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Hot tips on temperature specs

Machine Design
Robert Repas
Robert Repas
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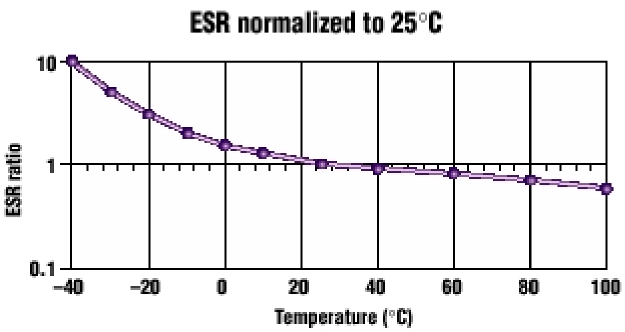
Don't trust what you see on data sheets when choosing power supplies for hot or cold environments.

Brandon Hallen
Bear Power Supplies
Phelps, N.Y.

Power supplies designed with openly spaced components operate at lower temperatures than supplies with tightly packed circuit boards. Lower operating temperatures help extend the life of the supply.

This poorly designed power supply surrounds its storage capacitors with a large heat sink designed to dissipate significant heat. High temps degrade capacitor performance over time, reducing storage capacity and magnifying ripple. Power supplies designed for long life have capacitors sitting away from heat sinks and other high-temperature components.



Effective series resistance, or ESR, of capacitors rises as temperature falls. High ESRs reduce storage capacity while boosting ripple in the output of the capacitor. A supply that meets specifications at room temperature may fail to reach them at -20°C.

The process of choosing ac/dc power supplies involves much more than checking listed ratings against load demand. Designers must consider factors such as the enclosure housing the supply, whether there are other heat sources nearby, and if operation will be continuous or intermittent. Another point to note is over what period of its life the supply must meet specifications for power, noise, and other factors.

The selection process must allow for what power-supply life span means to the end user or the application. For example, inexpensive supplies designed to last perhaps five years at room temperature are probably fine for most consumer use. Industrial users demand much more. They don't want to replace components every five years. They expect reliable operation 24/7, under demanding environmental conditions, for 10 to 15 years or more.

What identifies the "lifetime" of a power supply? Is it how long the supply operates within spec or merely how long it works? For applications such as turning on a motor or powering self-regulating systems, it's probably enough that the power supply just keeps working.

On the other hand, power supply noise can degrade system performance in sensitive applications such as those found in telecom and sensing. These supplies must generally stay within spec for power output, noise, and ripple over their entire lifetime.

Of particular concern is capacitor degradation from high temperatures. Higher output-voltage ripple can hamper system performance long before the supply puts out less power or fails.

To make matters worse, engineers can't always take manufacturer temperature ratings at face value. Fine-print conditions — such as any required derating, airflow, or heat sink needs — still make temperature ratings nothing more than design engineer opinion. It's a best estimate of the maximum temperature at which the supply can run while still giving a reasonable life span.

SPEC'ING TEMPERATURES

There are two factors that determine the maximum operating temperature of a power supply. The first is unequivocal: It's the temperature at which one or more components will instantaneously fail. This is a function of such qualities as the maximum semiconductor temperature, the melting point of the solder, or the temperature at which insulation fails. Exceed this temperature for long, and the supply will suddenly stop working.

The second factor determines the listed temperature ratings and is more subjective. It involves how key components such as bulk storage capacitors gradually degrade. Power supply designers start by determining how long they should reasonably expect the supply to last under normal conditions. The rate of degradation greatly depends on temperature, so they choose capacitors with size and temperature ratings to get the desired life expectancy.

The problem lies in the terms "reasonably" and "normal." The meanings of these words are in the eyes of the beholder — or the spec writer. Power supplies should work for some time at maximum rated temperature. But that is no guarantee of supply lifetime under what some users might consider "normal" conditions. And it may not meet some engineers' idea of "reasonable."

Is it possible to use the manufacturer's mean time between failure (MTBF) to get an idea of how long the power supply will last? The simple answer is, "No." When MTBF is specified, it is usually to the MIL-HDBK-217 standard for ground benign conditions or the Bellcore spec "Ground, Fixed, Controlled GB, Pe = 1.0." This means nearly zero environmental stress: nonmobile, temperature and humidity controlled environments without shock and vibration. In other words, it's not even close to the environment a unit sees in a factory or outdoors.

The MTBF expected at 25°C may bear little semblance to the MTBF the unit sees when running at 45°C or higher. Good MTBF at room temperature does not necessarily translate to good MTBF at higher temperatures. That depends on the power-supply design. Two supplies with the same MTBF at 25°C may give radically different results at 45°C.

THE DERATING GAME

Prevailing wisdom says to derate power supplies operating at higher temperatures. This comes from experience: Engineers have learned that you can't reliably get more than 10 W or so from a 15-W rated power supply under anything but ideal conditions.

It's a given that any supply runs cooler and, therefore, more reliably at less than full load. Unfortunately, there is no useful rule-of-thumb derating equation or rule. As with MTBF, power supply performance depends heavily on power supply design. If you need 10 W at 30°C, a 20-W supply from one manufacturer may be just as reliable or even more so than another's 30-W supply.

Some manufacturers list their high-end temperature spec with the footnote "derating required" or provide derating curves. Some supplies are rated only for their maximum output with either a specified airflow across them or attached to a specified heat sink. Other manufacturers list temperature specs at full load and half load. Again, these specs are a matter of the manufacturer's opinion about "reasonable" life expectancy at the given temperature.

When engineers can't rely on temperature specs or MTBF, they should look at the power supply itself. When the cost of downtime or maintenance of the system is high, it's typically worth the extra time and expense to get evaluation units of the supply for testing.

There are some recommended procedures when placing a supply under test. First turn it on and let its temperature stabilize. Then, carefully measure the temperature on the transistors and diodes using a thermocouple or IR thermal probe. Needless to say, exercise caution around power converters — they are high-voltage devices! The lower the temperature on these sensitive components, the longer they last.

At first glance it appears measurements of temperature rise should take place in the planned enclosure under the anticipated load. But you can get reasonably good information from tests at room temperature in the lab. Temperature rise will be fairly linear: A 40° rise starting at room temperature closely translates into the same 40° rise starting from a hotter baseline in an enclosure.

Next, if possible, look at the design and construction of the supply. Items to note include component rating limitations and physical layout of the parts. A simple visual check of some power supplies reveals they may not last long at high temperatures.

For example, look at the location of capacitors in relation to other heat sources. As mentioned earlier, the rate at which electrolytic capacitors wear out depends heavily on temperature. Many poorly designed power supplies have capacitors sitting right next to devices that radiate large amounts of heat. Power-supply designers concerned with long life and reliability place the caps as far as possible from major heat sources.

Also check the physical size of the capacitors. Bulkier capacitors tend to last longer then smaller units. Don't forget to look at the temperature rating on the capacitors and other components. If two different supplies have roughly the same temperature rise in performance tests, the one with higher-temp parts will last longer. While initially higher priced, it may cost less in the long run.

DESIGN CHOICES

Power-supply designers can make several choices that let supplies run cooler and, thus, more reliably. For example, larger, higher-rated capacitors and larger wire reduce generated heat. More-sophisticated circuit designs, such as synchronous rectification, greatly affect efficiency and thus temperature rise. Large heat sinks keep semiconductor junctions cool. However, anything that makes a supply run cooler adds cost.

Manufacturers specializing in commercial and industrial power supplies generally use high-quality components and advanced design techniques to minimize power dissipation. These supplies are more expensive than consumer-grade systems, where cost is the primary concern. But the added cost is worth it for systems in high-volume production lines or mounted in hard-to-reach locations. Measures that double the life of a power supply usually cost only about 10% more.

Anything that keeps down the temperature of the enclosure reduces power supply stress, improves reliability, and extends system life. One simple means towards this end is to choose supplies that run cool. Another method is to radiate heat to the outside.

For the most part, designers of outdoor or industrial equipment must assume that the power supply will use convection cooling in an enclosure. Active cooling is often not an option because of the expense, noise, and the addition of another possible failure mode to the system. So it's best to use enclosure materials that allow good heat dissipation. Aluminum is the best choice while plastic is the worst. Add cooling fins or air vents if feasible. Encapsulated supplies offer additional protection from dust, debris, and moisture if the enclosure has air vents.

While not perfect, attaching the power-supply heat sink directly to the case may help remove more heat.

Supplies sitting outdoors can see extreme cold that can wreak just as much havoc as heat. Here the problem is the supply's ability to start up and perform to full capability. Northern climates expect outdoor systems to operate reliably down to -40°C.

Output ripple voltage is always higher at cold temperatures. As temperature drops, the effective series resistance (ESR) of the dielectric material in the capacitors rises. At -40°C it may be 10 greater than the ESR at room temperature. This limits power output and jacks up noise and ripple, reducing system performance.

A key factor is the performance of the power controller ICs. While some are specified down to -40°C junction temperature or lower, many are only rated down to -25°C. There is no guarantee components will operate below their specified temperatures. For example, one commonly used three-terminal regulator in commercial power supplies was specified for use to 0°C. It would not even start below that temperature.

When designing systems for subzero temps, it's a good idea to discuss the application with the power-supply manufacturer. Make sure they specify operation at those extremes and always test evaluation units to verify their claims. Do not assume the supply works properly at low temperatures just because the manufacturer claims it will.

It makes sense to look beyond manufacturer-published ratings to find supplies that will last many years. By examining the temperature rise and construction of several different supplies, engineers are more likely to find the right supply that has the life span for outdoor and industrial equipment.

MAKE CONTACT
Bear Power Supply, (315) 548-5000, bearpwr.com

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