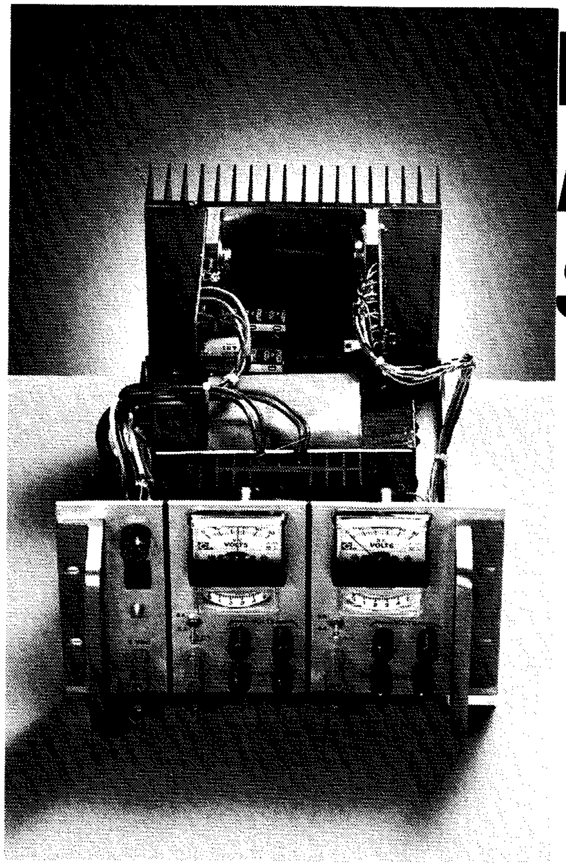
UNIVERSAL LABORATORY POWER SUPPLY



This universal power supply offers high performance and flexibility at low cost.

REINHARD METZ

WHILE NUMEROUS BENCH POWER SUPPLIES have emerged over the years, few combine the performance, flexibility, and low cost of the version described here. This article describes a well-regulated, modular, lab-grade power supply with dual 0–50-volt, 0–5-amp DC supplies, and a single 5-volt, 3-amp DC supply. It uses two identical custom PC boards, one for each 50-volt supply. There's also a customized heat sink with space for both PC boards that minimizes point-to-point wiring in the 50-volt supplies. However, because of the modular design, you can customize the configuration as needed. See Table 1 for a performance summary.

Circuit description

Figure 1 is the schematic of the power supply. The value of the design lies in the use of IC1, an LM317HVK adjustable series-pass voltage regulator, for broad-range performance. The "HVK" suffix specifies the high-voltage version of the regulator. The remainder supplies voltage-setting and current-limiting functions. The input to to IC1 comes from the output of BR1, which is filtered by C1 and C2 to about +60-volts DC, and the input for current-sense comparator IC2 comes from BR2, which also acts as a negative bias supply for regulation down to ground.

The purpose of IC1 is to maintain the OUT terminal at 1.25- volts DC above the ADJ terminal. The current drain at the ADJ terminal is very low (nominally 25 μA) and, as a result, R15 and R16 (the coarse and fine voltage adjustments) and R8 form a voltage divider, with 1.25 volts appearing across R8. The bottom end of R16 connects to a −1.3-volt reference level generated by D7 and D8, letting the R8-R15 divider set the output voltage all the way down to ground when R15 + R16 = 0 ohms. In general, the output voltage is determined by:

$$(V_{OUT} - 1.25 + 1.3)/(R15 + R16) = 1.25/R8.$$

Thus, the maximum value from each variable supply board is:

$$V_{OUT} = (1.25/R8) \times (R15 + R16) = 50.18 \text{ volts DC}.$$

Using potentiometers R15 and R16 to control the voltage, V_{OUT} ranges from 0–50 volts DC. As current demand increases, the drop across R2 increases, and at about 0.65 volts (which corresponds to about 20 mA), Q1 and Q2 turn on, becoming the main current path. Also, R3 and R4 ensure that Q1 and Q2 share the load equally. Current limiting is provided by IC2. Its noninverting input uses the output voltage as a reference, and its inverting input is connected to the

TABLE 1—PERFORMANCE SUMMARY

Characteristic	Capability
Number of supplies	2 (fully floating)
Voltage range	0—50 VDC
Current range	0—5 A
Coarse vs. fine control ratio (both current and voltage)	1:10
Voltage regulation	0.01% line, 0.1% load
Current limiter	0.5%

NOTE: (a) There's a current-limiting LED;
(b) Has internal +5 VDC, 0—3 A supply.

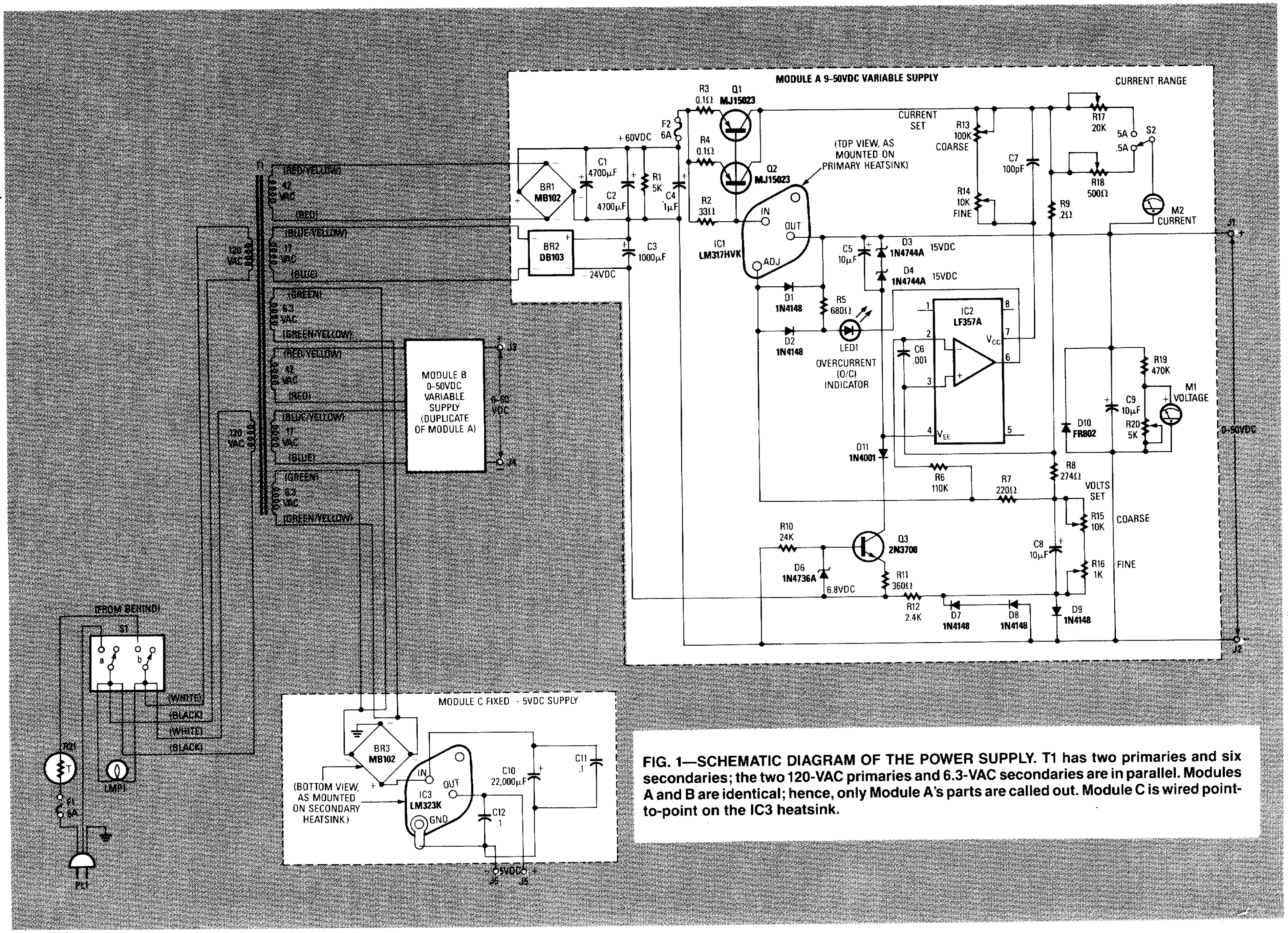


FIG. 1—SCHEMATIC DIAGRAM OF THE POWER SUPPLY. T1 has two primaries and six secondaries; the two 120-VAC primaries and 6.3-VAC secondaries are in parallel. Modules A and B are identical; hence, only Module A's parts are called out. Module C is wired point-to-point on the IC3 heatsink.

voltage divider created by R6 and current-limit potentiometers R13 and R14.

The drop across R6 is about 1.25 volts, the reference voltage mentioned above as being the difference between the OUT and ADJ terminals of IC1. Current from Q1 and Q2 flows through R9, creating a drop across R13 + R14. Thus, IC2 trips when the drop across R9 creates current through R13 and R14, causing the voltage at the non-inverting input to exceed V_{OUT}.

That sets the current limit point at: $(I_{OUT} \times 0.2)/(R13 + R14) = 1.25/100K$; $I_{OUT} = 0–5$ amps. That corresponds to a range of about 0–5 amps. At the current limit point, IC2's output goes low, pulling the ADJ lead down via D2 and lighting LED1. Additional current for D5 is provided by R5. As the ADJ lead is pulled low, the output follows, until the output current drops to a level corresponding to the setting of R13 and R14.

Since the output voltage can be anywhere from 0–50 volts, the power supply for IC2 must track that range using D3, D4, and Q3. Next, D9 ensures that the output voltage doesn't rise when the supply is shut off, while D10 protects against supply back-feeding. Finally, M1 monitors voltage and M2 monitors current. The power supply is modular; each PC board is used for one 50-volt supply, and includes all parts other than those for the front panel and the 5-volt supply. Since a dual 50-volt version may be popular, T1 accomodates two supplies and the 5-volt supply, and a custom heat sink for the two PC boards is available.

Construction

The transformer is mounted on a 6- × 5- × 1-inch L-bracket in the center of the supply, and the heatsinks for IC1 and BR1 go on the back of the transformer bracket. A 6- × 8- × 6- × 11-inch U-shaped cover of 1/16-inch aluminum completes the assembly. Complete all drilling and preparation before assembly, but install only the transformer and its bracket for now, to make wiring easier for you.

Next, assemble the PC board(s) for the 50-volt supplies; Fig. 3 shows the parts placement diagram. Install all components except Q1, Q2, and IC1. Check resistor values as you go, and mount the heat sink for BR1 before installation. Don't forget to observe polarities on all the electrolytic capacitors. Use the alignment holes with 6-32 screws for the PC board(s). Install Q1, Q2, and IC1, using mica insulators, heat sink compound, and 6-32 screws. Check for shorts from

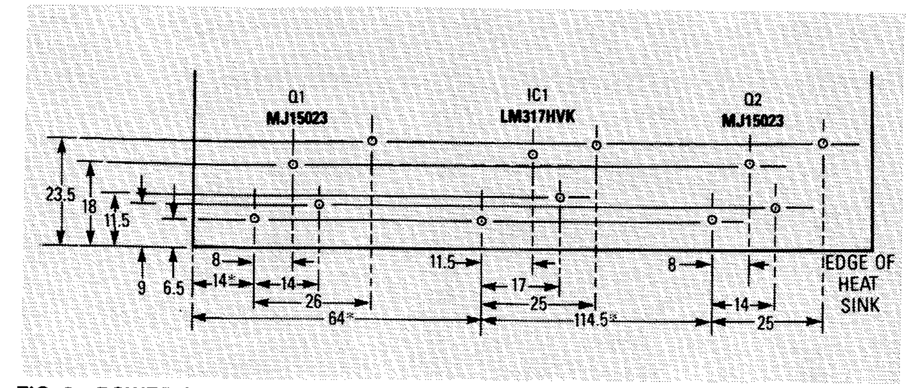


FIG. 2—POWER SUPPLY HEAT SINK LAYOUT. All marked dimensions are in millimeters, all mounting holes are ¼-inch in diameter, all lead holes are 3/16-inch in diameter, and add 3 mm to all dimensions with an (*) to align the PC boards.

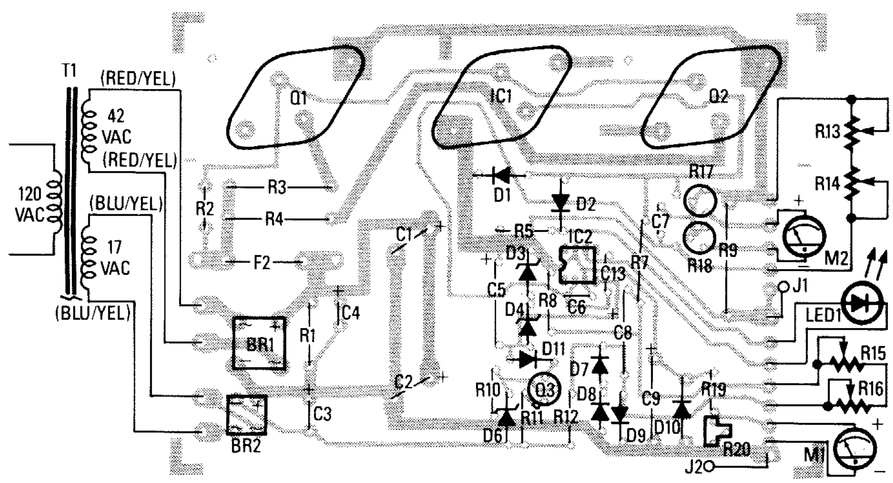


FIG. 3—PARTS PLACEMENT DIAGRAM FOR 50-volt supply. Only one primary and the two relevant secondaries of T1 have been depicted, for brevity.

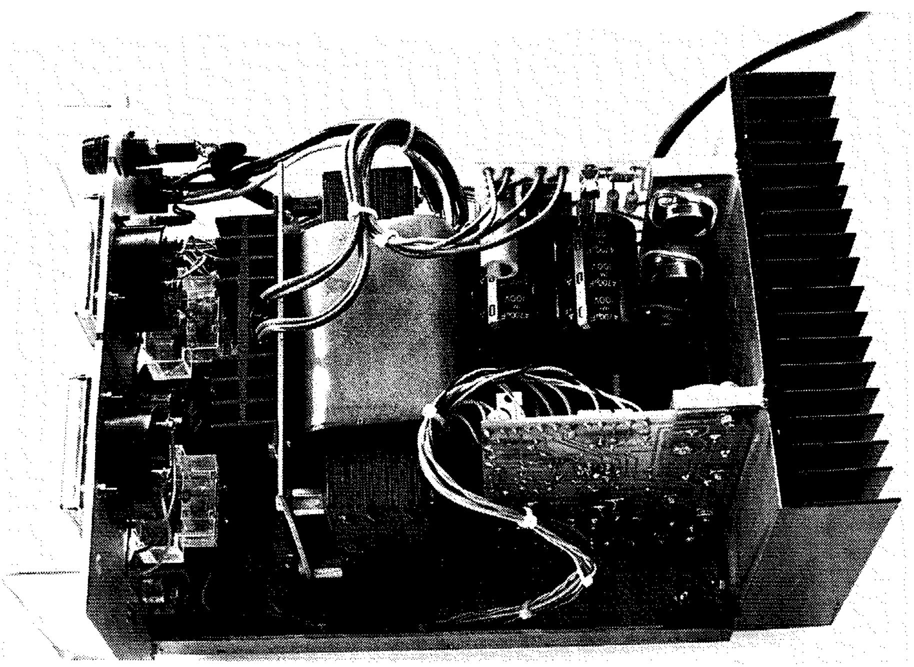


FIG. 4—PROTOTYPE OF THE POWER SUPPLY. Note the custom PC board heatsink at right, and how S1, F1, LMP1, and R21 are wired.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise indicated.

R1—5000 ohms, 1-watt
R2—33 ohms
R3, R4—0.1, 3-watt
R5—680 ohms
R6—115,000 ohms, 1%
R7—220 ohms
R8—274 ohms, 1%
R9—0.2 ohm, 5-watt
R10—24,000 ohms
R11—360 ohms
R12—2400 ohms
R13—100,000-ohm potentiometer
R14, R15—10,000-ohm potentiometer
R16—1000-ohm potentiometer
R17—20,000-ohm PC-board-mounted potentiometer
R18—500-ohm PC-board-mounted potentiometer
R19—470,000 ohms
R20—5000-ohm PC-board-mounted potentiometer
R21—thermistor in-rush protector (Keystone KC003L)

Capacitors

C1, C2—4700 µF, 100 volts (Panasonic P6430)
C3—1000 µF, 50 volts, Panasonic P6272
C4—1 µF, 63 volts
C5—10 µF, 500 volts
C6—0.001 µF, ceramic disc
C7—100 pF, mica
C8, C9—10 µF, 50 volts
C10—22,000 µF, 16 volts (Panasonic P6420)
C11, C12—0.1 µF, ceramic disc

Semiconductors

IC1—LM317HVK adjustable, series-pass, high-voltage regulator
IC2—LF357A JFET input, 8-pin DIP comparator
IC3—LM323K 5-volt DC regulator in TO-3 case
D1, D2, D7, D8, D9—1N4148 germanium diode
D3, D4—1N4744A, 15-volt, 1-watt Zener diode
D6—1N4736A, 6.8-volt, 1-watt Zener diode
D10—FR802 8-amp, 100-volt fast-recovery silicon rectifier (TO-220 package)
BR1, BR3—MB102 10-amp, 200-volt bridge rectifier
BR2—DB103 1-amp, 200-volt bridge rectifier
Q1, Q2—MJ5023 or ECG68 PNP silicon transistor
Q3—ECG128 or 2N3700 1 watt general purpose NPN silicon transistor
LED1—yellow light-emitting diode

Other components

F1—8-amp fast-blow fuse
F2—6-amp fast-blow fuse
T1—600 VA transformer; 120-volt AC primary; two 42-volt, 5-amp secondaries; two 17-volt, 250-mA secondaries; and one 7-volt, 3-amp secondary
PL1—120-volt AC pilot light
M1—50 mA meter (GC Electronics 20-1110)
M2—100 µA meter (Jewell 81T)
S1—120-volt, 10-amp DPST switch
S2—SPDT switch
J1, J3, J5—red banana jack
J2, J4, J6—black banana jack

Miscellaneous: 8-inch wide × 6-inch high × 11-inch deep aluminum case with ⅛-inch predrilled aluminum plate as front panel (including holes for handles) and 8- × 11- × 3/32-inch steel plate with a 1-inch lip on the bottom, two front-panel-mounted case handles, 6- × 8- × 3-⅛-inch dual-supply main heatsink, heatsink for 5-volt DC regulator with TO-3 case, heat sink for BR1, 3-wire power cord, knobs, four rubber feet, panel-mounted fuse holder (for F1), two PC-board mounted fuse clips (for F2), PC board (Digi-Key #F040), three TO-3 transistor insulator kits, silicone grease, wire, solder, etc.

NOTE: The following parts are available from A&T LABS, P.O. Box 552, Warrenville, IL 60555; plated PC board with parts placement silkscreen, $19.00; 600 VA custom dual-supply transformer (T1), $66.00; custom dual-supply main heatsink, $42.00; LM317HVK (IC1), $8.00; MJ4502 (Q1 and Q2), $6.00; M1, $16.00. Send check or money order, except for COD orders via UPS in the U.S. If you don't order T1, add 5% shipping and handling for U.S., and 10% for Canada. If you order T1, add 12% for U.S., and 17% for Canada; Illinois residents add 6.75% sales tax.

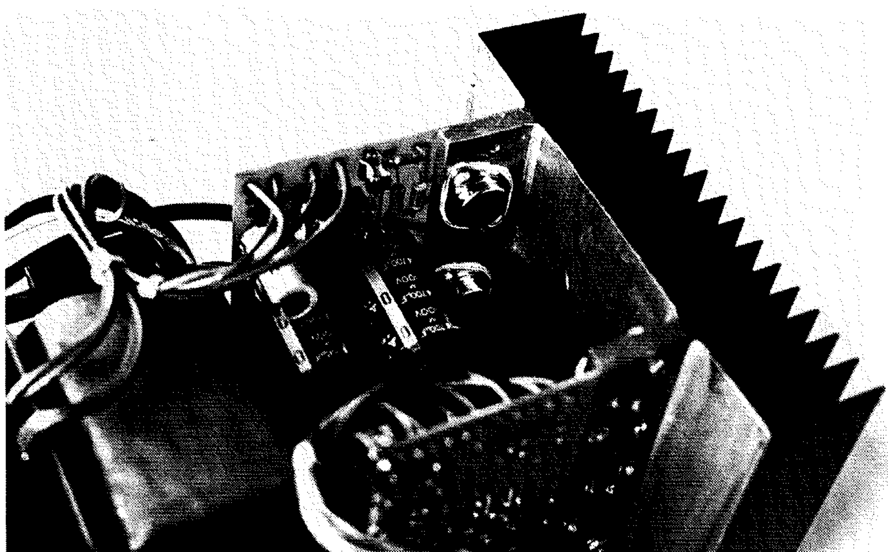


FIG. 5—PRIMARY HEAT SINK ASSEMBLY CLOSE UP. You can see how Q1 and IC1 are attached, the silicone grease used for heat transfer, and how the heatsink is attached to the PC boards. The mica insulators aren't clearly visible from this perspective.

Q1, Q2, or IC1 to the heatsink. Note that BR1 and BR3 have different pin connections than BR2.

A variety of meters can be used with this design. Sensitivity differences are compensated with PC-board-mounted resistors and potentiometers. The values in the parts list call for 50 µA/2500 ohms for M1, and 100 µA/700 ohms for M2. In most cases, panel meters require some faceplate disassembly or removal to mark them for 50 volts and 5 amps DC at full scale. Assuming sensitivities of I_V and R_V for M1 and I_I and R_I for M2, the resistor values are:

- R19 = $25/I_V$, R20 = $2 \times R_V$.
- R17 = $2 \times (1.0_I - R_I)$, for 5 amps full-scale.
- R18 = $2 \times (0.1/I_I - R_I)$, for 0.5 amp full-scale.
- R18 = $2 \times (0.2/I_I - R_I)$, for 1 amp full-scale.

Proceed with the point-to-point wiring from the PC board to the front panel. Those wires should all termi-

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nate in a row on one end of the PC board. Figure 4 shows the general chassis layout, and Fig. 5 shows the juncture between the PC boards and the custom heatsink close up. Use 16-gauge or heavier wire for the leads to J1–J4, and twisted pairs to R13-R14 and R15-R16. If you're including the 5-volt supply, install BR3, C10, C11, and IC3 with the secondary heatsink using point-to-point wiring. Connect T1, wire the primaries, and mount the primary heatsink and front panel. You should now be ready to turn on the supply.

Checkout

Install F1 and F2, apply power, and check for +60 volts DC across C1 and C2. Check for a bias supply of −25 volts DC across C3. Vary R15 and R16, and observe the output voltage change. When the current limiter is fully counterclockwise, the output voltage may be zero, regardless of adjustments. When current limiting occurs, LED1 should glow.

R-E