Considerations When Substituting Polymer and Tantalum Capacitors for High CV MLCCs

By Craig Hunter and Dave Richardson

Across the entire electronics industry, customers are experiencing MLCC shortages, especially for larger case sizes and higher capacitance devices. Under these conditions they are evaluating polymer tantalum and molded tantalum capacitors as alternatives. They are finding a “sweetspot” in circuit applications like filtering and for voltage stabilization. This article covers the evaluation and testing process and provides some necessary tips for a successful substitution.

To insure a successful substitution, we need to look at a few performance differences that result from the use of different materials and construction and then consider some of the parametric differences to see if they are compatible with circuit performance goals.

CAPACITANCE

The most likely MLCC candidates for replacement utilize a “class II” dielectric material. This class II ceramic (typically X7R or X5R) has a capacitance value that will vary over the temperature range. This characteristic is called the temperature coefficient of capacitance (TCC - see Fig. 1).

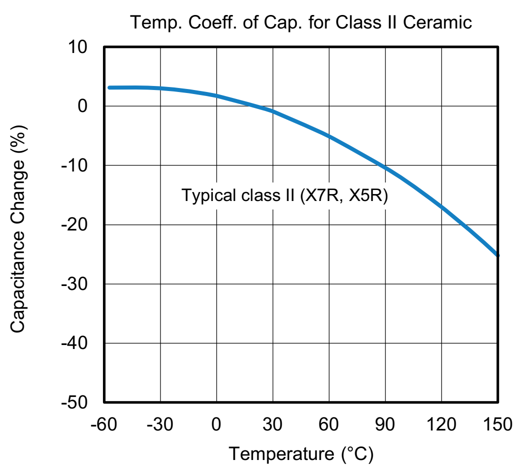

Fig. 1

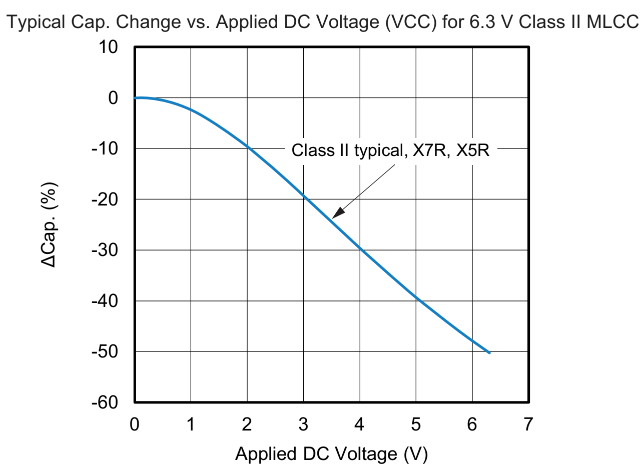

Fig. 2

For a typical X5R device this is ± 15 % from -55 °C to +85 °C.

The class II dielectrics also have a voltage coefficient of capacitance (VCC - see Fig. 2). As the voltage applied to the MLCC approaches the rated voltage, capacitance will drop significantly. These TCC and VCC characteristics are cumulative. So for a class II device operating at +85 °C and near rated voltage, the capacitance could be as little as 30 % of the specified datasheet value.

By comparison, polymer tantalum capacitors do not have a significant VCC effect, and therefore the capacitance value under applied voltage conditions remains quite stable. In addition, the capacitance for these devices actually increases slightly as temperature increases (see Fig. 3).

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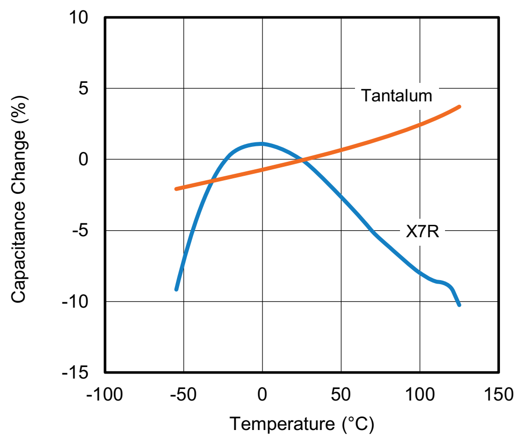

Fig. 3

Overall then, for surface-mount applications that require higher capacitance values like bulk energy storage or power filtering, polymer tantalum capacitors provide superior capacitance performance over MLCCs with similar ratings. In fact, if capacitance is the driving factor in the application, you may be able to replace multiple MLCCs with a single polymer tantalum.

RATED VOLTAGE, DERATING, AND POLARITY

It is generally considered "safe" to run MLCCs up to full rated voltage, though many designers will derate by about 20 % to provide for the VCC effect that yields lower effective capacitance values in the circuit.

Industry guidelines suggest that designers should derate polymer tantalum devices by 10 % for 10 V ratings and below and by 20 % for products rated above 10 V. By comparison traditional tantalum (MnO_2) parts are typically derated by 50 %, but can provide a superior cost solution if they meet the circuit performance requirements.

While polarity is a non-factor for MLCCs, it must be maintained for polymer and tantalum devices. This precludes it from some switching applications where reverse voltage spikes can occur.

EQUIVALENT SERIES RESISTANCE (ESR)

ESR is the real part of the impedance (Z) and incorporates all of the resistive losses in the capacitor. When a signal is passed through a capacitor, energy is lost due to heating effects of the ESR.

MLCCs have a lower ESR than polymer tantalums, where the voltage and capacitance are similar. Lower ESR devices are more efficient at decoupling noise to ground, can handle higher RMS ripple current, and are more effective at delivering momentary high currents. It should also be noted, that very low ESR can sometimes lead to instability in feedback loop circuits.

EQUIVALENT SERIES INDUCTANCE (ESL)

The physical dimensions of capacitors primarily determine the ESL. Long side termination designs for MLCCs have been used to decrease inductance in high speed applications. But overall, for similarly sized devices of "normal" construction, there is unlikely to be a significant difference in performance due to the inductive component.

High speed circuits are an exception where inductive loads may delay the delivery of the required current from the capacitor and therefore impact circuit performance. The effects on impedance (Z) vary with case size and can be seen in Fig. 4.

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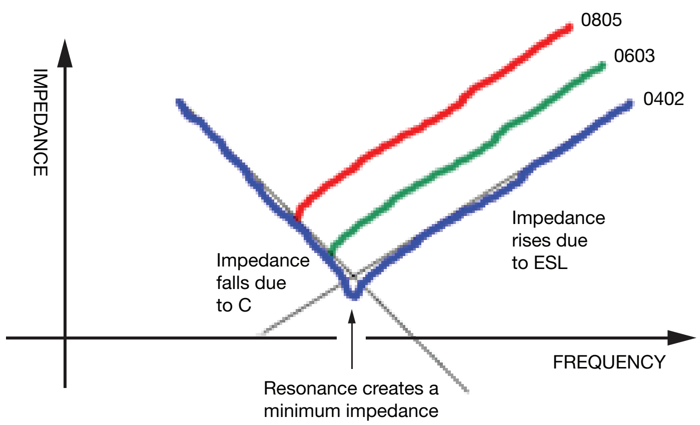

Fig. 4

DC LEAKAGE CURRENT (DLC)

This value is specified differently depending on capacitor type. Rather than get into the weeds, it is reasonable to summarize by saying that MLCCs have a lower leakage current and outperform polymer tantalums by a factor of around five.

SCORECARD AND OTHER RELEVANT INFORMATION

MLCCs offer superior ESR and DCL results and are also non-polarized. So if polymer tantalums are selected, polarity must be maintained on the PCB. Mechanically, MLCCs are more susceptible to cracking when using larger case sizes on boards during the pick and place and assembly process.

High capacitance MLCCs may exhibit a piezo-effect which can result in interference with higher frequencies and “sing” / “whistle” with audible noise making them a poor choice in some DC/DC conversion and audio applications.

Polymer tantalum capacitors provide high and stable capacitance values, which remain virtually unaffected when voltage is applied. But they have higher ESR and DCL than class II MLCCs. Their materials and construction make them less susceptible to mechanical damage through board flexure and high temperature reflow methods.

SUBSTITUTING DEVICES

When making a change, designers should consider:

- Capacitance (TCC and VCC)
- Case size (especially profile height)
- Voltage rating and derating
- Polarization (for polymer and tantalum)
- Dynamic parameters
  - DCL
  - ESR
  - ESL
- MLCC’s and tantalums have similar in-circuit reliability performance so extensive life testing is typically not necessary

To help you get started, below is a quick reference table for that can be used as a starting point for replacing MLCCs with polymer and tantalum MnO_2 devices.

QUICK REFERENCE DATA

CASE SIZE	CAPACITANCE	VOLTAGE	VISHAY POLYMER TANTALUM	VISHAY MnO_2
1608 / 0603	0.68 µF to 22 µF	2.5 V to 50 V	T55 standard range: www.vishay.com/doc?40174 T58 extended range: www.vishay.com/doc?40189	TMCJ: www.vishay.com/doc?40176 298D: www.vishay.com/doc?40065
2012 / 0805	0.1 µF to 47 µF	2.5 V to 50 V		TMCP: www.vishay.com/doc?40179
3216 / 1206	0.1 µF to 220 µF	4 V to 75 V		TMCS: www.vishay.com/doc?40177 293D: www.vishay.com/doc?40002