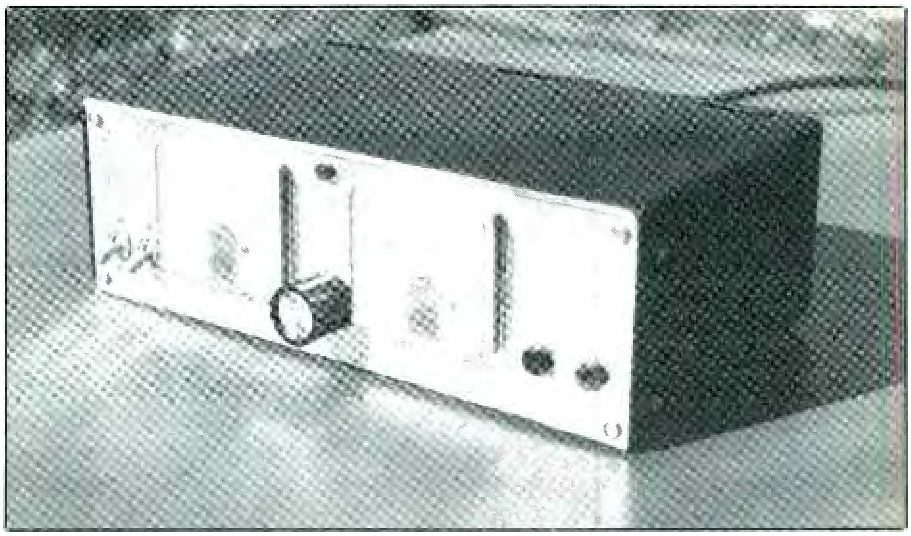
A Precision Low-Voltage DC Power Supply

This laboratory-grade power supply offers two user-selectable output voltage ranges, is short-circuit protected and can go all the way down to 0 volt

By Dennis Eichenberg



Circuit designers, service technicians and serious electronics experimenters can benefit from use of a laboratory-grade low-voltage power supply. "Laboratory-grade" usually means when one is considering a very expensive commercial product. Fortunately, you can build a laboratory-grade power supply, such as the Low-Voltage Precision DC Power Supply described here, for only moderate cost.

This Power Supply provides a clean, precise output that is adjustable from 0 to 9 volts dc, which can be used in instrument calibration and circuit testing, as well as for general bench tasks. Two user-selectable ranges are available: a low range that gives very fine resolution control for 0-to-150-millivolt outputs, and a high range that starts at 0 and goes up to 9 volts. Both deliver up to 2 amperes of current, and both feature current limiting for short-circuit protection. With the components specified, maximum ripple is a low 2 millivolts peak-to-peak.

Separate voltmeter and ammeter movements are built into the Power Supply to provide simultaneous indication of output voltage and current. The voltmeter automatically switches range when the output voltage range selector is operated.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the circuitry used in the Low-Voltage Precision DC Power Supply. Power from the 117-volt ac line enters through the ac line cord shown at the upper-left. The incoming 117 volts ac is stepped down to 25.2 volts dc by power transformer *T1*. The center tap on the secondary side of *T1* is grounded so that full-wave bridge rectifier *RECT1* can provide both positive and negative voltages referred to ground for the remaining circuitry.

Capacitors *C1* and *C4* provide low-frequency filtering of the pulsating dc emerging from *RECT1* for the positive and negative voltage-regulator circuits made up of *IC1* and *IC2*, respectively. High-frequency noise filtering is taken care of by *C2* for *IC1* and *C5* for *IC2*.

Relay *K1* has its coil wired in parallel across the primary of *T1* after POWER switch *S1*. This relay has two sets of normally-closed contacts that connect separately to bleed resistors *R1* and *R2* across *C1* and *C4*, respectively. The purpose of these resistors is to discharge the capacitors when the power supply is shut down to prevent an output spike from occurring.

Positive dc power from the + output of *RECT1* is delivered directly to POWER indicator *LED1* through current-limiting resistor *R15*. Any time the supply is powered up, this LED will be on.

The pure positive dc voltage that results from the filtering action of electrolytic capacitor *C1* is passed through voltage regulator *IC1* and emerges as a tightly regulated +15 volts. Capacitor *C3* at this point provides additional high-frequency noise filtering for this line.

In a similar manner, the pure negative dc voltage that results from the filtering action of *C4* is transformed into a tightly regulated −5 volts by *IC2*. As above, *C6* at this points provides additional high-frequency noise filtering for this line.

Operational amplifier *IC3* and its associated components make up a voltage-reference source for the Power Supply. Zener diode *D1*—a 9-volt, 7.5-milliampere device with a temperature coefficient rated at 0.01/%°C—serves as a very stable and accurate voltage reference, which is required for the Power Supply to be precise under all operating conditions. Op amp *IC3* functions here as a buffer for the zener diode.

With RANGE switch *S2* set to its HI position, the Supply's high range is selected. OUTPUT LEVEL control *R7* provides the means for adjusting this range from 0 to 9 volts. Setting *S2* to its LO position places potentiometer *R7* in series with fixed resistor *R6* for precision adjustment of the Supply's low range from 0 to 150 millivolts.

The reference voltage from pin 6 of *IC3* is delivered to noninverting (+) input pin 3 of operational ampli-

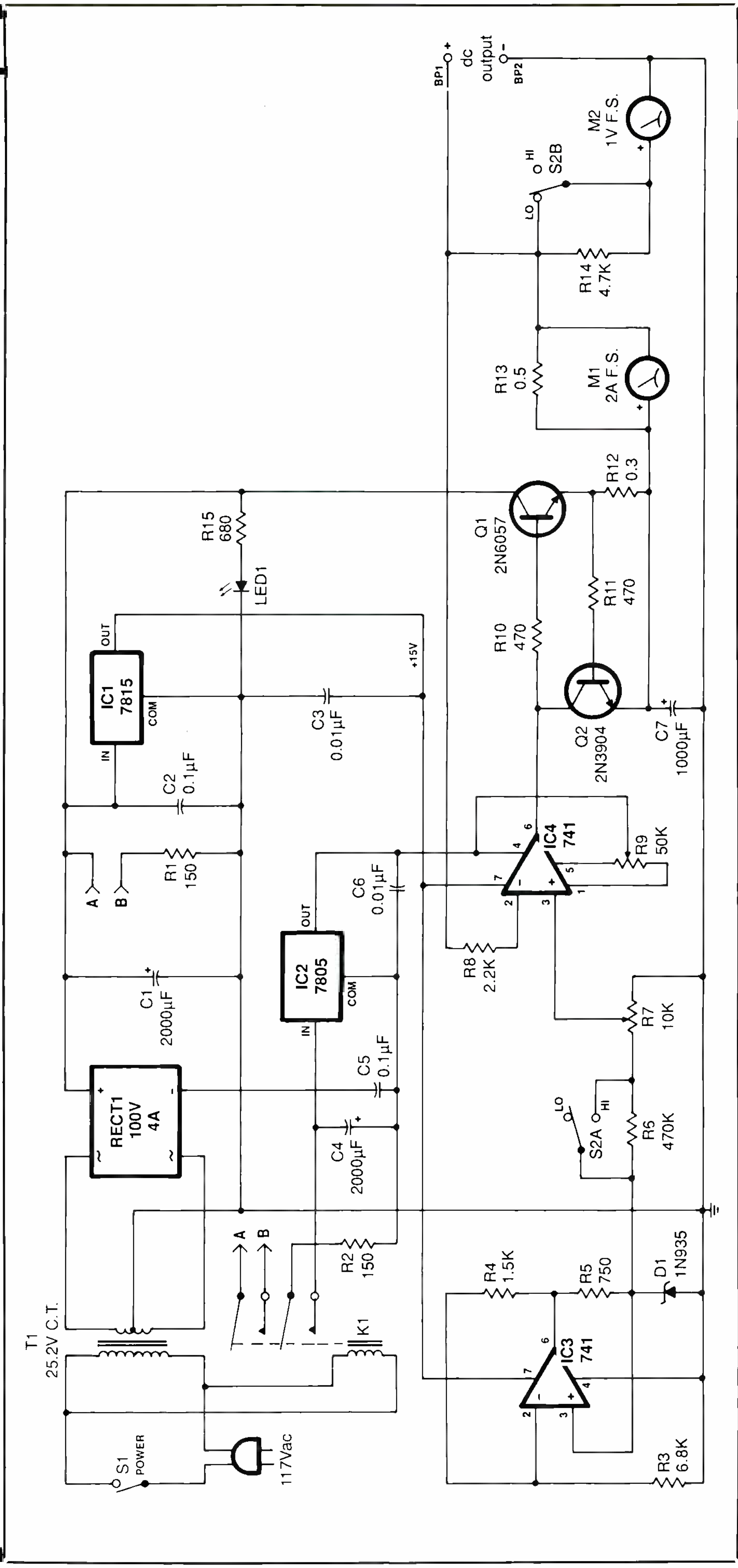


Fig. 1. The complete schematic diagram of the Precision Low-Voltage DC Power Supply circuitry.

PARTS LIST

Semiconductors

D1—1N935 precision zener diode (see text)
IC1—7815 + 15-volt regulator
IC2—7805 – 5-volt regulator
IC3,IC4—741 operational amplifier
LED1—Jumbo red light-emitting diode
Q1—2N6057 silicon npn Darlington transistor
Q2—2N3904 or similar general-purpose silicon npn transistor
RECT1—100-volt, 4-ampere full-wave bridge-rectifier assembly

Capacitors

C1,C4—2,000-μF, 25-volt electrolytic
C2,C5—0.1-μF ceramic disc
C3,C6—0.01-μF ceramic disc
C7—1,0000-μF, 25-volt electrolytic

Resistors (¼-watt)

R1,R2—150 ohms, 1-watt, 10% tolerance
R3—6,800 ohms, 1% tolerance
R4—1,500 ohms, 1% tolerance
R5—750 ohms, 1% tolerance
R6—470,000 ohms, 10% tolerance
R8—2,200 ohms, 10% tolerance
R10,R11—470 ohms, 10% tolerance
R12—0.3 ohm, 3-watt, 5% tolerance
R13—0.5 ohm, 3-watt, 5% tolerance
R14—4,700 ohms, 5% tolerance
R15—680 ohms, 10% tolerance
R7—10,000-ohm panel-mount 10-turn potentiometer
R9—50,000-ohm pc-mount trimmer potentiometer

Miscellaneous

BP1,BP2—Five-way binding post or banana jack (one red, one black)
K1—117-volt ac relay with 3-ampere dpst contacts
M1—2-ampere dc full-scale ammeter movement (see text)
M2—1-volt dc full-scale dc meter movement (see text)
S1—Spst toggle or slide switch with 3-ampere or more contacts
S2—Dpst toggle or slide switch with 0.5-ampere or more contacts
T1—25.2-volt, 2.8-ampere center-tapped power transformer
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); sockets for IC3 and IC4; TO-3 mounting kit for Q1; suitable enclosure (see text); ac line cord with plug; rubber grommets; control knob for R7; six- and two-lug terminal strips; thermal transfer compound; small-diameter heat-shrinkable or plastic tubing (see text); lettering kit and clear acrylic spray (see text); ½-inch spacers; machine hardware; hookup wire; solder; etc.

fier *IC4*, which buffers the signal. Potentiometer *R9* permits nulling (zeroing) the output signal from *IC4* when potentiometer *R7* is set to its minimum position.

The output at pin 6 of *IC4* goes to the base of series-pass transistor *Q1* via bias resistor *R10*. Over-current protection is provided by *Q2*. This transistor senses the output current of the power supply flowing through *R12*. Capacitor *C7* provides circuit output filtering, and resistor *R8* protects *IC4* from shut-down transients.

Output current of the power supply into an external load is indicated by ammeter *M1*, and output voltage is indicated by voltmeter *M2*. Both meter movements are identical 1-volt dc units that have a dc resistance of 47,000 ohms. Resistor *R13* serves as a shunt for *M1*. A current of 2 amperes flowing through this 0.5-ohm resistor develops 1 volt across the resistor. This provides a full-scale indication for *M1*.

The 1-volt range of *M2* is sufficient for the LO setting of *S2*. For the HI setting of the switch, however, *R14* is switched in series with the meter movement to make up a voltage divider that changes the range of *M1* to 10 volts full-scale.

Construction

There is nothing critical about component placement and wire runs in this Low-Voltage Precision DC Power Supply. Therefore, you can assemble the project using any traditional wiring method. If you wish, you can design and fabricate a printed-circuit board on which to mount and wire together the active circuitry. Alternatively, you can use perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. Whichever way you go, however, be sure to use sockets for *IC3* and *IC4*.

Not all components mount on the circuit board. Those that do not include the POWER and RANGE switches, relay, power transformer, LED, meter movements, OUTPUT LEVEL control, bridge rectifier, some resistors (*R1*, *R2*, *R6* and *R12* through *R15*) and capacitors (*C1*, *C2*, *C4*, *C5* and *C7*), and transistor *Q1*.

Once you have decided upon which type of circuit board you will use, install and solder into place the IC sockets. Follow up with the voltage regulators, zener diode and transistor *Q2*. Take care to properly orient these devices before soldering any leads or pins into place. Then install and solder into place the fixed resistors, capacitors and trimmer potentiometer.

Prepare 10 8-inch lengths of stranded hookup wire by stripping ¼ inch of insulation from each end. Tightly twist together the fine wires at all ends and sparingly tin with solder. Solder one end of each wire into place on the circuit board for connection later to off-the-board components. The completed circuit-board assembly wired on perforated board is shown in Fig. 2.

Select an enclosure that is large enough to accommodate the circuit-board assembly and all other components and has suitable front-panel space on which to mount the meter movements, POWER and RANGE switches and POWER LED, and the two OUTPUT five-way binding posts or banana jacks. A suitable enclosure is shown in the lead photo.

Machine the enclosure as needed. This includes cutting suitable-size/shape holes for the meter movements in the front panel and an entry hole for the ac line cord through the rear panel. When you are done with the machining operation, deburr all holes and cutouts made in metal panels to remove sharp edges. Place a rubber grommet in the hole for the ac line cord.

If you wish, paint the prepared front panel with one or two coats of white or light-gray spray enamel. Allow each coat to thoroughly dry before applying the next and proceeding to lettering the legends. Use a dry-transfer lettering kit to label the switch positions, the OUTPUT LEVEL control and both meter movements. Protect the legends with two or more light coats of clear acrylic spray. Allow each coat to dry before spraying on the next.

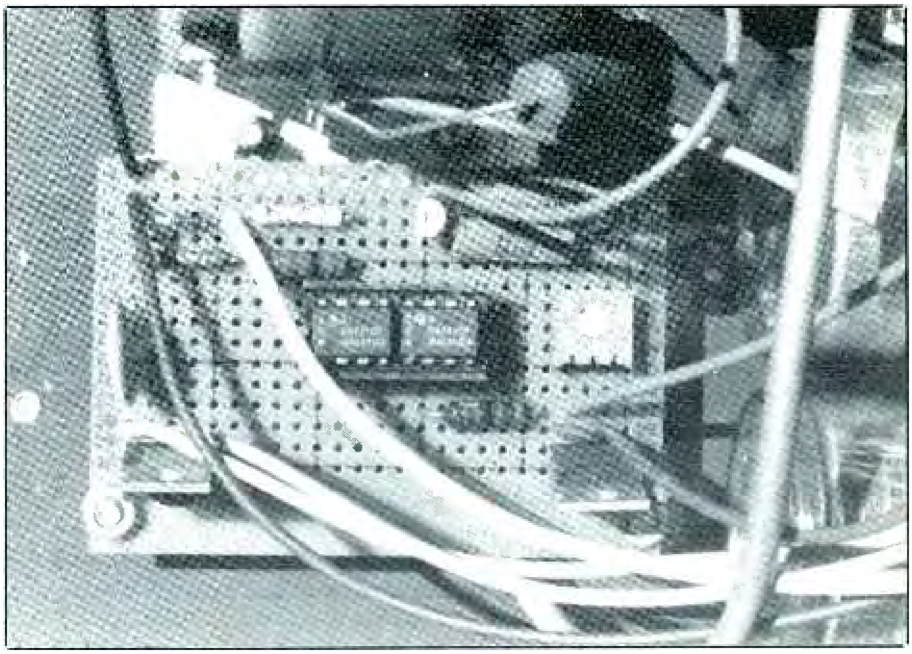


Fig. 2. A close-up view of the small circuit-board assembly on which the active circuitry is mounted and wired.

Fabricate a heat sink for *Q1* from a 2 × 3-inch sheet of aluminum stock. Power transistor *Q1* comes in a TO-9 package. It must be installed on its heat sink with the aid of a TO-3 mounting kit so that it is electrically insulated from but thermally coupled to the heat sink. Machine the heat sink to accommodate the socket. Deburr all drilled holes. Then mount *Q1* to the heat sink, using thermal compound to assure good heat transfer from the transistor to the heat sink.

Plan the layout in and on the enclosure so that the circuit-board assembly is as far as possible from the power transformer to minimize electrical noise in this circuitry. Mount the transformer in place with 6-32 × ½-inch machine screws, nuts and lockwashers, sandwiching the mounting lug of a two-lug terminal strip under the nut of one mounting screw.

Mount *C1* and *C4* with wire ties and self-adhering wire-tie saddles. Use a 6-32 × ½-inch machine screw and lockwasher to mount the relay in place. Then mount a six-lug terminal strip near these capacitors.

Use ½-inch spacers and 4-40 × ¾-inch machine screws, nuts and lockwashers to mount the circuit-board assembly in the chosen location. Mount the heat sink/*Q1* assembly near the circuit-board assembly and a two-lug terminal strip near this for the wires that will connect to the OUTPUT binding posts or jacks.

Use the hardware provided with them to mount the meter movements in their respective locations on the front panel of the enclosure. Then mount the two switches, panel-mount potentiometer and binding posts or banana jacks in their respective holes.

The LED mounts on the front panel. Line the hole you drilled for it with a small rubber grommet to serve as the mounting medium. Alternatively, you can use a standard LED panel clip to aid in mounting this POWER "on" indicator. If you use neither mounting device and the LED does not hold in place by friction, use a small daub of fast-setting clear epoxy cement to secure it in place.

When wiring the circuit, take particular care with the sections in which potentially lethal 117-volt ac line power is present. Make sure everything in these sections is fully insulated and that all connections are electrically and mechanically secure before soldering them. Use No. 18 or larger gauge stranded hookup wire for the connection between *S1*, the coil of the relay and the power transformer.

Also use No. 18 or larger stranded wire to make the connections from the power transformer to the bridge rectifier assembly, which should be mounted on the six-lug terminal strip. Use wire of the same gauge to interconnect the bridge rectifier, relay contacts, *C1* and *C4*.

Mount resistors *R1* and *R2* on the six-lug terminal strip. Then use No. 22 or larger-gauge stranded hookup wire for wiring to the LED. Crimp and solder one lead of *R15* to the lead of the LED. Clip the other lead of the LED to a length of ½ inch and form a small hook in the remaining stub.

Slide a 1-inch length of heat-shrinkable or other plastic tubing over the free ends of the wires that are to connect to the LED network. Crimp and solder these wires to the other lead of the resistor and lead stub of the LED (observe polarity). When the connections cool, slide the tubing over them to completely insulate them and shrink into place. Then make the connections between the circuit-board assembly, *Q1* on the heat sink and potentiometer *R7* and mount *R12* on the socket for *Q1*.

Make the connections between the circuit-board assembly and two-lug terminal strip for the output binding posts or banana jacks. Mount *C7* on the terminal strip. Then use No. 18 or larger-gauge stranded wire for the interconnections between the two-lug terminal strip, meter movements, switches and OUTPUT binding posts or banana jacks.

Install *R6* and *R14* on *S2*. Install *R13* on *M1*. The meter movements connect into the circuit via No. 18 hookup wire terminated in No. 6 terminals.

Tightly twist together the fine wires in each conductor of the ac line cord and sparingly tin with solder. Route the free end of the line cord through its rubber-grommet-lined hole and tie a strain-relieving knot in it a suitable distance from the unprepared end inside the enclosure. Crimp and solder the two conductors to the two-lug terminal strip mounted in place via the hardware that secures the power transformer to the enclosure. Finally, wire together the primary circuit of the power transformer. An interior view of the finished prototype of the project is shown in the photo in Fig. 3.

Calibration & Use

You need a dc voltmeter or a multimeter set to the dc-volts function to calibrate the Power Supply. Set the meter to safely accommodate at least 15 volts of input. Connect the common lead of the meter to the negative (black) OUTPUT binding post or banana jack. Then connect the "hot" meter lead to the + (red) binding post or banana jack. Set the POWER switch to "off" and the RANGE to its LO position. Rotate the knob on the OUTPUT LEVEL control fully counterclockwise.

Plug the Power Supply's line cord into an ac outlet and set its POWER switch to "on." Monitor the meter display as you adjust the setting of trimmer potentiometer *R9* until the output reading from the Power Supply is as close as possible to 0 volt. This done, set the RANGE switch to HI and verify, via the voltmeter or multimeter, that the output of the Power Supply is still 0 volt.

Slowly rotate the knob on the OUTPUT LEVEL control clockwise while monitoring the reading indicated on the external meter. The output potential from the power supply should reach +9 volts when this control's knob is fully clockwise and the RANGE switch is set to HI. The voltmeter on the Power Supply should now verify this reading. If so, set the RANGE switch to the LO position and verify via both meters that the output is 150 millivolts.

If all checks out well to this point, connect a 10-ohm, 10-watt resistor across the OUTPUT binding posts or banana jacks. Set the RANGE switch to HI and the OUTPUT LEVEL panel control to fully counterclockwise. Turn on the Power Supply and slowly adjust the knob on the OUTPUT LEVEL control clockwise while observing the panel meters.

You should observe both pointers steadily rise from minimum toward maximum until the control reaches full clockwise rotation. At this point, the output potential from the Power Supply should be approximately 9 volts and output current should register approximately 0.9 ampere. The load resistor will get warm rather quickly; so do not maintain this test for an extended period.

When you are finished testing the Precision Low-Voltage DC Power Supply, finish assembling it. You now have a Power Supply that will provide the precise power required for your most demanding low-voltage testing and experimenting. **ME**

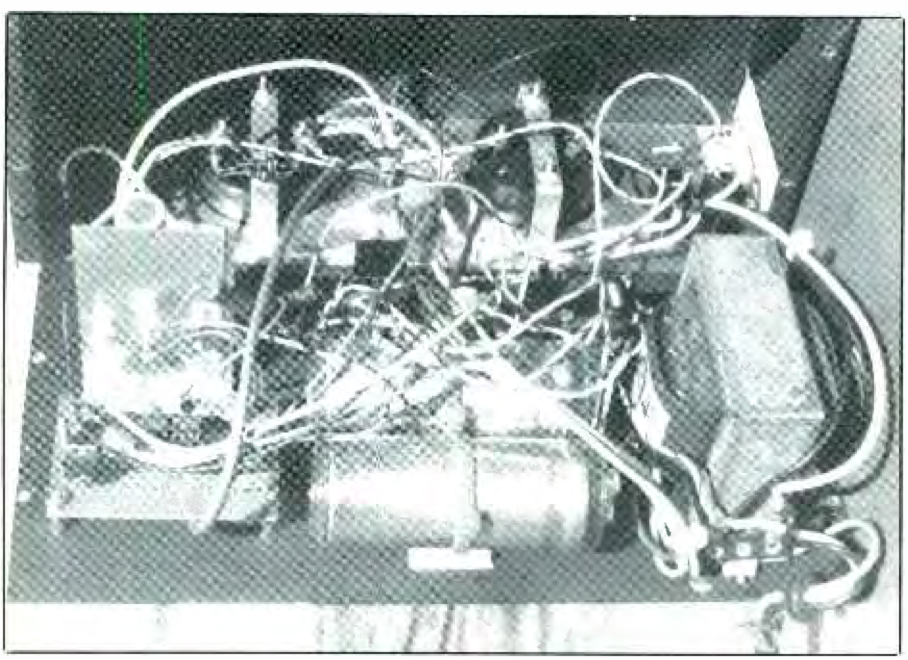


Fig. 3. Interior view of completed Power Supply. Note that the circuit-board assembly at the lower-left is positioned as far as possible from the power supply at the lower-right.