BY HIREN SHAH • XP POWER

Designing small, efficient ac/dc switching power supplies

POWER SUPPLIES MUST PERFORM TO THEIR SPECIFICATIONS AS WELL AS MEET INTERNATIONAL STANDARDS WITH RESPECT TO EMC PERFORMANCE, SAFETY, AND INPUT PROTECTION. THESE TIPS INVOLVE SAVING SPACE WITHOUT COMPROMISING ELECTRICAL PERFORMANCE.

AC/DC-power-supply design is evolutionary, rather than revolutionary, developing largely as a result of gradual improvements in semiconductors and passive-component technologies and materials. Invariably, power-supply-design objectives involve not only meeting basic input and output specifications but also meeting them within a given package size and tight cost constraints. Some tried-and-true techniques, in a logical sequence from the input to the output of the power supply, can help you meet your goal.

The largest components in input filters are the inductors and capacitors. It pays to keep track of the latest products from all of the main toroid manufacturers, as sizes continue to shrink with developments in materials. With respect to Class X capacitors, which must operate across the mains line, you may be tempted to use ceramic types for their small size. However, these devices can fail catastrophically in the face of input spikes. Metallized polypropylene types, although larger, cope better with these spikes, as they have an inherent self-healing property. Self-healing removes a fault or short circuit by vaporizing the electrode in the region of the short and restoring the capacitor to useful life. Any loss of capacitance is negligible in normal operation. As with magnetic components, there will be gradual reductions in capacitor size over time.

To meet safety requirements with respect to creepage and clearance, you must leave a physical-safety margin at the edges of bobbins for winding inductors and transformers. A triple-insulated, UL-certified, copper wire can remove the need for these gaps; you can then wind right to the edge of the bobbin. With this process, you can reduce the overall size of the switching transformer, often the largest component on the board, by as much as 20%.

Carefully select the working voltage of aluminum-electrolytic capacitors to get the best combination of minimum size and extended operating life. These capacitors have longer operational life when you use them at no more than 80% of their rated voltage. If you use the capacitors at full rated volt-

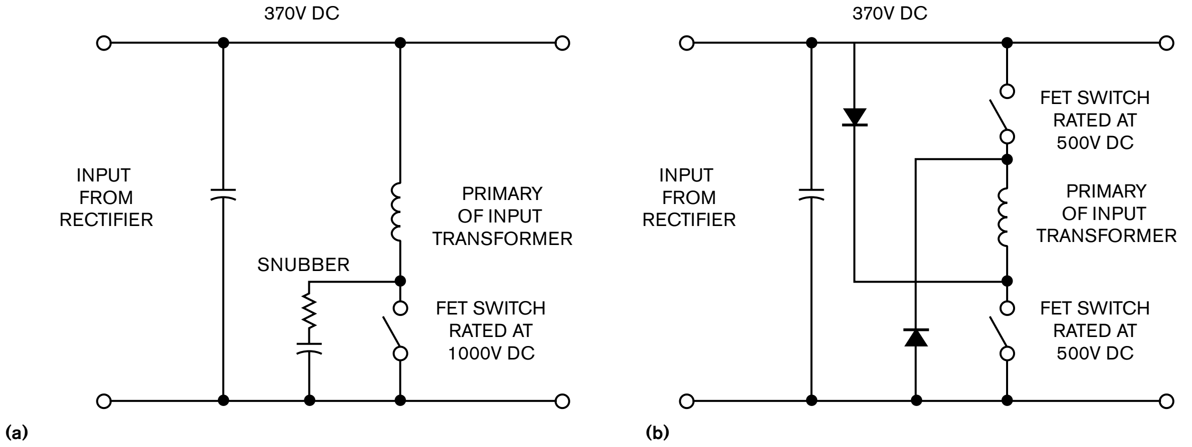

Figure 1 Although it minimizes component count, a single 1000V FET switch (a) is more expensive and less efficient than a circuit with dual 500V FET switches (b).

age, leakage current produces heating losses that can degrade the components. The rule of thumb is that every 10°C increase in temperature halves the life of the capacitor. In practice, the dielectric layer in the capacitors will reform to the voltage at which you are using them, and any voltage surge can result in circuit failure, so the design should take this information into account, too. Use components with a 105°C temperature specification for the longest operating life. In practice, a relatively large capacitor will be necessary anyway, not just for ripple reduction but to provide the required dc holdup time in the event of short-term disruption in the ac input. Typically, a holdup time of 10 to 20 msec is necessary. Large electrolytics have high ESR (equivalent series resistance) at higher frequencies, so it's always good practice to include a much smaller capacitor—often a plastic-film type, around 0.22 μF—in parallel to reduce this value.

Designers base most of their products on a dc input to the switch of 370V, based on 1.4 times the high-line ac voltage of 264V. If you use a single MOSFET for switching, having the back EMF that the stored energy in the input-transformer primary generates when the switch opens will mean that you have to use a 1000V-dc-rated MOSFET. These devices are available but relatively expensive. They also have high forward resistance (R_{DSON}) that may reach 40 mΩ, compromising efficiency. You also need to include a snubber circuit to prevent high voltage spikes from damaging the MOSFET and to add reset winding in the main transformer and other components, increasing component count, cost, and board space. A smarter approach is to use two 500V MOSFET switches (S_1 and S_2) as in **Figure 1**. The switches operate simultaneously on either side of the transformer secondary, and the diodes conduct at approximately 1V above the input voltage, clamping the maximum voltage that back EMF creates, protecting the input capacitor, and eliminating the need for a snubber circuit. Costs for 500V MOSFET switches are approximately one-sixth that of 1000V-rated versions, and a number of vendors now offer devices with forward resistance as low as 5 mΩ.

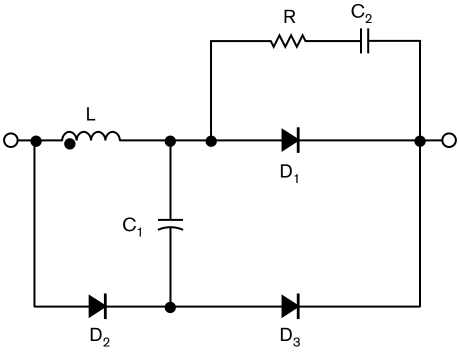

Figure 2 The snubber circuit you need with conventional diodes adds cost and complexity.

Figure 3 The compact MFA350 350W ac/dc switching power supply from XP Power achieves 11.2W-per-cubic-inch power density.

SiC (silicon-carbide) rectifiers in boost converters may appear to be expensive, but when you calculate the reduction in component count that's possible, the reduced power-supply assembly cost, and the savings in board space, you'll probably find that an overall cost disadvantage no longer exists. What's more, their use can deliver a 1% improvement in total power-supply efficiency. Conventional diodes permit high reverse current, and the design needs to dissipate the energy in a snubber circuit comprising two diodes, two capacitors, a resistor, and an inductor (**Figure 2**). The negligible reverse current of the SiC diode eliminates these six components and reduces losses, leading to improved efficiency. Both Cree (www.cree.com) and Infineon (www.infineon.com) offer SiC diodes.

It's now also economical to combine through-hole and surface-mount techniques in the design of ac/dc switchers. You can implement control functions on the underside of the pc board using surface-mounted devices.

Where possible, affix power semiconductors directly to the power-supply case or U-channel. You no longer need thermal pastes. Thermal-transfer components from companies such as Bergquist (www.bergquistcompany.com) allow you to solder the tabs of power devices directly to a copper pad that is already bonded to an electrically insulating but thermally conductive substrate. This approach is inherently more consistent and reliable than using thermal pastes. Where you need forced-air cooling, you might consider three-wire intelligent fans. The fan speed varies with temperature to ensure that the fan runs only as fast as it needs to for given operating conditions, reducing both noise and power consumption. However, the relatively high prices of these fans and the ready availability of low-cost fan-control chips make implementing your own control circuit more cost-effective. Fan noise is another consideration. Experiment with the format and spacing of finger guards. Placing finger guards a few millimeters away from the panel on which the fan is mounted, rather than flush with it, can reduce fan noise by 5 to 6 dB. In a system that uses a number of power supplies, this reduction is audible.

Don't let all the hype about digital control for ac/dc power supplies carry you away, unless your application absolutely needs it. Designers have widely implemented digital control in point-of-load converters, but doing so adds considerable cost to ac/dc power supplies. The chips may now be available at 50 cents or so, but when you consider the additional components necessary, manufacturing costs, and the cost of connectors, implementing digital control will add $10 to $15 to the cost of an ac/dc power supply. This figure may be acceptable for a 1-kW power supply, where it is a small proportion of the total cost, but for low- to medium-power units, the additional cost is rarely justifiable.

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There is always room for creativity in mechanical design. Consider the range of applications for which you may use the power supply at the outset. For example, it may be possible to design the overall physical dimensions so that the power supply fits horizontally or vertically into an industry-standard enclosure format (**Figure 3**). You can design the pc board to accept plug-in connectors or screw terminals, adding no cost but greatly improving the application flexibility. And remember the small things, such as accessibility of fuses and reversible cable-retention devices, so that the walls of the system enclosure or other protuberances don't obstruct them. Stacking components to save PCB (printed-circuit-board) space is another technique that designers often overlook. For example, it may be possible to stack the inductors in a filter network on top of capacitors, simply fixing them with adhesive. This approach can also help EMC performance by keeping filter component interconnects very short.

To look at some power supplies, you might think that someone dropped the components onto the board from a great height and then connected them! Careful component layout that follows a logical flow from input to output is good engineering practice. The product looks better, is easier to test and service, and performs better. Remember, every bend in a PCB track adds a little inductance that can create electromagnetic interference. **EDN**

AUTHOR'S BIOGRAPHY

Hiren Shah is responsible for new-product development in the United States for XP Power, including managing the design team, working with sales and marketing to identify customer and market ideas for new products, and ensuring that the company launches its products on time. He received a BSEE from MS University of Baroda, India, in 1981 and has been with XP Power for 12 years. His interests include hiking, reading, and travel.