

GE
Critical Power

Conduction-Cooled Fanless Power Supply Units – The Why & The How



Abstract

Two contradictory requirements pose significant challenges for power supply unit (PSU) design engineers: first, the constantly growing output power requirement; and second, the need to shrink the form factor of the PSU. Higher output power increases the heat generated by the PSU, but tighter and more compact enclosures often constrain the choice of a thermal management method.

Of course, many applications have been able to direct air flow from fans onto the hot surfaces of a PSU to remove heat via forced air convection. However, fans are not appropriate for all applications since they tend to have lower Mean Time Between Failure (MTBF) and hence they are less reliable than the electronics they cool. In outdoor applications, dust accumulation and harsh operating conditions can also limit a fan's reliability considerably.

For applications where fans are not feasible, conduction cooling is a likely solution. Conduction cooling, which is sometimes referred to as fanless cooling, dissipates heat from a PSU with heat sinks, cold plates or other similar techniques. The heat removal medium employed in a conduction cooling subsystem could be air, water, oil, metal or special liquids. One example of a conduction-cooled fanless front end AC-DC PSU is GE's CCR0512, which dissipates heat via either a heat sink or cold plate.



1.0 Introduction

When Moore's law predicted that the circuit density of semiconductors would double approximately every two years, few realized its implications on PSU efficiency ratings and cooling requirements. A doubling of load current actually quadruples the power loss (I^2R) of a PSU. This dramatic increase in the power loss can take a toll on the efficiency of a power supply. The rule of thumb is that about 30 percent of power loss is inherent in the AC to DC power conversion¹. Figure 1 shows that the efficiency of a PSU increases as its output load rises, but only up to a certain point, after which a higher output load will decrease the PSU's efficiency due to power losses.

Decreased output power efficiency means more heat is being dissipated by the PSU, which in turn must be removed by effective cooling mechanisms. The cost of thermal management has become so great that in some applications, such as a one unit height (1U) server data center, the annual cost of cooling a server is approaching its procurement cost².

This situation challenges the industry to innovate highly efficient power supplies and cooling technologies that will play critical roles in the movement toward so called 'green' information technology (IT) datacenters (Green IT). At the same time, these innovations are expected to reduce the capital

expenditures (CAPEX) and operating expenses (OPEX) of datacenters as well. Assisting in this movement are various industry initiatives such as 80 PLUS™, an independent and voluntary program which certifies PSUs that are at least 80 percent power efficient at 20, 50 and 100 percent of load.

2.0 Power Supply Cooling Technologies

The three basic types of cooling technologies for a PSU are:

- Active forced air convection
- Passive natural convection
- Passive conduction

The typical application of active forced air convection involves mechanical fans that drive air at a constant or variable speed across a hot surface, such as the transformer heat sink of a PSU, to remove the heat. The size and air flow capacity of a fan-based cooling application will depend on the requirements of the PSU being cooled. In some applications, diverters, which target the air flow directly onto the heated components, will increase the fan's heat removal efficiency.

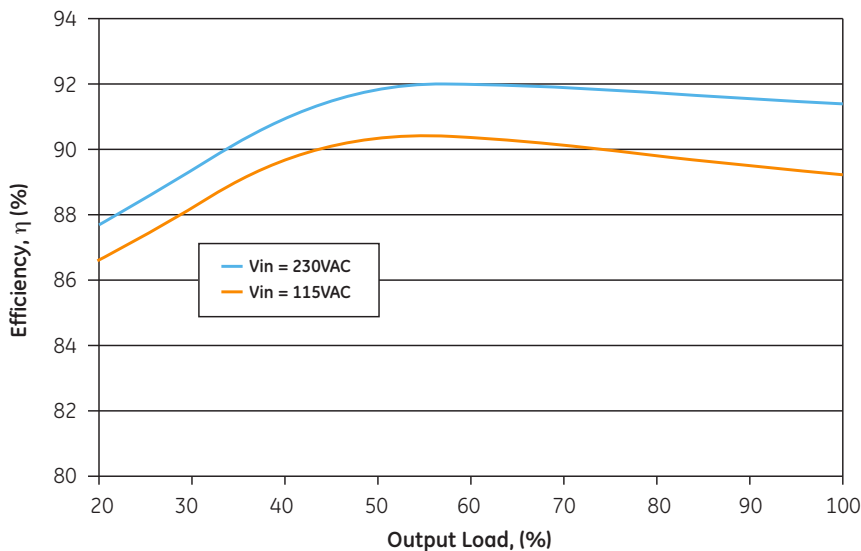


Figure 1: PSU power converter efficiency vs. output load

The main restrictions on the deployment of fans in cooling applications stem from their mechanical nature. That is, their moving parts raise reliability, noise and vibration issues. Because of the likelihood of failure, fans are typically replaced at regular intervals. Otherwise, a failed fan could lead to serious damage to the electronics. In some applications, such as hospital and medical equipment, the noise generated by a constantly whirring fan motor is unacceptable for patients and staff. In scientific and research laboratories, where highly precise measurements are collected, fans cannot be implemented because the vibrations and noise from their mechanical parts might interfere with the lab's precise measurements. Fan speed control techniques that actively slow down the fan under conditions of lower output power and/or lower ambient temperatures can help in such situations.

Passive natural convection relative to cooling PSUs usually involves an open air rack of some sort where the natural movement of air across electronic components adequately removes excess heat. Passive refers to the absence of fans or other mechanical means to facilitate the movement of air or other cooling media through the system being cooled.

Passive conduction is another thermal management methodology that does not involve fans either, but it differs from convection insofar as heat sinks, cold

plates and other means are brought into contact with the hot surface. The heat is conducted through the colder material and away from the PSU or other electronic components.

Neither of these passive cooling technologies requires fans. In fact, by definition they exclude mechanical means of cooling. Some specific examples of fanless conduction cooling follow:³

2.1 Heat Sinks

A heat sink typically consists of a metal attachment which is connected to the PSU or other component that is dissipating heat. The metal in the heat sink will conduct the heat away from its source. Once the heat has migrated by conduction, it could be removed from the heat sink through natural air convection or other means. When designing such a system for thermal management, the engineer must ensure that the heat sink is in contact with the PSU. Heat sinks, while simple, can take up valuable physical space that might be better utilized for other purposes.

2.2 Heat Pipe

The basic heat pipe consists of a pipe with a circulating liquid. One end of the pipe is in contact with the hot surface. The liquid in the pipe vaporizes from the heat being dissipated by the PSU. When the vaporized liquid encounters a cooler surface in the pipe,

it condenses back into its liquid state and recirculates through the cooling system. Heat pipes can be effective in carrying heat away from the heat source to a heat transfer mechanism.

2.3 Cold Plate

Cold plates rely on a fluid, either water or some other refrigerant, to remove heat. Typically, the cold plate would have small pipes in metal casings embedded beneath the surface of the plate. When the refrigerant liquid moves through these pipes, they remove heat from the surface that the plate is in contact with. Once conducted away, the heat can be transferred away from the cold plate through natural air convection or other means. This sort of thermal management system is very effective.

2.4 Ionic Wind

A convection method, the so called ionic wind cooling system, is based on the fact that air will move between two electrodes. This moving air will remove heat. The advantage of an ionic wind system over fan-based convection cooling systems is the ionic wind system has no moving parts to wear out, become unreliable, and cause noise and vibration.

2.5 Submersion Liquid Cooling

With this sort of cooling system, the PSU or the entire system is submerged in an electrically inert fluid. Submersion liquid cooling systems provide excellent convection properties and also protects electronic components from humidity and water damage.

3.0 A Conduction Cooled Fanless AC-DC PSU

An example of a conduction-cooled fanless PSU is the CCR0512 from GE's Critical Power business. The CCR0512 is a 12 volt/500 watt output AC/DC front end PSU with hot plug and redundant load sharing capability (See Figure 2). It is only 0.5U tall and offers flexibility and space efficiency. A heat sink or cold plate can be attached to conduct heat away from the unit. Figure 3 below shows the output power performance of a CCR0512 equipped with a 0.6-inch horizontal heat sink. As would be expected, increasing ambient temperatures and lower levels of air flow as measured in linear feet per minute (LFM) will cause a derating in the output power of the CCR0512.



Figure 2: CCR0512 with Horizontal Heat Sink

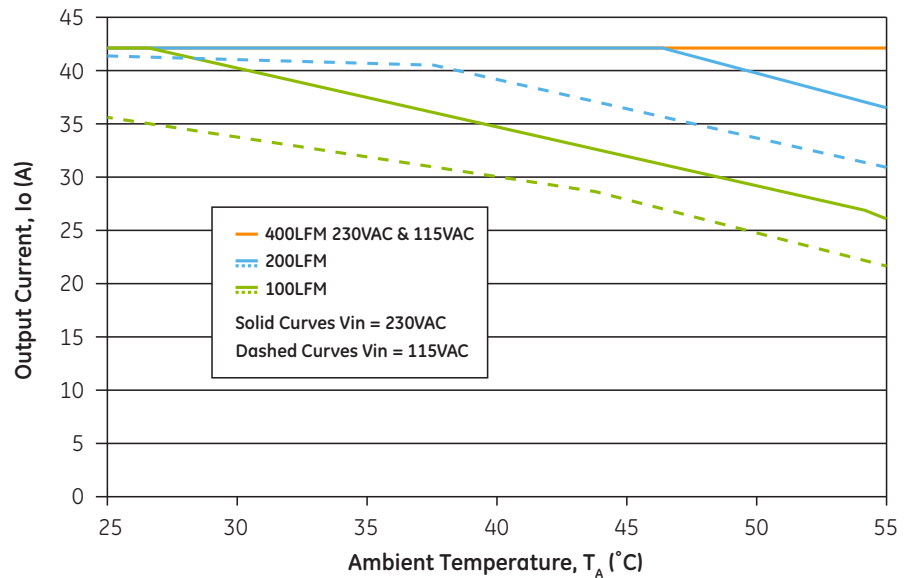


Figure 3: Derating output current versus airflow and ambient temperature, 0.6" horizontal heat sink, front to back airflow.

The CCR0512 is well suited for a number of applications, including:

- Medical equipment where fan-generated noise would not be acceptable
- Lab equipment where sensitive instruments might be affected by noise and vibration
- Outdoor applications such as signage, score boards and lighting systems where fan failures would jeopardize system operations
- Any sort of system in an inaccessible location where replacing fans is very difficult

- Applications that use the PSU in a fully sealed enclosure, such as those conforming to the Ingress Protection Code (IP67), which provide no access to the PSU or fan

For more details on the CCR0512 and to order samples, heat sinks and an evaluation board, click here: <http://www.geindustrial.com/products/embedded-power/ccr>. A datasheet on the CCR0512 is available here: <http://apps.geindustrial.com/publibrary/checkout/CCR0512?TNR=Data%20Sheets|CCR0512|generic>.

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4.0 Conclusion

The continued progress of the electronics industry presents many challenges, including how to effectively cool PSUs which are constantly increasing in power density. In many applications, conduction cooling technologies and methods are required because fans and forced air convection are not acceptable. In many other applications, such as Green IT datacenters, conduction cooling has become essential in the reduction of CAPEX and OPEX. No doubt the role of innovative PSU solutions which employ conductive cooling like GE's CCR0512 rectifier will expand in significance as the industry continues its progress.

5.0 References

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