

Understanding power supplies and inrush current

New inrush-current-limiting techniques increase the reliability and life expectancy of power supplies

BY MICHAEL ALLEN
Bear Power Supplies
Phelps, NY
<http://www.bearpwr.com>

In ac/dc power converters above a few watts, a large inrush current flows when the input capacitors are suddenly charged during the initial application of power. If unrestricted, the inrush current can easily exceed 50 A at the peak of the ac cycle and severely stress the converter's fuse and input rectifiers—significantly reducing the reliability and life expectancy of the modules.

Power-supply susceptibility

Universal power supplies are particularly subject to high inrush current since their input capacitors must be large enough to handle line voltages as low as 110 Vac, as well as voltages as high as 240 Vac at turn-on. Designers of commercial, industrial, and medical systems need to pay special attention to inrush current. In these environments, a power-supply failure or a tripped circuit breaker can be inconvenient at best, and expensive or dangerous at worst.

Supplies for outdoor use—such as security systems—are typically in remote hard-to-reach locations. Accessing the device to replace a power supply is usually inconvenient and expensive. Industrial facilities—such as manufacturing plants—often have multiple supplies on a line, and the combined inrush current can trip a circuit breaker.



New inrush-current-limiting techniques can protect power supplies from early failure.

The result is unplanned downtime that can be extremely expensive—up to 30% to 40% of profits, according to a recent study.

Large inrush currents

A typical power supply (see Fig. 1) has lumped equivalent impedance R_1 from the common-mode choke, bridge rectifier, line cord, and wiring. This is typically a few ohms.

C_1 is used for EMI filtering and is usually around 0.1 μF . It does not hold enough energy to present much of an inrush-current problem. C_2 , the bulk storage capacitor, can be many

hundreds of microfarads and is usually sized to meet a minimum holdup time and ripple-current rating.

This figure shows that if the switch is closed near the top of the ac cycle, a large input current can occur, limited only by R_1 , making it quite possible to get an inrush-current spike of 50 A or more on a nominal 120-Vac line (170 V peak). In countries where the nominal line voltage is 240 Vac, the inrush current can exceed 100 A.

This large inrush current degrades the performance and lifetime of the power supply in a number of ways:

- The sparking of the switch contacts leads to premature switch failure. It can also cause the line circuit breaker to trip, especially if there are multiple power supplies on the same circuit.
- The current can thermally overstress the input rectifiers, causing immediate power supply failure.
- High currents on the fuse cause heating, which can slowly degrade the fuse over time.

Power-supply manufacturers use one of several inrush-current-limiting

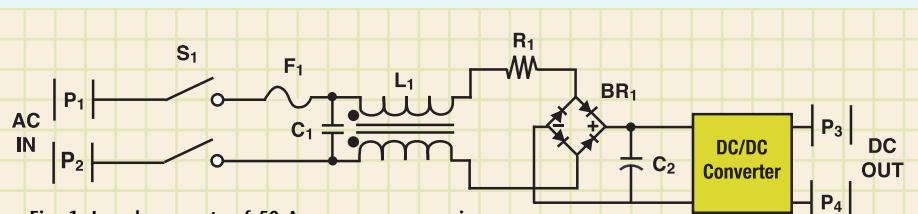


Fig. 1. Inrush currents of 50 A or more are possible on a 120-Vac line if the switch is closed near the top of the ac cycle.

techniques to avoid these problems. The method used can tell the power-supply buyer a great deal about the quality and reliability of the supply.

Resistor in series with line

For very small power supplies—a few watts at most—adding a resistor in series with the line is a simple and practical solution to limit the inrush current. The large resistance required to limit peak inrush current causes too great a loss in efficiency to be used in higher-wattage power supplies.

Series NTC resistor

Many power-supply manufacturers use a negative temperature coefficient (NTC) resistor in series with the line. An NTC resistor offers tens of ohms of resistance when cool, dropping to less than one ohm as its temperature increases.

If the power supply is cool when turned on, the NTC provides good inrush-current limiting. Its effect on efficiency is reduced as the power supply warms up. However, this approach is not effective over large temperature extremes.

A power supply used outdoors in the northern winter may never warm up enough for the NTC's resistance to drop. Conversely, a supply in the hot summer sun will be very warm even with the power off, so that the warm NTC resistor will fail to provide adequate inrush-current protection on startup.

An NTC resistor can also be problematic when a user turns the system off and then immediately switches it back on. The capacitor voltage may drop, but the NTC resistor will not cool quickly enough to provide inrush-current protection.

Parallel electronic switch

Placing a relay or electronic switch in parallel with either a resistor or NTC can offer high impedance only at startup. The supply manufacturer must ensure that the switch is turned on even at low line conditions so that the resistor does not burn up during brownouts.

Series electronic switch

All three of the above techniques require a resistor with at least a 5-W power rating in order to charge C_2 in a reasonable time without failing. For

example, a 25- Ω resistor would be needed to limit the current to 15 A peak at a high universal line of 265 Vac (375 V peak).

The instantaneous power in this resistor would be over 5 kW. A larger-value resistor would have less peak power, but would take longer to charge C_2 , resulting in the same dissipated energy. These high-wattage resistors are large and expensive, adding bulk and cost to the power module.

New current-limiting technique

A new patent-pending technique for inrush-current limiting consists of an electronic switch in series with C_2 . A control circuit uses zero-crossing techniques to monitor the ac line and turn on the power supply only when the input line is low. C_2 will then charge in a quarter cycle, limited by the rise in voltage of the ac line.

This technique effectively limits the inrush current to about 8 A. It does not require high-wattage resistors, enabling smaller power modules. It is effective over a wide operating temperature range (-40° to 70°C) since it does not employ an NTC resistor.

This new technique is most effective in supplies less than 500 W. At higher power, charging C_2 in a quarter cycle still results in a fairly large inrush current. For these larger supplies, a switch in parallel with a resistor is recommended.

Inrush-current specs

Higher inrush-current specifications equate to greater stress on the rectifier and lower reliability.

When looking at inrush-current specs, consider the following:

- Is the inrush current rated as average or peak? Many companies specify the half-cycle average inrush current. Peak current is 40% larger.
- Is the inrush current specified only at 120 Vac or 240 Vac? You must consider the inrush current over the real line voltage, which can be as high as 265 Vac in universal supplies.
- Is the inrush-current-limiting technique effective over your entire expected operating temperature range? This can be problematic when using an NTC resistor for inrush-current limiting. ■