REVISITING THE 12-V POWER SUPPLY

◊ Some readers have caught the "power dissipated in the filter capacitor" goof that was in the November 1992 *QST* power-supply article.[1] The readers are absolutely correct: An *ideal* capacitor does not dissipate power. This error occurred in an attempt to address an additional requirement when choosing a filter capacitor: the capacitor's ability to handle ripple current.

In a high-current power-supply design, the filter capacitor has to supply a large amount of current between the peaks of the rectified dc output of the full-wave bridge. This drives up the physical capacitor size, both to achieve the required capacitance and to reduce the capacitor's internal resistances. *Power is dissipated in the capacitor only because of the current and the capacitor's internal resistances.* The power dissipated should be small as long as a physically large capacitor is used.

It's best to select a capacitor that provides a low ripple voltage on the unregulated dc prior to the regulator. This allows the use of a lower transformer secondary voltage which, in turn, reduces the pass-transistor power dissipation. Use the following formula (from the *Handbook*) to determine the capacitance required for a given output current and ripple voltage. This allows selection of capacitors for various load currents. Remember: Capacitors can be connected in parallel, if needed, to get the desired capacitance value.

In this equation, C is in microfarads (µF), f is in hertz (120 Hz for a full-wave rectifier), and E_{ripple} is expressed in peak-to-peak volts.

$$C = \frac{\left(I_l\right)\left(\frac{1}{f}\right)}{E_{ripple}} \times 10^6 \qquad \text{(Eq 1)}$$

Using this equation yields a value of 45,000 µF for the filter capacitor in a 15-A supply with 1 V RMS (approximately 2.8 V P-P) ripple on the unregulated dc. Additional capacitance proportionally reduces the ripple voltage; a higher load current proportionally increases the required capacitance value.

In my prototype supply, I used a filter capacitor I had on hand. The preceding formula shows a 2.8 V P-P ripple with a 45,000 µF capacitor. The ripple voltage on the prototype (with a 19,000 µF capacitor) measured about 3.3 V P-P at a load current of 15 A. The transformer secondary voltage under load is high enough so that the regulator provides the required output without losing regulation because of the ripple voltage. However, the ripple voltage causes additional power to be dissipated in the pass transistors.

Heat-Sink Size

One reader commented that the internal heat sink was rather small for the amount of power dissipated in the transistors, and that the fins should be oriented vertically rather than horizontally. The heat-sink arrangement in my prototype supply was determined by parts availability and is adequate for my application because the supply is used for intermittent operation—such as with an SSB transmitter.

Those contemplating constructing a *continuous-duty* supply should definitely increase the heat-sink area and orient the fins vertically. The heat sink should also be mounted *outside* the cabinet where it is offered unrestricted airflow. For additional information on thermal design, see the *Handbook's* power-supply section.

Fusing

One reader suggested placing a fuse between the filter capacitor and the regulator. If this was done in the design presented, the fuse *would never open!* Even with a short on the output, the supply *limits the output current* to a set maximum value (assuming the fuse rating was higher than the current-limit value). However, adding a circuit breaker or fuse between the filter capacitor and the regulator, and moving the *hot* side of the overvoltage SCR to the regulator side of the circuit breaker can provide additional protection.

With the SCR gate still sensing the output voltage, an overvoltage condition will turn on the SCR. When that happens, the SCR looks like a short circuit across the filter capacitor. Then, the circuit breaker will open, disconnecting power from the regulator. This provides better protection against overvoltage because the power is disconnected from the output. Also, power is no longer dissipated in the pass transistors when the SCR is conducting. The fuse or circuit breaker also acts as a backup in the event that the regulator's current-limiting circuit malfunctions. For best results, a low-value resistor should be added in series with the SCR to create a "soft-short" condition. Size the resistor to draw enough current to open the fuse or circuit breaker used.

Pass Transistors

Another reader had some important information about the pass transistors. The 2N3055 transistors should have a resistor connected from base to emitter to ensure that they can be completely cut off under a no-load condition. The value of the base-to-emitter resistors should be about 33 ohms. Connect the resistors directly between the base and emitter of each transistor (Q1-Q3).

The base-emitter resistors are required because the collector-to-base leakage current can be as high as 5 mA when the transistors are hot and operated at maximum V_{CE}. Because the V_{CE} of the transistors is well under 20 V, we can use a lower value for the leakage current.

Assuming that we use the three transistors, and that since the V_{CE} is under 20 V, a value of about 3 mA for the maximum leakage of a new transistor would be reasonable. If no base-to-emitter resistors are used, the resulting emitter current can be calculated by multiplying the transistor gain, plus one, by the leakage current. Over time, the transistor leakage will increase (it can be up to 10 times higher for parts operated near their limits). The parts in my design are not operated near their limits, therefore the resistors are sized to provide a base-to-emitter voltage of about 0.3 with a 9-mA leakage current. This value is a compromise based on the use of three transistors, a low V_{CE}, and a collector current of only 5 A per transistor. Because the base leads are tied together—and the emitter leads are also tied together through the emitter resistors—the net resistance of the three 33-ohm resistors in parallel is about 11 ohms.

The measured V_{BE} of the transistors with a 15-A load is about 1 V, for a power in each 33-ohm resistor of 30 mW. A standard ½-W resistor can be used and fits easily across the base and emitter leads of the TO-3 package transistors. The TIP-112 has similar resistors built into its case, so we don't have to add them externally.

To accommodate the leakage current of the transistors (now reduced by the base-emitter resistors), it's best to have an internal load on the supply output. The regulator's voltage divider is a 1.8-mA load at an output of 12 V dc. That may be enough for new transistors, but is not enough to accommodate a possible 30- to 40-mA leakage current from aged transistors. A resistor of about 300 ohms or less connected from the junction of R1 through R4 to ground provides a path for the current. The maximum value of the resistor can be calculated by R = E ÷ I, where E is the regulated output voltage and I is the leakage current of the transistors. The next-smallest standard value should be used. Moving the 75-ohm bleeder resistor to this location would also work.

[1] E. Oscarson, "A 12-V, 15-A Power Supply," *QST*, Nov 1992, pp 36-41.

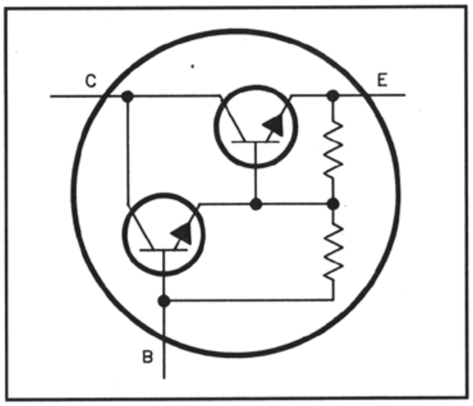

Fig 1—Correct representation of Q5, the TIP112 transistor.

Cosmetics

Lastly, a cosmetic error that got into the design is the schematic representation of Q5, the TIP-112 transistor. The correct diagram is shown in Fig 1.

In the Fig 1 caption, R10 should be identified as 330 Ω, ½ W. Delete R11.

I would like to thank all the readers for their comments and for the additional information.—*Ed Oscarson, WA1TWX, 70 Behrens Rd, New Hartford, CT 06057*

MORE ON ELEVATED RADIALS

◊ I've been doing some NEC modeling of AM broadcast antennas, and I believe that the results will be of interest to others. This latest research indicates that elevated radials can be used in conjunction with a *ground-mounted* vertical monopole to achieve results that are as good as can be obtained from a conventional ground-mounted tower with 120 buried radials.

The general layout is given in Fig 2. The ground rods can be omitted without hurting the electrical performance of the antenna, and the masts, which are used to support the elevated radials, can be conductive (metal) or nonconductive (the difference in radiated field strength is 3% or less).

The vertical monopole (ground-mounted on a base insulator) has a physical length of 0.25 λ. The four radials slant upward from the feed point at a 45° angle until reaching the desired height (H), then extend outward horizontally from that point. The computer analysis appears to indicate that the height of the radials (H) can be as little as *4 to 5 feet* on 80 meters, but a height of 10 to 15 feet produces a slight increase in signal strength, and would be better from a safety standpoint.

How long should the radials be for best performance? As a *general* rule, if the radials are suspended at a height of H above ground, then their length should be equal to 0.25 λ *plus* H. In other words, if H = 10 feet, then at 3.8 MHz, the length of the radials should be 0.25 λ (which is 64.7 feet) + 10 feet = 74.7 feet. The feed-point impedance depends on many variables, but NEC-GSD predicts values in the range of 22 to 31 ohms. Complete information can be found in A. Christman and R. Radcliff, "Using Elevated Radials with Ground-Mounted Towers," *IEEE Transactions on Broadcasting*, Vol 37, No 3, Sep 1991, pp 77-82. —*Al Christman, KB8I, Grove City College, 100 Campus Dr, Grove City, PA 16127-2104*

Note: All correspondence addressed to the Technical Correspondence column should bear the name, call sign and complete address of the sender. Please include a daytime telephone number at which you can be reached if necessary.

Keep the author(s) in the communications loop. Whether praising or criticizing a work, copy the author(s) on comments sent to Technical Correspondence.

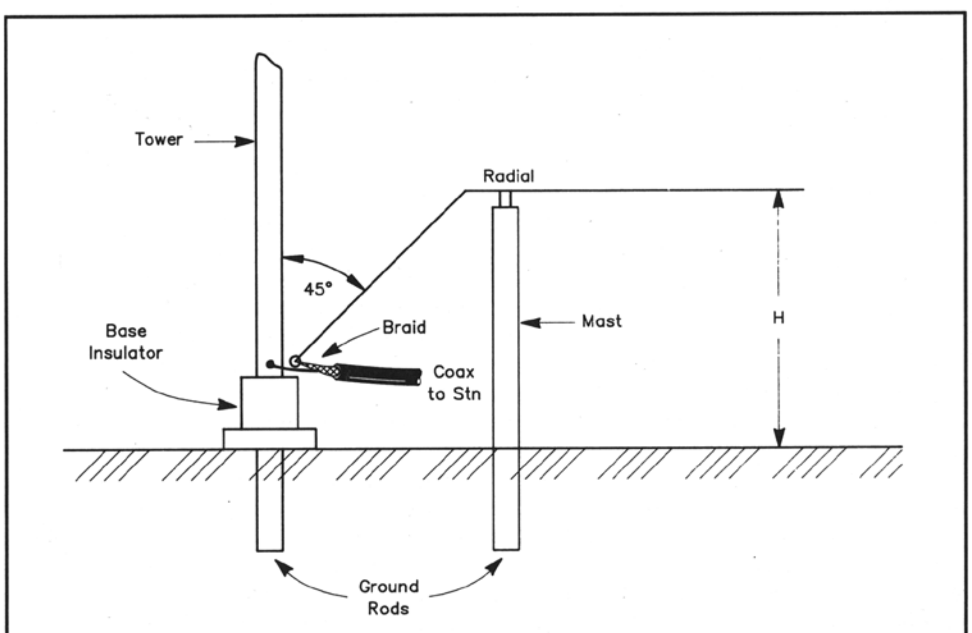

Fig 2—Elevated radials can be used in conjunction with a ground-mounted vertical monopole to achieve results equal to those of a conventional ground-mounted tower with 120 buried radials. The ground rods can be omitted without hurting the electrical performance of the antenna. The masts supporting the elevated radials can be conductive (metal) or nonconductive (the difference in radiated field strength is 3% or less).