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MLCC Shortages—Polymer Electrolytics Can Help

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As many OEMs, plus tier one and tier two manufacturers will attest, the multi-layer ceramic capacitor (MLCC) industry is currently experiencing a significant capacity and supply issue. The last time it was like this was around the turn of the millennium. Manufacturers are putting in capacity, but this takes time to feed through and presents little comfort for manufacturers and engineers dealing with looming line-stop situations, and supply chain managers who are having to seek parts from non-preferred sources.

At times like this, engineers should explore new options and alternative techniques that don't necessitate circuit or product redesigns. Polymer electrolytic capacitors such as Kemet's KO-CAP series capacitors are one alternative that, given certain conditions, can help. Going to polymer electrolytics isn't always trivial, but if certain things align, they can be a viable route to take.

This article discusses the operating conditions under which polymer electrolytics are viable replacements for MLCCs in power supply applications. The KO-CAPs are used as examples, though the same principles may be applied with other tantalum-based polymer electrolytic capacitor series. These guidelines are demonstrated using a buck converter design example.

Background On Polymer Electrolytic Capacitors

KO-CAP is KEMET's tantalum-based polymer electrolytic capacitor. Like any other tantalum capacitor, it comprises a slug of sintered tantalum powder that has a tantalum pentoxide layer grown on it, with a layer of conductive polymer acting as the cathode. This conductive polymer gives the capacitor much lower ESR than "traditional" tantalum capacitors.

For engineers, solving problems is the norm and as is the case with many engineering challenges, making the decision to change from MLCC to polymer electrolytic capacitors is a matter of managing tradeoffs. There are a number of parameters and factors that must be considered when assessing the opportunity to switch capacitor technologies. The main, and most critical ones being: capacitance, voltage, ESR, frequency, leakage current, size, and qualifications.

The flow chart in Fig. 1 can serve as a guide to making decisions when considering each design parameter.

Critical Parameters

Polymer electrolytic capacitors tend to have more capacitance than similarly sized ceramic capacitors. However, they don't come in values smaller than 680 nF. So, if the total capacitance needed is less than that, polymer electrolytic capacitors are not a viable option. When it comes to capacitance, it is usually a very strong value proposition to replace a bank of MLCCs with just one or two polymer electrolytics.

In any tantalum-based capacitor, the dielectric layer is very thin—a typical value being about 20 nm. Having such a thin dielectric gives a large amount of capacitance, but it also has the effect of limiting voltage. A "high voltage" polymer electrolytic capacitor would be anything more than 35 V. In general, if your operating voltage is more than 50 V, a polymer electrolytic capacitor is not a suitable option.

ESR is another important parameter requiring consideration. Ceramic capacitors have lower ESR than their equivalent polymer electrolytic counterparts. That is not to say that there aren't some very low ESR polymer electrolytic capacitors; some even go as low as 8 mΩ, but a typical cutoff of 10 mΩ is adequate.

When considering the frequency characteristics of polymer electrolytics it is the self-resonant frequency which requires close attention. In general, you want to operate capacitors below this point. Although it isn't always the case, if your switching frequency goes beyond 1 MHz, then you may be approaching the limits.

Bias is a simple but not to be overlooked aspect when looking into the viability of an alternative to MLCCs. Polymer electrolytic capacitors are polar devices; therefore, they cannot take reverse bias voltage and be utilized in a location in which reverse bias is possible or needs to be tolerated.

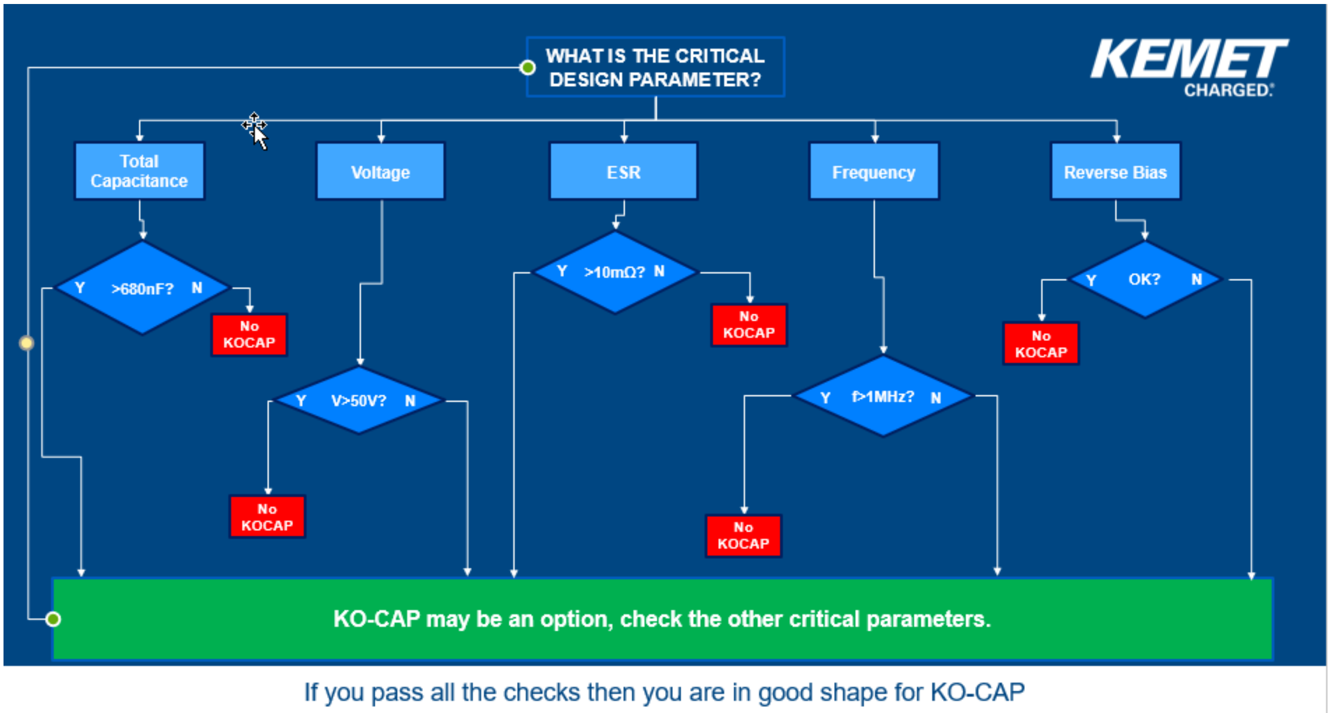

Fig. 1. Flowchart showing the decision tree for replacing MLCCs with KO-CAP tantalum-based polymer electrolytic capacitors.

A Replacement Example

Having considered all the key parameters, let's see how these guidelines for capacitor replacement can be applied in an actual power supply design. The example in this case is a buck converter design for automotive applications, based on the TI TSP54560B-Q1 buck converter IC. The circuit diagram can be seen in Fig. 2.

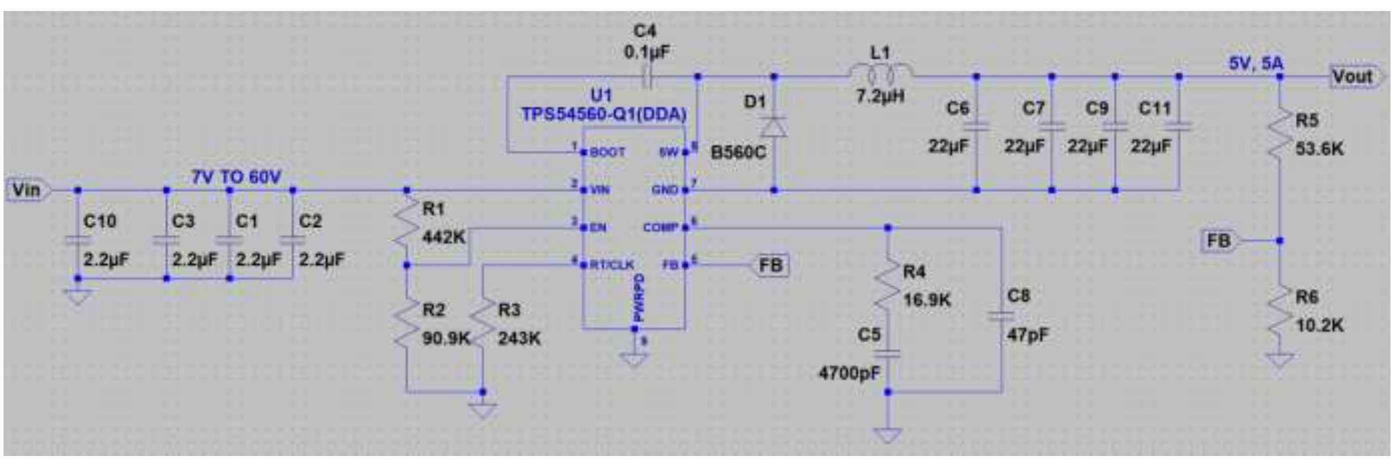

Fig. 2. A buck converter application where MLCCs have become unavailable.

Assuming no availability of MLCCs, using the replacement guidelines we come to the following conclusions.

Input Side

In Fig. 2, C1, C2, C3, and C10 are the input-side capacitors. They are 2.2-µF 50-V 1206 X7Rs. There isn't a drop-in replacement for the ceramics, but it is possible to take the total 8.8-µF capacitance and replace the four ceramics with one 10-µF 35-V KO-CAP. It is more than the original capacitance needed, but it is still within the required range for this regulator. ESR, leakage, and frequency are not of concern on the input side, as long as the input isn't direct battery voltage. A simulation tool such as KEMET's K-SIM can be used to show their side-by-side comparison.

From a cost perspective, the replacement of four MLCCs with a single device will typically yield a significant cost reduction.

Output Side

On the output side, we have C6, C7, C9, and C11; 22-µF 10-V X7R 1206s. In this case, there is a drop-in replacement KO-CAP. It is 6.3 V but that is more than the output voltage range. In this case, the KO-CAP ESR is higher than the ceramic equivalents, but still within the design specification limits. The switching frequency of the circuit is 300 kHz and the series resonant frequency (SRF) of the proposed replacement device is around 1 MHz, so the KO-CAP is acceptable.

In terms of cost, the situation is similar to the input side. That MLCC is nearly twice the cost a KO-CAP replacement, which can save close to 50%.

C4, C5, and C8 are other caps that support the functionality of the buck converter IC. There are suitable candidates for substitution because of both their physical size and capacitance value. However, such low-value MLCCs are not experiencing quite the same supply issues. In this example, leakage current is not discussed very much because that is only a concern in systems that have fixed non-rechargeable batteries.

Conclusion

Finding drop-in replacements for difficult or impossible to source MLCCs is possible but it doesn't offer the same value proposition as replacing a bank of capacitors with a much lower quantity of polymer electrolytic capacitors. Sometimes a review of a problem application will reveal that substitution won't be feasible. But during times of capacity and supply issues, finding solutions through other avenues can be very worthwhile. Not only can it overcome the initial problem, it can bring other benefits too.

About The Author

Wilmer Companioni is technical marketing manager at KEMET Electronics. Prior to joining KEMET, Wilmer worked in both technical sales and design engineering for major mobile device manufacturers.

For more information on capacitor issues in power design, see How2Power's [Design Guide](), locate the Component category and Capacitors.