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CARR'S CORNER

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Building Small DC Power Supplies, Part 2: The Voltage Regulated Supply

Last month we took a brief look at the basic low-voltage, low-current (LVLC) DC power supply. These supplies are used to power solid-state circuits. They have output voltage ratings of 1.5 VDC to 28 VDC, with +5 VDC, +9 VDC and +12 VDC being most common. Some circuits also need negative output voltages in the same values. The current ratings range from 100 mA to 5 amperes, with 1 ampere (1,000 mA) being most common. In this installment, we will take a look at small voltage-regulated power supplies.

Why Voltage Regulation?

Most electronic circuits work better when the applied DC voltage is stable. Oscillators, for example, will "pull" slightly in frequency when the DC power supply voltage changes. When you hear it on CW, this phenomenon is called "chirp," and is undesirable (not to mention illegal).

The principal reasons that DC power supply outputs vary are: 1) variation in the AC input voltage and 2) variation in the load current drawn from the power supply. The input voltage variation is from the AC power mains, and there is little practical that one can do about it on the AC side. Normally, the "110 volt" AC line will vary from 105 to 125 VAC RMS. At my house, the meter tends to sit between 120 and 124 volts most of the time. During "brown-out" conditions, seen mostly in the summer months when huge amounts of current from air conditioners strain the system, the voltage might drop to 95 volts or so.

The mechanism of voltage variation from changes in DC load current is shown in Figure 1. Here we have a representative "equivalent circuit" containing a load resistance (R_L), a load current (I), an ideal (lossless) voltage source (V), and an internal resistance (R_S). It is this internal resistance that is the problem. When switch S1 is open, the load is disconnected from the power supply. Voltmeter M1 will read the full value of V. At this time, Vo does not appear. But when S1 is closed, the load is connected to the voltage source, and current I flows. The output voltage V_O will be $V - V_S$, or $V - IR_S$. As I varies, so do V_S and V_O.

Although one can reduce the effects of the load current variation, it cannot be eliminated altogether. The "cure" is to make the current capacity of the power supply much larger than the required load current. But this method is expensive, wasteful and heavy (components weigh a lot). A better way is to use voltage regulation . . . it will take care of both forms of variation.

Another value for voltage regulation was shown to me by a salesman named Walter who used to call on a shop where I was employed in the early 1960s. We serviced car radios and two-way radios, and as a result required bench power supplies. Walter came in and told me he could sell me a DC bench power supply " . . . with the equivalent of 1,000,000 µF (1 farad) of ripple filtering. Although I was initially skeptical, Walter was right. The power supply was voltage-regulated (a rarity in those days) with a solid-state voltage regulator circuit, and the voltage regulation reduces dramatically the amount of ripple.

Photo A shows the ripple before (top trace) and after (bottom trace) the voltage regulator circuit. The circuit used for this measurement was a moderately loaded 12 VDC, 1 ampere, DC power supply. Note that the "before" ripple is about the same as we saw last month for the 1,000 µF case. The ripple factor was about 400 mV. The bottom trace shows 5 mV of ripple which, because the top and bottom scales were taken using the same vertical deflection factor, barely makes a difference from a purely straight line. That's where Walter got his "1,000,000 µF" of ripple reduction.

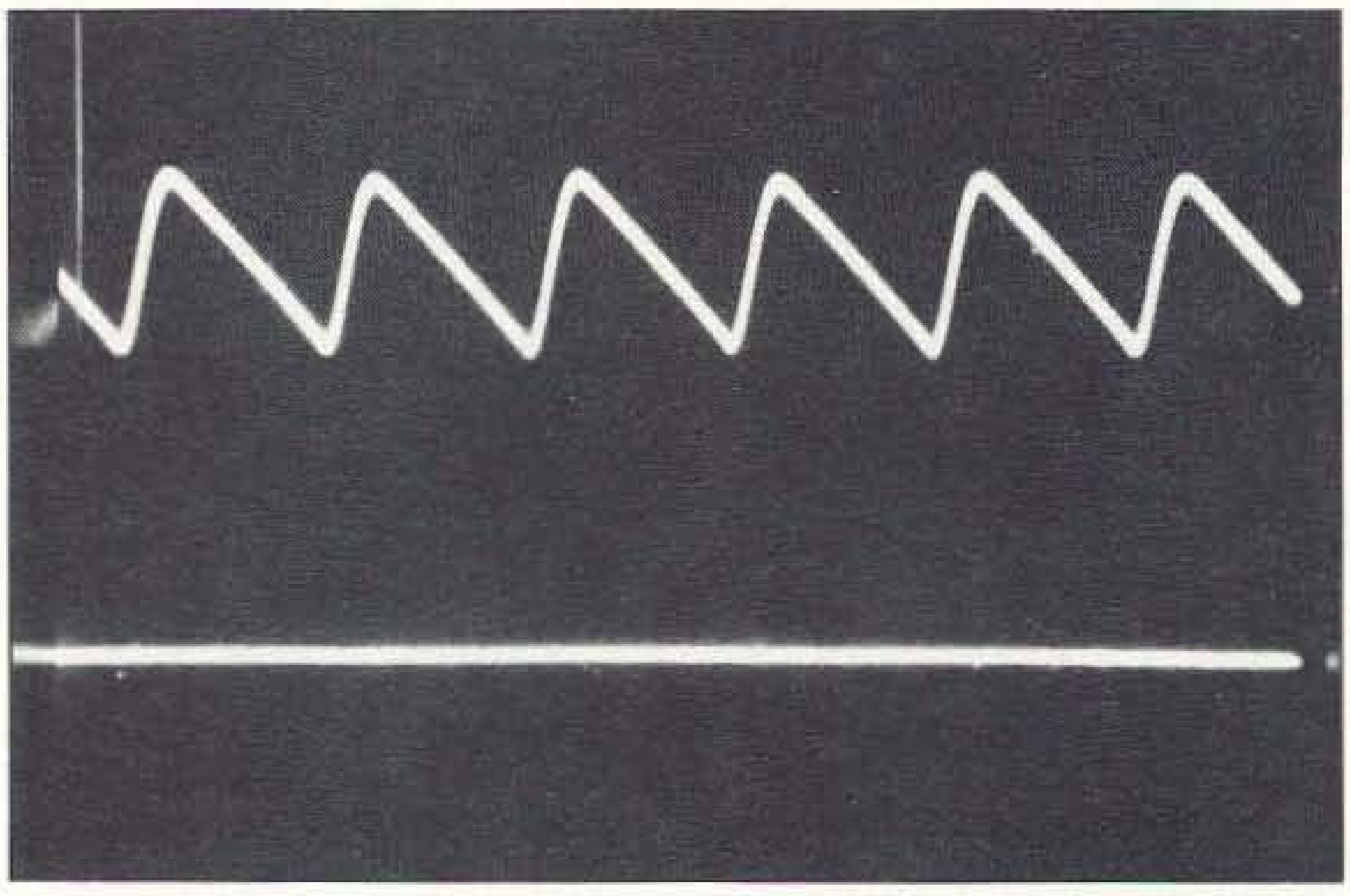
Photo A. Top trace is ripple at the input of the regulator, and the bottom trace is the ripple at the output (to same scale).

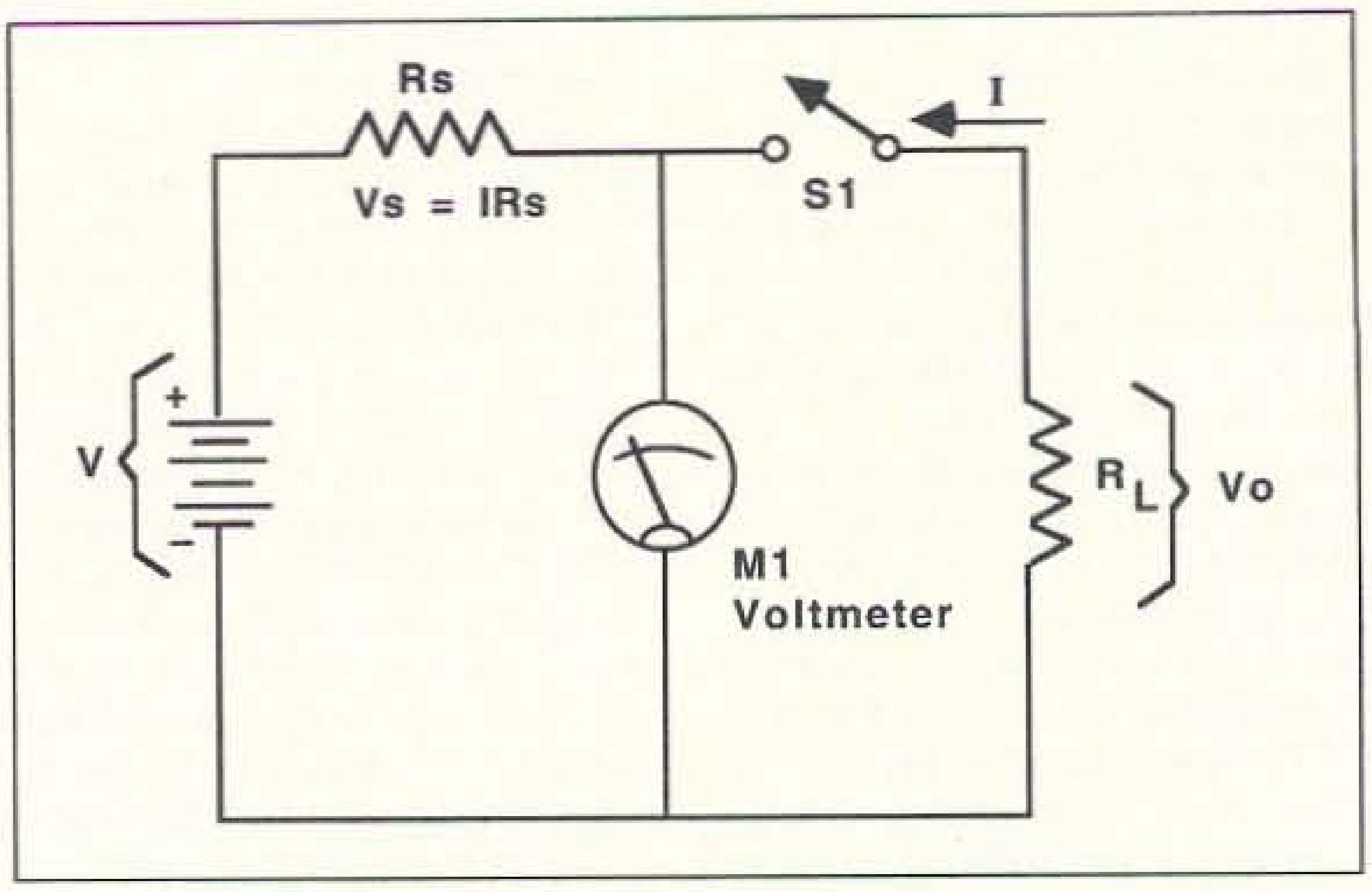

Figure 1. Equivalent circuit showing how voltage variation occurs.

Figure 2 shows the basic circuit for a voltage-regulated DC power supply that is based on the circuit we discussed last month, married to a three-terminal integrated circuit voltage regulator device (IC1). The rectifier is selected according to the criteria we used last month, i.e. a peak inverse voltage (PIV) of not less than 2.83 times the RMS voltage of the transformer (T1) secondary, and a forward current rating equal to not less than the maximum load current (plus a little reserve if you are conservative). As a practical matter, a 1,000 volt PIV, 1 ampere bridge rectifier will suffice for all 5 to 28 volt DC, 1 ampere, power supplies.

The regulator shown here is a positive voltage regulator; i.e. the input and output voltages are positive with respect to common (which in this case is a chassis ground). Several different forms of regulator are available in various combinations of current and regulated output voltage. For positive regulators, the two main lines are the LM-340n-xx and the 78xx (which for practical purposes are interchangeable). In both cases, the "xx" is replaced with the required output voltage, and the "n" with a letter denoting the package style. For example, the LM-340-05 (or LM-340-5) and 7805 are +5 VDC output regulators, while the LM-340-12 and 7812 are +12 volt regulators.

The current rating of the voltage regulator is given by a letter designation in the LM-340n-xx series, and sometimes in the 78xx series as well. The "T" package is a TO-220 three-lead plastic package similar to certain plastic audio power transistors. It is often rated at 1,000 mA (1A), although without a good heat sink 750 mA is more like it. The "K" package is the same as a TO-3 diamond-shaped power transistor package. It is good for 1 ampere, and in certain configurations (with a heat sink) up to 5 amperes. For example, the LM-323 is a +5 VDC, 3 amp regulator, while LM-338 is a 5 amp variable voltage regulator. In labeling the LM-340n-xx, therefore, an LM-340T-xx is capable of 750/1000 mA depending on heat sinking or your courage, and LM-340K-xx is a 1 ampere regulator.

The filter capacitor in Figure 2 is C3. The general rule for setting the value of this ripple filter for voltage-regulated circuits is to use 2,000 µF per ampere of maximum load current (some people accept 1,000 µF/ampere). For this reason, in the 1 ampere supply of Figure 2, the capacitor is set to 2,000 µF (more can be used, if desired—it's not that critical).

Capacitors C4 and C5 are intended to guard the regulator (IC1) from noise transients propagated on the input power, and from RF that gets into the circuit. These capacitors should be 0.1 µF to 1.0 µF, and are mounted as close as possible to the body of the voltage regulator. Capacitor C6 is set according to the rule: 100 µF/ampere. Its purpose is to guard against sudden, rapid rise time, changes in load current demand. It holds a small charge that dumps into the circuit when the load changes, while giving the regulator its necessary milliseconds to catch up. Capacitor C7 is optional, but is required in power supplies used in ham stations. It guards against the RF that might arrive through the DC output terminals. Place C7 as close as possible to the output terminals.

Diode D1 is used to prevent charge in capacitor C6 from causing damage to the voltage regulator during shutdown. It has a current rating of 1 ampere, and a voltage rating of 1,000 volts PIV.

Note that a heat sink is shown on IC1, the voltage regulator IC device. If the regulator is used in a circuit that can output more than about half the full rated output of the regulator, then it's a good idea to use a heat sink.

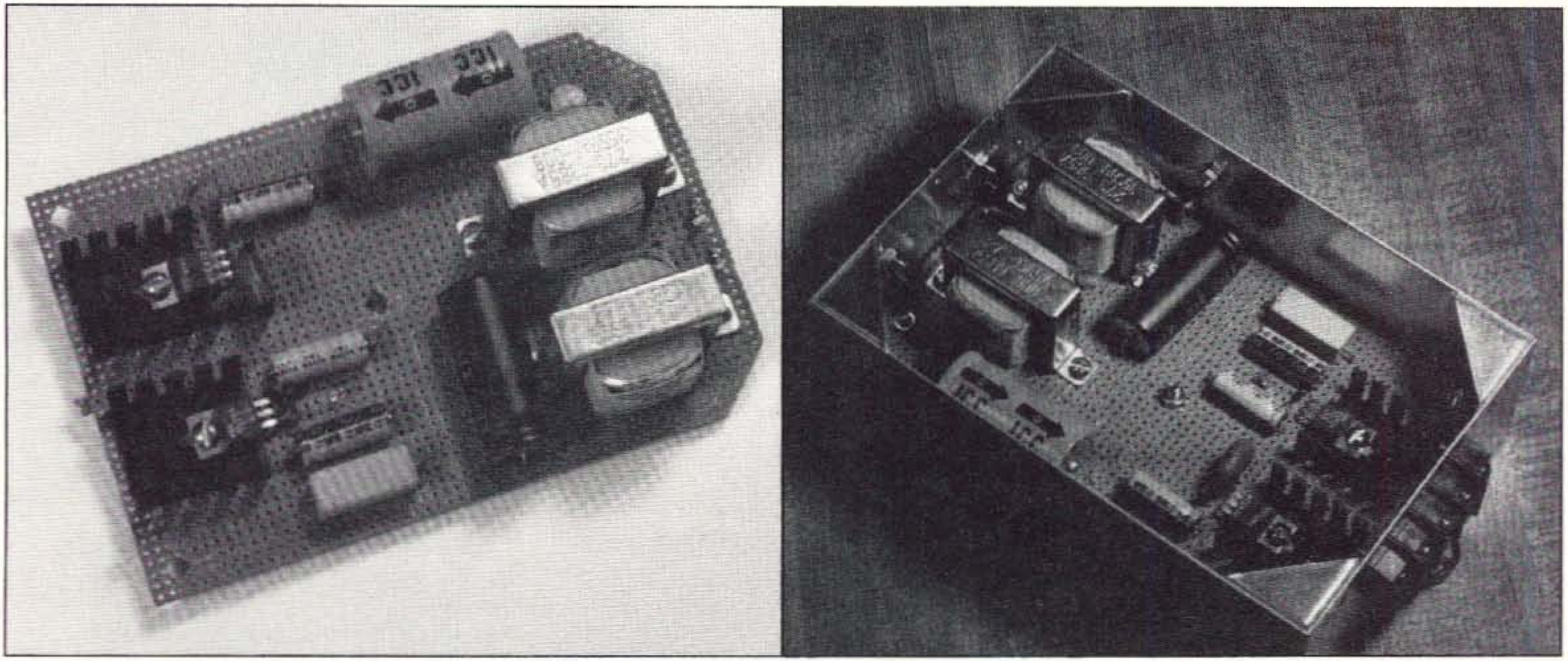

Photo B. a) Perfboard detail; b) Finished power supply.

The mounting tab of "T" package devices, and the case on "K" package devices, is also ground, so be aware that the heat sink will also be ground (keep hot leads away from it).

Photo B(a) shows the construction of a simple 1 ampere, low voltage DC power supply wiring board, while Photo B(b) shows a typical finished product. The wiring is done "point-to-point" on the back of a piece of perforated wiring board. This board is available from most parts distributors (for perfboard and other DC power supply components, see the catalog of Ocean State Electronics, POB 1458, Westerly RI 02891; 1-800-866-6626). Note in Photo B(a) the use of heat sinks on the "T" package regulators. Also note the wide spacing between the heat sinks. Also note that the transformers are mounted on the board. This type of construction should only be used for small, low-current applications. Heavier transformers will best be mounted on the chassis.

The chassis shown here is a shielded box . . . which is a good idea for a regulated power supply used around (or inside) radio transmitting equipment. For a bench power supply, use an appropriate cabinet.

Packet Radio Buffs

Dave Wolf WO5H sent me a copy of his new *Packet Power Newsletter.* It's an eight-page monthly intended to keep packet buffs up to date. He tells me that readers of this column can get a free complimentary copy if they mention this column and send a self-addressed stamped envelope (SASE). Sample copies are normally $1. Looks pretty good for packet buffs.

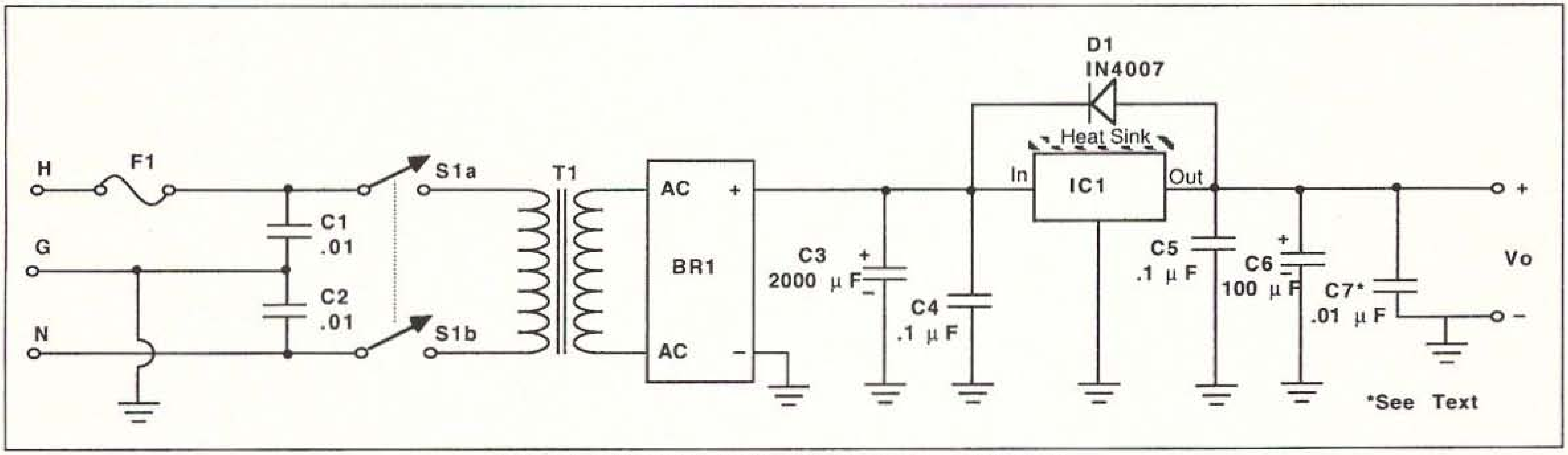

Figure 2. Circuit for the basic voltage regulator power supply.