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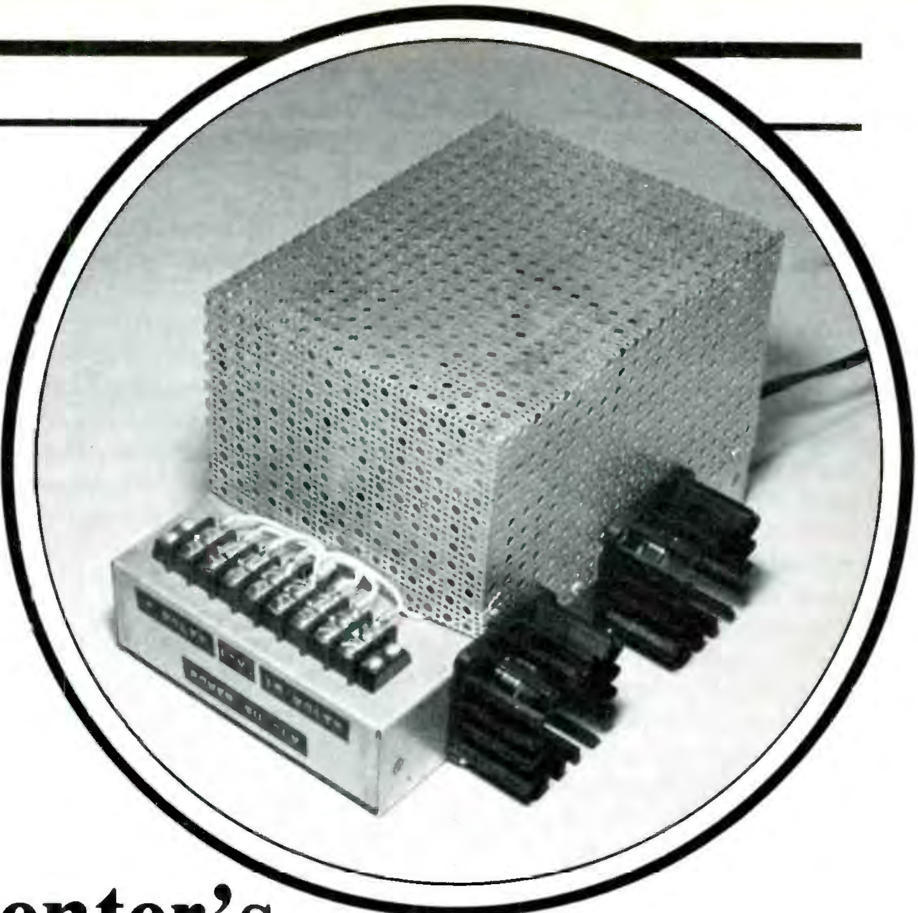


An Experimenter's Multi-Voltage Power Supply

Designed to provide all the voltages required by modern IC circuits, it may be all the power supply you ever need on your workbench

By William R. Hoffman

Most power supplies for the experimenter's workbench are inadequate for modern circuit designs. The problem is not that they do not provide sufficient current for complex circuits or that voltage regulation is not up to snuff. Rather, it is that even relatively simple circuits nowadays are likely to contain a mix of analog and digital IC devices that can require up to four different voltages and polarities. Few low-cost power supplies are capable of delivering what these circuits need. The solution to the dilemma is to build a power supply that can, such as the multi-voltage supply described here.

The Experimenter's Multi-Voltage Power Supply may be the ultimate low-cost solution to your breadboarding powering problem. It offers simultaneous outputs at +15, −15, +12 (or −12), +5 and −5 volts. Full regulation is supplied on all output lines, and current delivery is sufficient for the great majority of experimenter projects. This article discusses the design concept, provides the formulas and procedures to design and build your own supply designs, and lists and assortment of popular three-terminal voltage regulators along with their important specifications.

Designing The Supply

Designing a power supply for a particular set of needs requires that you give careful consideration to the transformer/rectifier and regulator circuits. Figure 1 illustrates four common transformer/rectifier circuits. Keeping in mind that the regulator requires an input that is 2 to 10 volts greater than its output voltage, select the circuit that most nearly supplies the correct voltage with the transformer you plan to use.

You can determine rectifier output

voltage relative to transformer output voltage using the appropriate formulas as follows:

(A) $V_O = T_O \times 0.7$
(B) $V_O = (T_O/2) \times 1.4$
(C) $V_O = T_O \times 1.4$
(D) $V_O = (T_O/2) \times 1.4$

The letters in the parentheses preceding each formula are keyed to the lettered configurations shown in Fig. 1. In these equations, V_O is a transformer/rectifier output voltage and T_O is total voltage at the secondary of the transformer. These are the approximate voltages that will be delivered to the input of the regulator. Keep in mind, too, that the result obtained with equation (D) is for *total* voltage from + to −; the voltage from + to ground and from − to ground will be half the calculated value.

The best way to undertand how to design a power supply (or any circuit, for that matter) is to run through an illustrative example. Let us assume for the moment that you want to build a 12-volt dc supply using a 24-volt center-tapped transformer. Using the formula for this particular circuit, you obtain $(24/2) \times 1.4 = 16.9$ volts output from the circuit, which is about the minimum voltage required by the regulator for this circuit.

The next step is to select the filter capacitor. This is a fairly simple task. Just keep in mind that the voltage rating of the capacitor should always be at least 50% greater than the calculated rectifier output voltage and that you should figure about 1000 to 2000 μF of capacitance for each ampere the supply is to deliver.

Selecting the appropriate regulator is your final task. Shown in Fig. 2A is a typical regulator circuit, which consists simply of the regulator IC itself and a 0.1-μF bypass capacitor. Choose you regulator according to the desired output voltage and current levels and polarity of output voltage. The IC Voltage Regulator specifications table shown elsewhere in this article will be a good reference for this step. The table lists most popular types of three-terminal regulators in IC packages.

Choose a positive supply regulator for a positive regulated output voltage or a negative supply regulator for a negative output voltage. Should your application require both positive and negative output voltages, use both types of regulators. If you already have a pair of same-polarity regulators (or cannot obtain both polarity devices), you can use these to fill your needs, as shown in Fig. 2B. It is extremely important that both transistor/rectifier circuits be *completely* isolated from each other when using same-polarity regulators. A center-tapped transformer will not do. You *must* use either a transformer with two separate and isolated secondaries or two separate transformers.

About The Circuit

Now that you know how to design a power supply, let us take a quick look at the Multiple-Voltage Power Supply that is the subject of this article. It is shown schematically in Fig. 3. Note that this supply actually consists of four different power supplies on the same chassis, each with its own transformer, rectifier, filter capacitor and

Designing Your Own Supply

Designing a power supply is a relatively easy task. Here are the steps to follow:

1) Determine what voltage(s) and maximum current your supply will have to deliver for your breadboarded projects.

2) Next, using Fig. 1 and the equations presented in the main article, determine what transformer/rectifier configuration will suit the parts you have on hand or can obtain.

3) Choose rectifiers that have an equal or greater current rating than your circuits will require, preferably the latter, and with a voltage rating at least twice that of the transformer's output voltage.

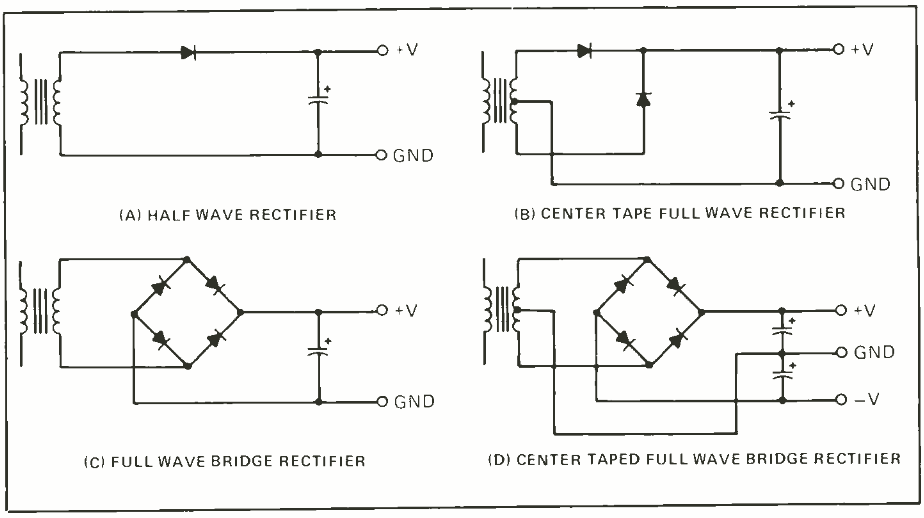
4) Determine the value of the filter capacitor, figuring 1000 to 2000 μF for each ampere the supply is to deliver.

5) Select the appropriate regulator(s) from the table.

6) Make sure to adequately heat sink all regulators; no regulator should ever become so hot that it is uncomfortable to the touch.

7) Select a fuse for the incoming ac line, figuring about ½ ampere for each ampere of current drawn by 5-to-6-volt sections and ⅔ ampere for each ampere drawn by 10-to-15-volt sections. A fast-blow fuse is best here.

Fig. 1. In these drawings are illustrated the four basic transformer/rectifier configurations commonly used in electronic circuit designs.



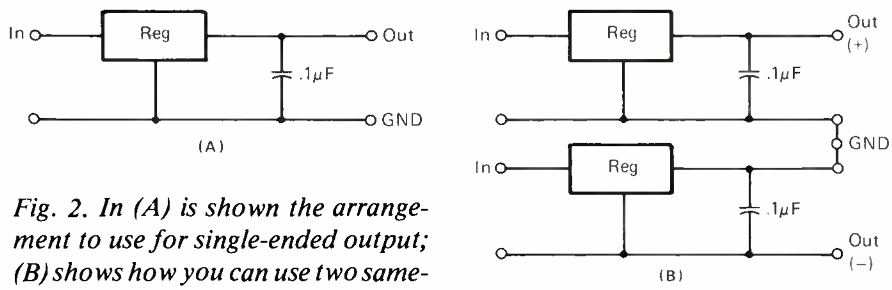


Fig. 2. In (A) is shown the arrangement to use for single-ended output; (B) shows how you can use two same-polarity regulators to obtain both positive and negative output voltages.

voltage regulator. Each of these supplies can be individually turned on and off, if desired, simply by putting an spst switch and appropriate size fuse in one transformer primary line and then wiring all to the main ac line cord. However, it is more convenient to use just one switch and fuse, as shown, to control power to all supply sections simultaneously.

In this power supply, the topmost section delivers + 15 and − 15 volts, the second + 12 (or − 12) volts, and the third and fourth sections + 5 and − 5 volts, respectively. Note in the last two sections that same-polarity (+ 5-volt) voltage regulators are used to provide the positive and negative outputs. Consequently, these sections each have their own separate transformer/rectifier and regulator circuits, as described above and that each polarity of the 5-volt output is referenced to the terminal between the + 5- and − 5-volt outputs.

Within the supply itself, no portion is referenced to chassis ground. This being the case, you can select the grounding desired in the circuit to which the supply is connected and thereafter use the 12-volt supply as either a positive or a negative source, depending on your circuit's needs.

Though the schematic in Fig. 3 does not show one, you can have a power-on indicator, too. Simply connect a panel-type neon lamp across the primary circuits of the transformer, after fuse *F1*. Before installing this pilot lamp, check to see if it has a current limiting resistor built in. If it does not, install a 100,000-ohm (100k) resistor in series with the lamp.

Construction

With the components specified in the Parts List, the power supply can be built on a standard 8″×4½″×1½″ aluminum chassis. The transformers and the 8-contact screw-type terminal block that serves as the supply's output connector mount on top of the chassis. The power switch (and power-on indicator and fuse holder, if you use these items) mount on one short wall, which should also be drilled to provide access for the ac line cord. On one of the two long walls you should mount the 5-volt and 12-volt regulators, using standard insulators and silicone or other thermal paste and appropriate hardware. The other long wall accommodates the 15-volt regulators, each mounted on pc-board type heat sinks with insulators, thermal paste and appropriate hardware.

Because of the simplicity of the power supply's circuit, no printed-circuit board construction is required. The entire circuit can be wired using standard solder-lug terminal strips mounted on the under side of the chassis and held in place with the same hardware that secures the transformers in place. The photo shows a pig-tail fuse soldered into the circuit, but you can use a bayonet-type fuse and holder. Chances of the fuse blowing are small; so a soldered-in fuse is fully practical. The regulators are all internally current limited so that a shorted load on any of the supplies will not be reflected back as an overload. The only time the fuse would blow is if one of the diodes or a filter capacitor shorted.

With regard to heat sinking the regulators, the heat sinks shown in the photo for the + 15- and − 15-volt supplies were chosen for compactness and radiating ability. Other

IC Voltage Regulator Specifications

IC type	Case	Current	Output Voltages
LM-309	TO-5 TO-3	200 mA 1 A	+ 5 volts only (negative regulator)
LM-320	TO-3 TO-5 TO-220	1.5 A 0.5 A 1.5 A	− 5, − 6, − 8, − 9, − 12, − 15, − 18, − 14 volts (negative regulators)
LM-340	TO-3 TO-220	1.5 A 1.5 A	6, 6, 8, 10, 12, 15, 18, 24 volts (positive regulators)
MC-7800	TO-3 TO-39 TO-92 TO-220	1.5 A 100 mA 100 mA	5, 6, 8, 10, 12, 15, 18, 24 volts (positive regulators)
MC-7900	TO-3 TO-39 TO-92 TO-220	1.5 A 100 mA 100 mA 0.5 A	− 5, − 6, − 9, − 9, − 12, − 15, − 18, − 24 (negative regulators)

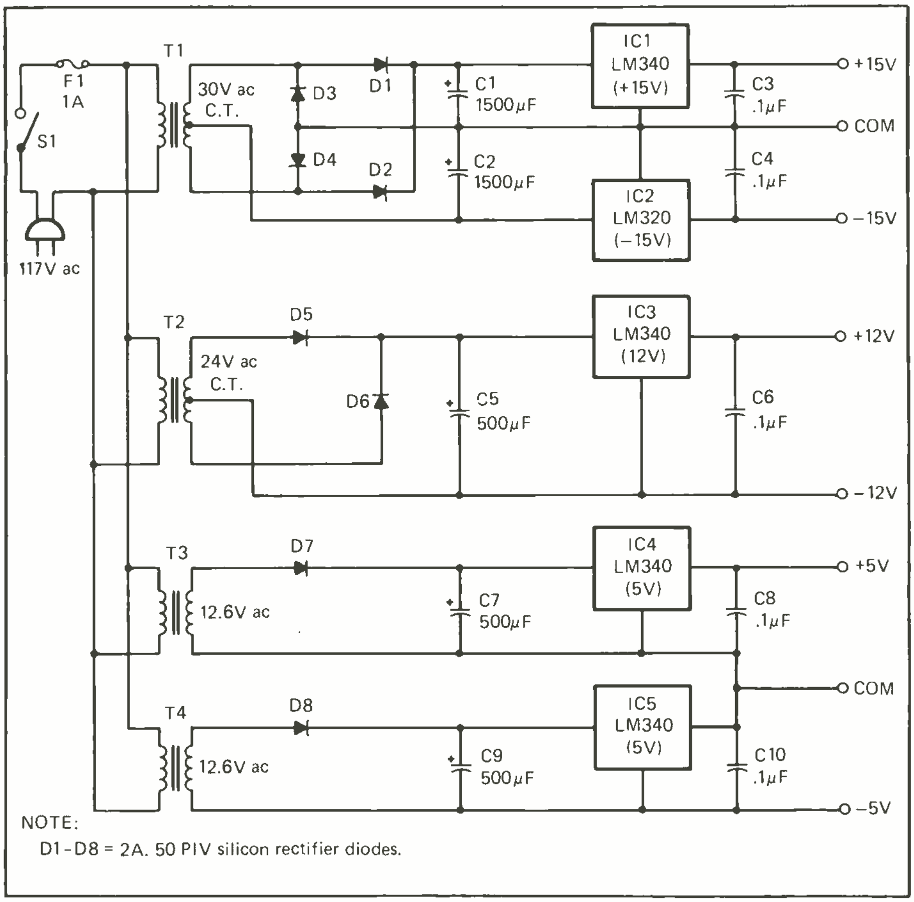
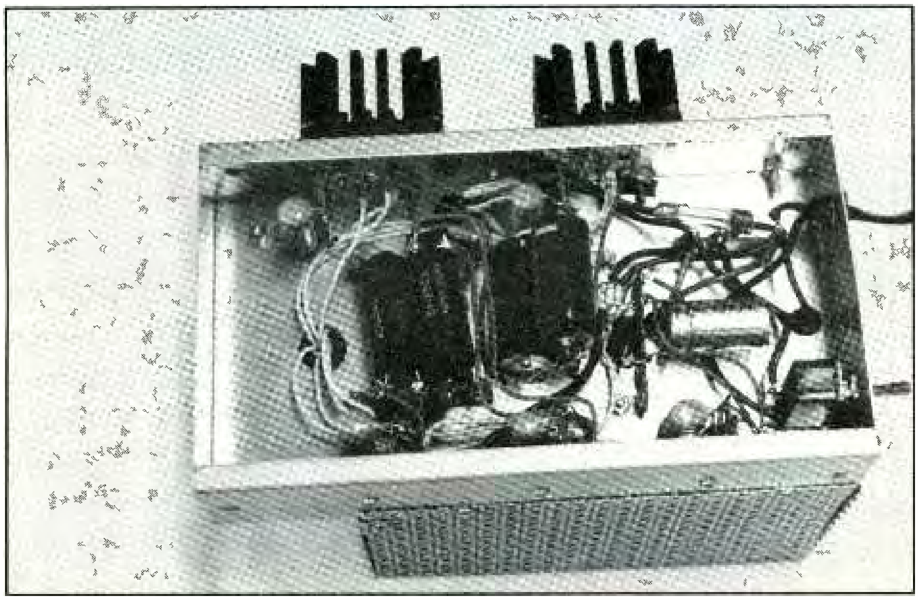


Fig. 3. Overall schematic of the multi-voltage power supply. Note use of separate transformer/rectifier/regulator arrangements for each output.

All components mount on terminal strips; incoming/outgoing wires pass through rubber-grommet-lined holes to guard against short circuits.



PARTS LIST

Semiconductors

D1 thru D8—2-ampere, 50 PIV rectifier diodes

IC1—LM340 (+15-volt) regulator in TO-3 case

IC2—LM320 (−15-volt) regulator in TO-3 case

IC3—LM340 (+12-volt) regulator in TO-220 case

IC4,IC5—LM340 (+5-volt) regulator in TO-220 case

Capacitors

C1,C2—1500-μF, 25-volt electrolytic

C3,C4,C6,C8,C10—0.1-μF, 100-volt plastic

C5,C7,C9—500-μF, 25-volt electrolytic

Miscellaneous

F1—1-ampere fast-blow fuse (see text)

S1—1-ampere, 125-volt spst toggle switch

T1—30-volt, 1-ampere center-tapped transformer

T2—24-volt, 0.5-ampere center-tapped transformer

T3,T4—6.3-volt, 0.5-ampere transformer

Metal chassis (8″×4½″×1½″); eight-lug screw-type terminal block; assorted standard solder-lug terminal strips; holder for F1 (optional); heat sinks; transistor sockets; panel-type neon lamp and 100,000-ohm limiting resistor (optional); semiconductor insulators; perforated metal for transformer cover; line cord with plug; plastic line cord strain relief; rubber grommets; labeling kit; heavy-duty stranded hook-up wire; machine hardware; solder; etc.

types can be used, including many of those available from surplus parts dealers. The actual need for a heat sink is determined by the load the regulators are to feed. Keep in mind that the greater the input voltage to the regulators from the transformer/rectifier circuits, the more power will have to be dissipated as heat. Because of this, the input voltages should be as close as possible to the regulators' minimum input voltage (see table).

As you build the multiple-voltage power supply, keep in mind that all conductors going to the terminal block and all leads from the transformers must go through rubber-grommet-lined holes for connection to the terminal strips on the underside of the chassis. Failure to do this might result in insulation wearing away and causing a short circuit to the chassis.

Checkout

There is only one check to be made once the circuit is fully assembled. That is to measure the voltages available at each of the supply's outputs. Just plug in the line cord, flip *S1* to on, and measure away with a voltmeter, noting polarities as you go. If you have installed a power-on indictor, the lamp should light when the power switch is flipped to on.

If everything checks out okay, turn off the power and disconnect the line cord from the ac line. Install the bottom plate on the chassis, checking to make sure that all electrically "live" points of the circuit do not come into contact with either the chassis or the plate. Then fabricate a "cage" out of perforated metal to fit over all transformers and bolt this into place. Finally, label each of the supply's terminal block positions with the appropriate output voltage and polarity **ME**