Quickly discharge power-supply capacitors

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A perennial challenge in power-supply design is the safe and speedy discharge, or "dump," at turn-off of the large amount of energy stored in the postrectification filter capacitors. This energy, $CV^2/2$, can usually reach tens of joules. If you let the capacitors self-discharge, dangerous voltages can persist on unloaded electrolytic filter capacitors for hours or even days. These charged capacitors can pose a significant hazard to service personnel or even to the equipment itself. The standard and obvious solution to this problem is the traditional "bleeder" resistor, R_B (**Figure 1**). The trouble with the R_B fix is that power continuously and wastefully "bleeds" through R_B, not only when it's desirable during a capacitor dump, but also constantly when the power supply is on. The resulting energy hemorrhage is sometimes far from negligible.

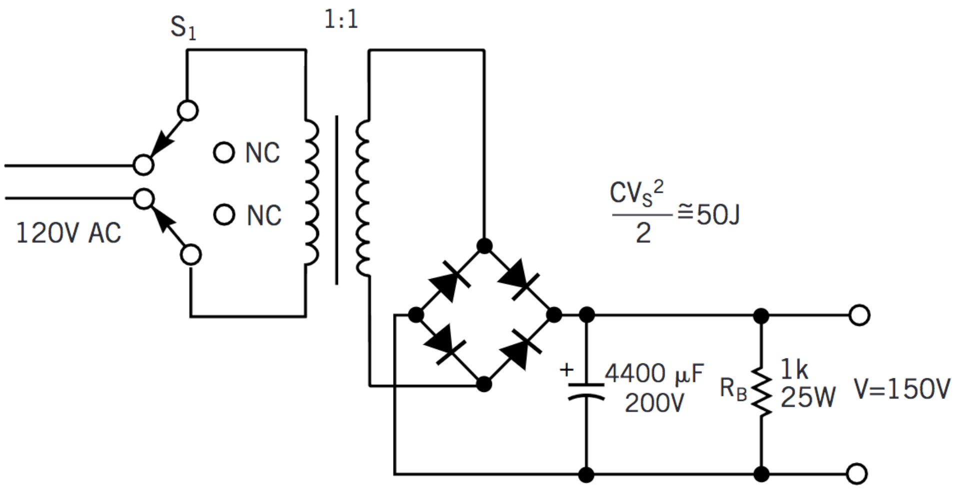

Figure 1 A bleeder resistor ensures safety but wastes much power.

Figure 1 offers an illustration of the problem, taken from the power supply of a pulse generator. The $CV^2/2$ energy stored at the nominal 150V operating voltage is $150^2 \times 4400$ µF/2, or approximately 50J. Suppose you choose the R_B fix for this supply and opt to achieve 90% discharge of the 4400-µF capacitor within 10 sec after turning off the supply. You then have to select R_B to provide a constant RC time no longer than 10/ln(10), or 4.3 sec. R_B, therefore, equals 4.3 sec/4400 µF, or approximately 1 kV. The resulting continuous power dissipated in R_B is 150^2/1 kV, or approximately 23W. This figure represents an undesirable power-dissipation penalty in a low-duty-cycle pulse-generator application. This waste dominates all energy consumption and heat production in what is otherwise a low-average-power circuit. This scenario is an unavoidable drawback of bleeder resistors. Whenever you apply the 10%-in-10-sec safety criterion, the downside is the inevitable dissipation of almost half the $CV^2/2$ energy during each second the circuit is under power.

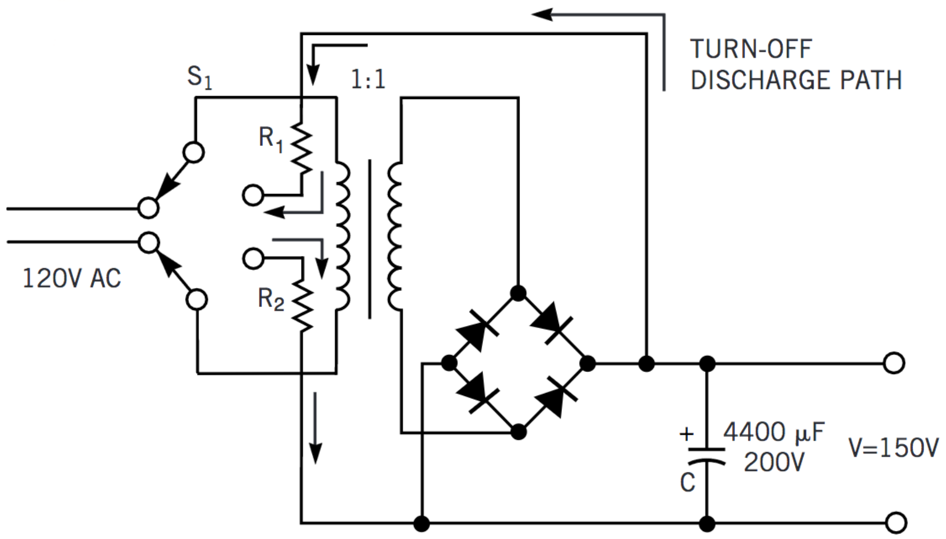

Figure 2 Otherwise unused switch contacts can dump energy while not wasting power.

Figure 2 shows a much more selective and thrifty fix for the energy-dump problem. The otherwise-unused off-throw contacts of the DPDT on/off power switch create a filter-capacitor-discharge path that exists only when you need it: when the supply is turned off. When the switch moves to the off position, it establishes a discharge path through resistors R_1 and R_2 and the power transformer's primary winding. The result is an almost arbitrarily rapid dump of the stored energy, while the circuit suffers zero power-on energy waste. Use the following four criteria to optimally select R_1, R_2, and S_1:

- The peak discharge current, $V/(R_1+R_2)$, should not exceed S_1's contact rating.
- The pulse-handling capability of R_1 and R_2 should be adequate to handle the $CV^2/2$ thermal impulse. A 3W rating for R_1 and R_2 is adequate for this 50J example.
- The discharge time constant, $(R_1+R_2)C$, should be short enough to ensure quick disposal of the stored energy.
- S_1 must have a break-before-make architecture that ensures breaking both connections to the ac mains before making either discharge connection, and vice versa. Otherwise, a hazardous ground-fault condition may occur at on/off transitions.