Happenings

by Tom Keim

Electrolytics and Film Capacitors Continue to Evolve

Power electronics engineers know that the most important component in a modern power conversion device is the solid-state switch. The properties of this device have widespread impact on the performance achieved in any converter, and advancements in the capabilities of new switch products are widely reported and closely followed. However, filter capacitors are also important components. In fact, much of the volume of any converter is normally taken up by these components and still more is given to other parts that serve to keep these components cool. Indeed, a considerable part of the design process for a converter is devoted to the selection and application of filter capacitors.

While advancements in power switches seem to occur continuously, and improved products are routinely developed as a result, capacitors currently appear very similar to those built 30 years ago. A closer look reveals an appearance to the contrary. The filter capacitors available today are different from those that were available a year ago, and there is ample reason to expect that change to continue. Major suppliers of filter capacitors have substantial product-development capabilities and regularly introduce improved products to the marketplace.

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First, consider aluminum electrolytic capacitors. These have been commercially important for as long as anyone can remember, and for many applications, they remain the least expensive solution. The basic process for making the oxide-coated foil has undergone continuous, incremental development for decades, and while this enhanced technical ability does differentiate the products on the market today from those of ten years ago, suppliers are using other techniques to expand their offerings. While most electrolytic capacitors are cylindrical, and noncylindrical form factors are not new, Cornell Dubilier Electronics, Inc., has been combining flattened foil construction and improvements, i.e., welded seals to introduce hermitically sealed flat packs (including the MLSH line announced in 2016 and the THA/THAS lines announced in late 2017).

Perhaps a more interesting dynamic is the tradeoff developing between aluminum electrolytics and film capacitors for use as the primary filter capacitor in power electronic products. For applications where first cost is of primary concern, electrolytics are often the choice. However, the substitution of film capacitors for electrolytics does not often have to occur on a microfarad-to-microfarad basis. For any voltage, film capacitors can have as much as 50 times higher root-mean-square (rms) current per microfarad, and, where current capacity is a design factor, this can be a major advantage. It may be possible for the film capacitor solution to be substantially smaller and lighter.

Electrolytic capacitors are known to have a more limited service life in comparison to film capacitors. Finally, film capacitors have a well-known self-healing capability, which results in local failures of the dielectric layer being automatically and safely rendered inert. The effect is the opposite of a cascading failure, since, after the event, the only change is a minor loss in capacitance and rms current capability. As with electrolytics, film capacitors are evolving with time (Figure 1). Ron Demcko of AVX reports that higher-quality dielectric films continue to become available, which, over time, could lead to an improvement by roughly 30%. A second, independent advancement may be achieved through the use of innovative packaging. AVX has demonstrated that using nonstandard shapes for the active volume produces an approximate reduction of 30% in active material volume, with a reduction of roughly the same percentage in both equivalent series resistance (ESR) and parasitic inductance. Demcko has suggested that the evaluation of these alternatives is greatly facilitated by the extensive use of digital simulation and modeling.

FIG 1 The (a) film and (b) electrolytic capacitors are both produced in a range of shapes. (Photos courtesy of Cornell Dubilier Electronics, Inc.)

Scott Franco, director of market development at Cornell Dubilier Electronics, Inc., puts some of the differences between these two technologies into perspective. On a microfarad-for-microfarad basis, electrolytics are much less expensive. But in many ripple filter applications, limitations on capacitor current (due to higher ESR and operating temperature limits) result in electrolytic capacitor solutions using many more capacitors in parallel than would be required by the voltage-ripple specification. Also, at bus voltages higher than approximately 600 V, electrolytic capacitors must be put in series, which requires a network of balancing resistors to ensure acceptable load sharing among the individual components. Film capacitors can be made with voltage ratings up to roughly 1,500 V, which eliminates the need to put capacitors in series for many applications. In general, electrolytics tend to be favored at lower voltages and in filters for single-phase rectifiers (where the minimum filter capacitance tends to be larger).

When asked about trends for the future, Franco talked about changes in the range of applications of converter circuits and the impact of these changes on selection of the capacitor, rather than changes in the capability of the capacitors themselves. In applications fed by the grid—which previously comprised virtually all ac/dc converters—filter capacitance had value in terms of increased voltage hold-up during momentary outages, and electrolytics were favored. With renewable energy applications becoming more prominent, being able to ride through a momentary sag is of less value, and the ratings of individual inverter modules are going up, favoring the higher-voltage capability of film capacitors. In remote applications, the longer service lifetime for film capacitors is a major advantage.

These differences between film and electrolytic capacitors are well known, as none of them are the result of any recent innovations. What is different is the range of applications for which power electronics are being used. In a residential battery backup for a desktop computer, first, cost is typically the deciding factor. However, in an offshore application or in a remote, unmanned wind farm, service life may be more important. In a safety-critical automotive application, gentle and observable degradation may be the most important value, while for some military or space missions, minimum weight and/or volume may have the highest value. As previously mentioned, power-handling capacitors in power electronics systems are not a static technology. The rate of change with time does not appear to be as rapid as for semiconductor switches, but the industry seems to be innovative and robust. Converter designers would be well advised to consider innovative options for new designs.

About the Author

Tom Keim (tkeim@alum.mit.edu) is a late-career engineer and a long-time Member of the IEEE. His specialty is high-performance electromechanical systems and the power systems that drive and control them. He has worked for a worldwide conglomerate, for a small (50 employees) innovative research and development company, as well as for a major research university and an engineering consulting company. He has 50 publications and 11 patents and is currently active as an author, inventor, and consultant.

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