LIMITING INRUSH CURRENT TO A SWITCHING POWER SUPPLY IMPROVES RELIABILITY, EFFICIENCY

Active inrush-current limiters—unlike fuses and circuit breakers—prevent dangerous situations instead of only reacting to them. Apply limiting techniques, and you need not employ extra-hefty rectifiers just to ensure rectifier survival during turn on.

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The input filter capacitor employed in many dc power-supply designs creates a potential problem—high inrush current. Fortunately, though, adding a few extra components can prevent inrush current and its associated circuit damage.

How does the input capacitor cause such problems? Intentionally chosen for high storage capacity and low equivalent series resistance (ESR), it behaves like a nearly perfect short circuit when the supply first turns on. The resulting short-duration peak inrush current can reach levels much greater than the tolerable single-cycle ratings of the supply's semiconductor rectifiers (thus destroying them) and still not contain sufficient total energy to open protective fuses or circuit breakers. Additionally, the supply's rapidly rising voltage and current levels could cause dv/dt- or di/dt-sensitive devices in neighboring hardware to fail or malfunction.

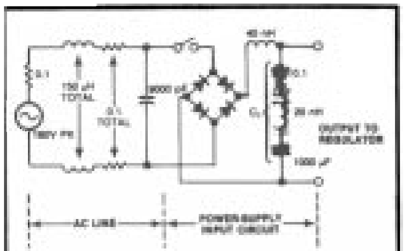

Fig 1—Based upon this generalized model, analysis indicates the inrush-current problem's magnitude. Chosen for its low ESR, the input filter capacitor (C_1) behaves like a nearly perfect short circuit when the supply first turns on.

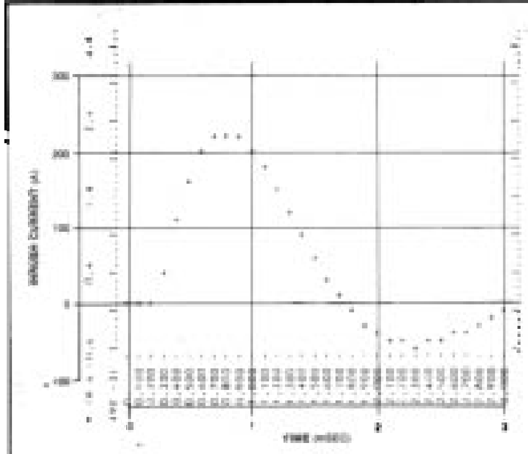

Fig 2—Peaks greater than 200A are predicted by ECAP for the circuit model shown in Fig 1. Rectifier-diode reverse-recovery capability would inhibit the indicated 50A overshoot in an actual circuit design.

Turn on an analysis before you turn on a power supply

Computer analysis proves useful

To appreciate the inrush-current problem, consider an estimate of its magnitude before examining possible control techniques. **Fig 1** depicts a model of the ac-input and rectifier/filter sections for a typical dc power supply. Although shown in a straight off-the-power-mains configuration, the model should be valid for any other design with the same output-power capability.

An ECAP computer analysis performed for this circuit assumed worst-case conditions: switch closure at 160V (peak voltage). The results (**Fig 2**) indicate that an inrush current greater than 200A can exist for several milliseconds.

Now compare this predicted performance with the measured characteristics (**Fig 3**) of a typical design. The current pulse's high level and short duration could generate severe, localized hot spots in rectifier junctions or cause false triggering of rate-sensitive devices elsewhere in the circuit.

A standard approach to current limiting is depicted in **Fig 4a**—a resistor. It's simple, reliable and easy to design in, but efficient it isn't. At any current level, it dissipates power that would otherwise be available to the load. The resistor does perform a surge-current-limiting function, however.

Alternatively, a thermistor-controlled current limiter (**Fig 4b**) alleviates the resistor's efficiency problems to some extent, but it aggravates the dropout-recovery problem. The same cold-to-hot resistance variation that permits turn-on current limiting and high efficiency at low operating currents fails in dropout-recovery situations: The thermistor's long thermal time constant prohibits fast recovery.

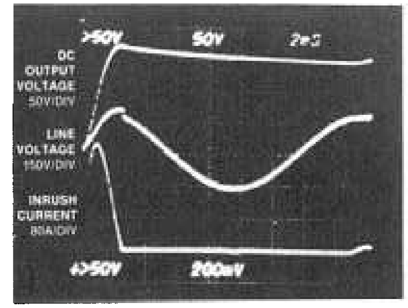

Fig 3—Measured inrush current *appears close to that predicted in* **Fig 2.** *This large current inrush could cause junction hot spots and generate troublesome EMI.*

SCR spells efficiency

In view of resistor and thermistor drawbacks, active soft-start designs offer a best-of-both-worlds

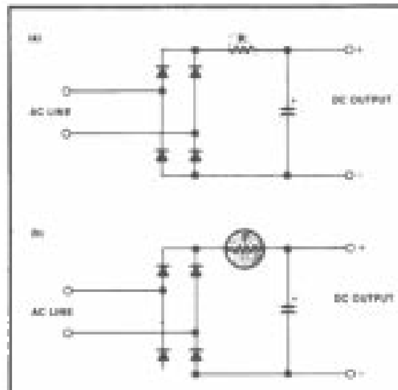

Fig 4—Two common methods of inrush limiting employ either a resistor (a) or a thermistor (b). But if the resistor is large enough to effectively control surge currents, it also significantly reduces efficiency. The thermistor, while more efficient, offers little protection during dropout recovery because of its long thermal time constant.

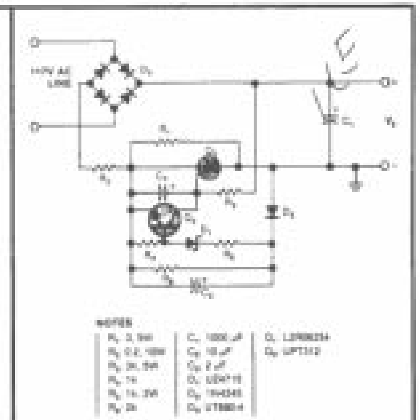

Fig 5—SCR soft starting bypasses the current-limiting resistor (R_1) only when the peak-detected voltage across C_1 drops below the zener breakdown, ie, when C_1 becomes almost fully charged through R_1.

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Switch out the limiting resistor when the inrush is over

timing capacitor C_2 (via R_3). The PUT fires when its trigger point is reached, turning the triac on. Thus, when V_O is initially low, C_2 charges slowly, and the triac triggers on late in the half cycle. As V_O rises, Q_1 turns on earlier in each cycle until nearly 100% conduction is achieved.