Power Systems Design: Empowering Global Innovation

Power supply failure survey – Part II

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Capacitors are examined for their contribution to the failure rate

In this second article about power supply failures, the capacitors are examined for their contribution to the failure rate. The causes of failure for different types of capacitors are discussed. In the last part of this article, the question was asked of group members "Why do power supplies fail?" and the results of the survey are repeated in Figure 1 below.

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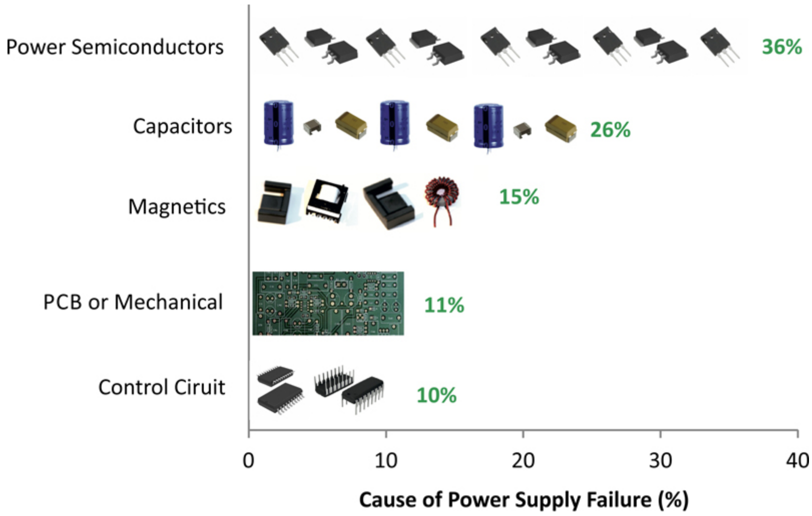

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Figure 1: Survey Results for the Cause of Power Supply Failures

The survey group saw semiconductors as the main cause of failures, and this was discussed in the last article of this series. Second on the list are capacitors. In this article, we will look at the issues that cause capacitor failures.

Power Capacitor Failures

While semiconductors topped the list of failures, they are usually very well documented components. Avoiding semiconductor failure is usually a matter of keeping voltage, current, and thermal stresses below the published limits in the datasheets. Capacitors have many different failure mechanisms. Overvoltage will cause failure for some types of capacitor, but the current rating is greatly variable. Current-carrying capability is dependent upon the type of capacitor, lifetime required, package, environment, and many other factors. Designing a capacitor into your power system and maintaining reliability over the long term is a challenging task in many applications. It is important to devote proper time and care to the selection of parts.

Figure 2 shows the results for the causes of capacitor failures. These are summarized as follows:

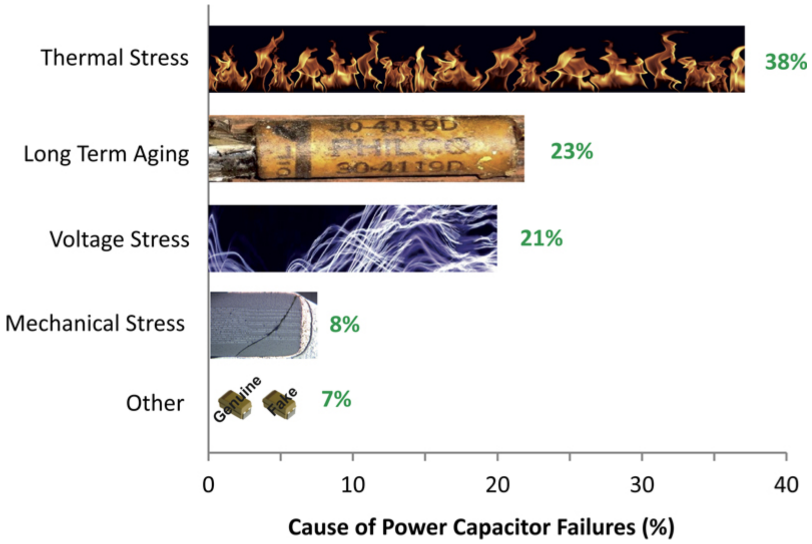

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Figure 2: Survey Results for Causes of Capacitor Failures

Thermal Stress: 50%Top of the list, perhaps surprisingly, is thermal stress. Many designers have learned over years of experience that capacitors will fail if kept too hot for too long. Since capacitors are usually in the vicinity of hot semiconductors, they are frequently exposed to temperatures well in excess of ambient. In optimizing high-frequency board layout, it is important to keep current loops small and tight. This implies that the capacitors must be kept as close as possible to the power switches. This also exacerbates the thermal problem.

Long-Term Aging: 23% Second in the list is long-term aging. This comes from experience with predominantly electrolytic capacitors which dry out over time, especially when placed in a hot environment.

Voltage Stress: 21%Depending upon the type of capacitor, they can be relatively tolerant of overvoltage events. Once again, electrolytics have dominated our industry until recently, and they usually come with a surge rating that lets you briefly exceed the voltage rating. Some of them will even recover after a failure. Other capacitor types are usually much less tolerant of overvoltage.

Mechanical Stress: 8%Much lower on the list is mechanical stress. This can apply to any type of capacitor.

Other: 7%A multitude of reasons make up the last category. Included in here is the same problem seen with semiconductors – counterfeit parts.

Power Capacitor Types

To understand the statistics for the failure mechanisms of Figure 2, it is important to split the capacitor failure problem into the different types of capacitor technology. A second part of the capacitor failure survey was run to ask which type of capacitors are most likely to fail. The results of this are shown in Figure 3.

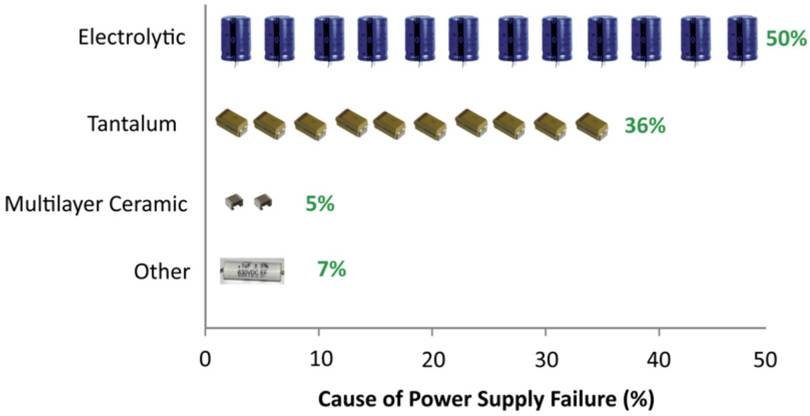

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Figure 3: Survey Results for Type of Capacitor Most Likely to Fail

Electrolytics: 50% Electrolytics are used more than any other type of capacitor, so not surprisingly they experience the most failures. The biggest problem with electrolytics is maintaining the electrolyte inside the component. Great advances have been made in technology to provide longer lifetimes and better seals. Ultimately, however, high temperatures inside the capacitor due to ambient temperature or high currents will cause loss of electrolyte over time. When enough loss has occurred, the ESR of the capacitor rises, temperatures climb further, and the part will eventually fail.

Tantalums: 36%Tantalum capacitors are an interesting case study in the power supply industry. Most engineers in our industry have heard the expression that you “need to let the smoke out” of power components—a humorous reference to failed components. One of the LinkedIn group attendees made the wry observation that with tantalum capacitors, you need to “let the fire out”. This refers to the rather alarming fact that the failure of a tantalum can be a very dramatic event that will incinerate other components and board material in the vicinity of the failed tantalum part.

What is even more alarming is that most designers feel that tantalums should be heavily voltage derated, as much as 50%, if the parts are to be reliable. Some manufacturers even go as far as derating the nameplate rating deliberately by this amount in order to get ruggedness. Other manufacturers will suggest putting large current-limiting resistors in series with the capacitors, which of course defeats the purpose of using them in a power environment in the first place. Despite this, tantalums continue to be used since they provide low ESR without the problem of electrolyte loss. They provide high values of capacitance that multilayer ceramics do not yet match.

You should be very careful if using tantalums for the first time. A 50% voltage derating is definitely encouraged, and you might want to check with experienced engineers to find out which manufacturers make the most rugged parts. The vagueness of exactly how to use and derate tantalums safely is something that probably would not be tolerated in any other type of component, and certainly not in semiconductors. The data sheets simply do not provide enough information to avoid all the hazards.

Multilayer Ceramics: 5%There are two main reasons for failure of MLC capacitors. First, is overvoltage, for which these capacitors have no tolerance. Always stay below the stated voltage rating. Large MLC capacitors are used frequently these days in high power applications. The big packages suffer from the problem of mechanical stress since they are not flexible. Special mounting techniques have been introduced by manufacturers to relieve stress on the large parts. Anything above a 1210 package must be mechanically designed for its proper mechanical and thermal stresses.

Other Types: 7%There are many other types of capacitors, usually used in high-power or specialist applications that can lead to various types of failure modes. Mechanical stress is often high on the list of causes.

Summary

The survey results in this article highlight the major causes of capacitor failures in switching power supplies. There are no perfect capacitors. Tantalum, electrolytic, and multilayer ceramic capacitors all have their own unique ways of breaking down. Each of them must be carefully considered when they are used in power environments.

Much research continues to be done by capacitor vendors to improve their parts, but failures still continue to be a significant problem. There are many other considerations to capacitor application not mentioned in this article, and it is recommended that you study datasheets and application notes very carefully during your design.

Ridley Engineering

References

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[3] Power supply workshops and training www.ridleyengineering.com/workshops.html