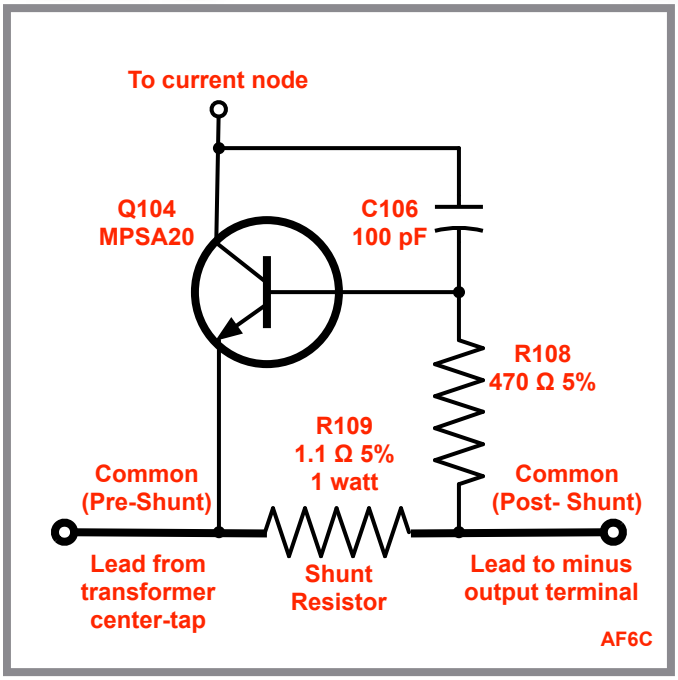

Figure 6F: The Current Limiting Circuit

Current Limiting (Figure 6F):

The current limiting circuit consists mainly of R108, R109 and Q104. Q104 is fully off during normal operation. Shunt resistor R109 (1.1Ω) is located in the main negative path of the voltage output. A voltage drop occurs across this resistor proportional to the current being drawn from the 'A' supply. Should this draw become greater than one-half ampere, the voltage drop across R109 will cause Q104 to start to conduct, drawing heavily from the current node, reducing the current available to the series regulator and causing output the voltage to drop, The feedback circuit will try to correct the voltage drop but will soon run out of available current as the Q104 can easily absorb the full 2.7 mA from the current node, shutting the power supply down indefinitely without damage, or until the over current condition is removed.

Pre-Shunt / Post-Shunt Circuit Common:

One may have noticed, looking at the partial schematics, that circuit 'common' is referred to as pre-shunt and post-shunt. The circuit common starts at the center-tap of the 58V transformer winding and extends to the negative output terminal for the power supply. In the path is a 1.1Ω resistor R109. This resistor is instrumental in measuring the output current for meter indication as well as current limiting. There is a small voltage developed across this resistor. Internal circuits use the common on the side of the shunt resistor that least creates output errors.

'A' Supply Metering:

When the METER switch is set to 'A' VOLTS, the meter is placed in series with a 19.9 KΩ 1% precision resistor (R13) between the output and post-shunt common. At 20 volts the current flowing through the meter is: 20 V/(19.950 KΩ) or, with negligible error, 1 mA – causing full scale meter movement on the black 0 – 20 scale.

When the METER switch is set to 'A' AMPS, the meter, in series with a 555 Ω 1% resistor (R107), is placed across the shunt resistor R109. Should 0.55 amperes flow thru R109, the voltage drop across it is 0.605 volts, and the current flowing through the meter is: 0.605 V/(605 Ω) or 1 mA, – causing full scale meter movement on the red 0 – 5.5 scale.

Heathkit IP-2718 Calibration:

After successfully completing the published resistance and voltage checks, calibration can be done. Calibration consists of first mechanically zeroing the meter, and then, with the three voltage controls set to full clockwise and the MODE switch in the TRACKING position, internal control R216 ('B' SUPPLY) then control R116 ('A' SUPPLY) are adjusted for 20 volts output on the meter. Finally, the MODE switch is switched to INDEPENDENT and the 'A' SUPPLY voltage checked to be sure it reads 20 V ±1 V.

Using the Heathkit IP-2718 Tri-Supply:

The author's Tri-Supply was purchased from a ham's estate. A quick look at the unit showed it to be in good shape, though in need of a cleaning. It powered on and immediately it was noted that the voltage setting potentiometers were in need of cleaning. It was also noted that in the TRACKING mode the voltages did not follow well.

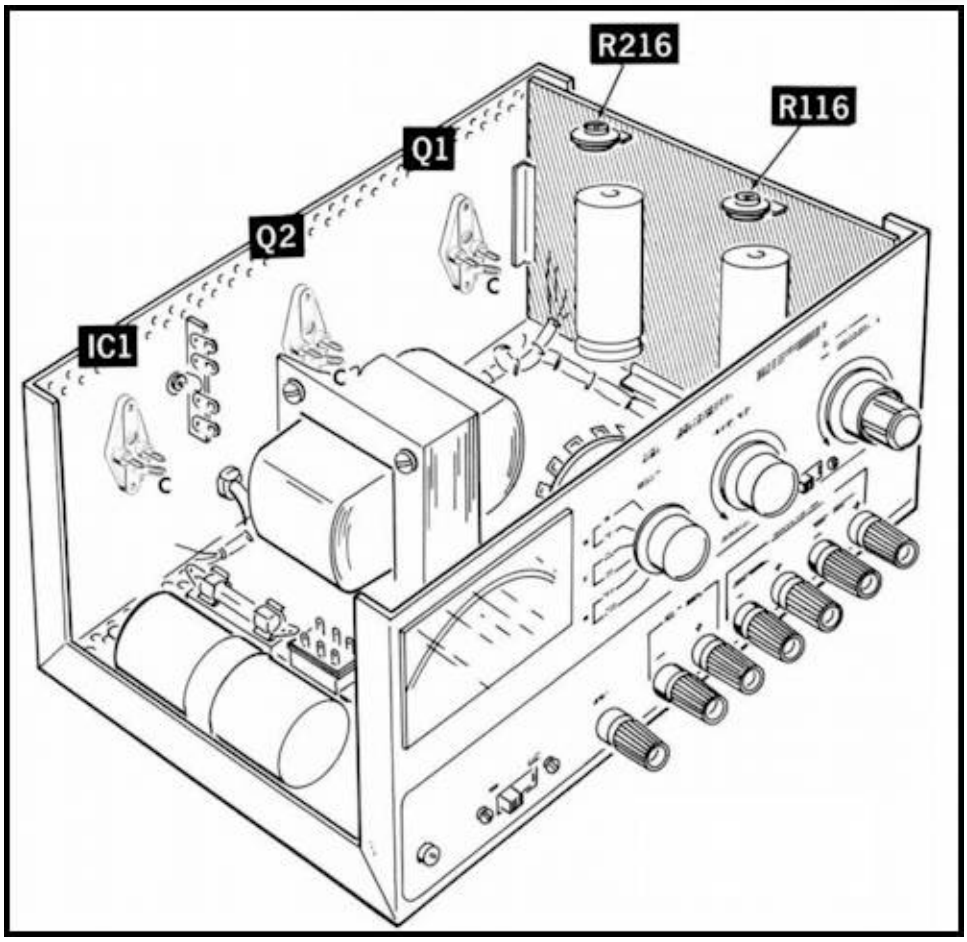

Figure 7: Internal drawing of the IP-2718 showing the major parts placement.Circuit board mounts vertically on right side. (Heath drawing)

The tracking circuit is not rocket science and it is assumed the problem is that the two sections of the dual concentric, clutched potentiometer do not follow each other within the specified tolerance. The pot will be taken out and checked. Finding a replacement may be a problem as the pot is not used in any other Heathkit (Heath Part #12-156). Still, the tracking feature is not that critical and can still be used with limited functionality.

Replacement of the electrolytic capacitors was not attempted, as all checked good. No twist-lock can capacitors are used so replacements should be easy to find. Axial lead capacitors are becoming more difficult to find at reasonable prices, though JustRadio[6] still carries a good selection at fair prices.

Heathkit IP-2718 Tri-Supply Assembly:

Most of the circuitry used in the IP-2718 mounts on a single circuit board located vertically near right side. The parts layout is open, making assembly easy.

Figure 7, a drawing from the IP-2718 Illustration Booklet, shows the location of the various parts. Note that IC1, Q1 and Q2 mount on the rear panel, and use the panel as a heat sink. The two calibration controls R116 and R216 are mounted on the circuit board and are easily accessible when the cover is removed.

Author Ramblings:

I often check the heathkit.com website to see if there is anything new on the horizon. Earlier this year I saw they have stopped taking pre-orders for their HM-1002 Precision RF Meter, announcing ***"Presently no further pre-orders are being taken until initial First Production Run deliveries are complete."*** The kit, while expensive, is a bargain if it

does all it is supposed to do. The surprise is that they took on such a high-end project for their first real amateur radio kit.

Last Christmas I came very close to ordering their "Most Reliable Clock", though why I need another digital clock I can't figure. Maybe I was just anticipating the adrenalin rush of putting together a new Heathkit after thirty some-odd years. When I saw the price had increased from $100 to $125 I hesitated and then never got around to ordering. I actually had planned to send a second one as a gift to one of my relatives. The kit would make a good article for this column so maybe I'll try again this fall.

73, from AF6C

Notes:

1. http://www.w6ze.org/Heathkit/Heathkit_094_IP27%20LVPS.pdf
2. "SLA" Sealed Lead Acid battery (Gel-Cell)
3. http://lcweb2.loc.gov/master/mbrs/recording_preservation/manuals/Heath%20Zenith%20Tri-Power%20Supply%20Model%20SP-2718.pdf
4. The current limiting point is also determined by the ambient temperature. It may not be possible to draw a full 1.5 A in hot ambient situations.
5. http://www.w6ze.org/Heathkit/Sch/IP2718-Sch.jpg
6. https://www.justradios.com

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

Figure 8: A larger front view of the Heathkit Tri-Power Supply IP-2718.