Enpirion® Power Applications Note

Use of MLCC Capacitors

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Issues to Consider when Using MLCC Capacitors in DC-DC Converters

Multi-layer ceramic chip (MLCC) capacitors are used quite often in dc-dc converter input and output filters instead of tantalum or aluminum electrolytics. MLCC's have low ESR, low ESL, and low cost. They also have no major reliability problems associated with them. All these properties make them suitable for power management applications. There are still, however, some issues to consider when using these capacitors in dc-dc converter circuits. Some ceramic capacitors can lose a lot of their value under certain conditions. This lost capacitance can degrade the transient response of a dc-dc converter, or it can even make the control loop of the converter unstable.

First of all, we only recommend using C0G, X7R, or X5R dielectrics. Since C0G capacitors are not available except for lower values, X7R and X5R become the only suitable choice for most cases. **We strongly recommend against using Y5V or any similar dielectrics in the input and output of a dc-dc converter.** These capacitors will lose up to 90% of their value in many typical operating conditions.

The capacitance per unit volume of the X7R/X5R dielectrics has increased quite a bit in the past few years. However, you should be careful about using the components with the highest capacitance densities. These capacitors lose a lot of their value at the higher frequencies where most dc-dc converter circuits operate. They lose even more capacitance when dc bias is applied to them.

Table 1 compares some typical X7R/X5R capacitor values in various case sizes made by a major manufacturer. We first measured the capacitor value with no dc bias at frequencies >100kHz using a network analyzer, and found the higher the capacitance density, the lower will be the value at high frequencies. Next, we examined the manufacturer's curves regarding the drop in capacitance at dc as a function applied bias voltage, and found again that the higher density capacitor values drop faster with dc bias.

Nominal Cap Value	Case Size	Thickness	Voltage Rating	Measured Value at 0V DC Bias freg>100kHz	% Capacitance Drop (Typical)	
					3V DC Bias	5V DCBias
10uF	0603	0.8mm	6.3V	5.2uF	45%	67%
	0805	1.25mm	10V	7uF	20%	40%
	1206	1.6mm	10V	10uF	5%	12%
	1210	2mm	25V	10uF	2%	5%
22uF	0805	1.25mm	6.3V	12uF	33%	55%
	1206	1.6mm	6.3V	19uF	15%	33%
	1210	2.5mm	16V	19uF	1%	8%
47uF	1206	1.6mm	6.3V	35uF	33%	60%
	1210	2.5mm	6.3V	43uF	12%	28%
	1812	2.5mm	6.3V	47uF	10%	20%

Table 1: Comparison of various ceramic cap values and case sizes

For example, neglecting the initial part-to-part tolerance and temperature effects, a 10uF/10V/1206 capacitor used in the input or output filter of a high-frequency dc-dc converter will actually be 9.5uF at 3V or 8.8uF at 5V. However, an 0805 capacitor with the same value and ratings can be as low as 5-6uF at 3V and 4-5uF at 5V, assuming that the frequency and bias voltage effects are cumulative. This is quite a difference in capacitance from the nominally designed value.

Based on the results shown in Table 1, we believe the optimum footprint for a 10uF capacitor is 1206, and for a 47uF capacitor is 1210. The 1812 footprint works slightly better than the 1210 for the 47uF, but we don't feel the small improvement is worth the added space and cost. For a 22uF capacitor the optimum footprint could be either 1206 or 1210 depending on the application.

Sometimes the designer may just want to get the maximum capacitance in a limited available footprint. If, for example, there is only room for a 1206 capacitor, the 47uF part will still have the most capacitance even if it loses a larger percentage of its value than the 22uF or the 10uF parts. In other applications, the product cost may also impact the chosen footprint. For example, if a 1210, 22uF capacitor is significantly more expensive than a 1206, then the 1206 component may be preferred even with the larger capacitance drop.

The third column in Table 1 shows the thickness (height) of each component. Manufacturers sometimes make the same capacitance and footprint in various heights. This is sometimes done to accommodate different voltage ratings. If the application allows, choose the thickest component available for a given capacitance and footprint. The taller capacitors have thicker dielectric layers that will not degrade as much with bias voltage or with frequency. All the components shown in Table 1 are the tallest available capacitors at the time of this writing.

It should be noted that the conclusions drawn in this design note are based on our measurements and observations on a small sample of parts as of this writing. In fact, the effect of frequency on capacitance cannot even be found in most manufacturers datasheets including the one used in this study. As technology improves in the future, the recommended optimum footprint for a specific value capacitor may become smaller. Nevertheless, the issues raised here will still be applicable, and dc-dc converter design engineers should always pay attention to them.

Contact Information

Altera Corporation
101 Innovation Drive
San Jose, CA 95134
Phone: 408-544-7000
www.altera.com

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