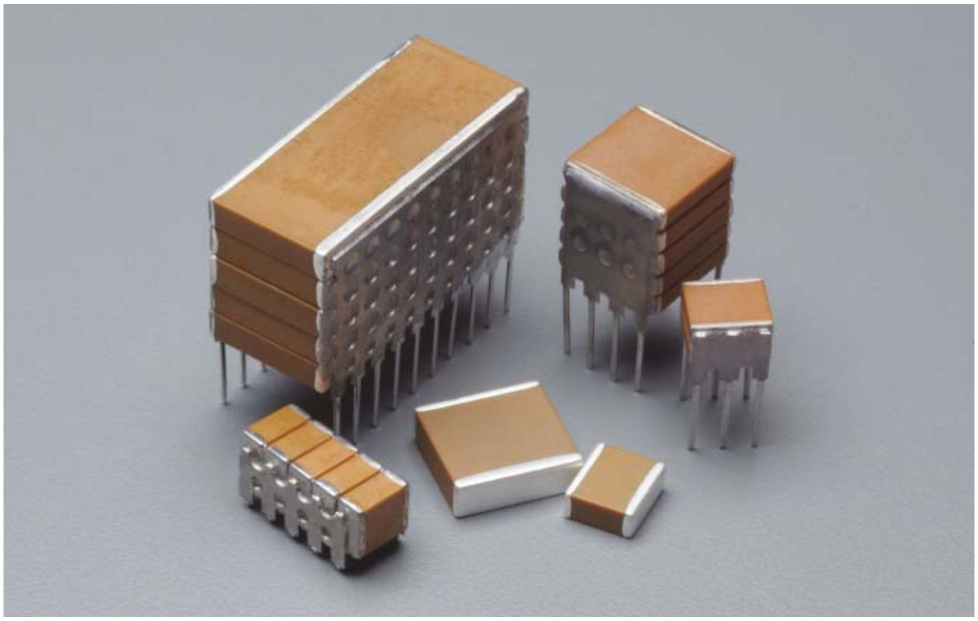
Capacitor Selection for Switch Mode Power Supplies



Ceramic Capacitors

Ceramic capacitors characterize a family of capacitors that utilize a variety of different ceramic materials as their dielectric to achieve a wide range of performance characteristics. These dielectrics offer a sizeable assortment of dielectric constants tailored towards specific applications and some of these K values are extremely high in comparison to other capacitor technologies. It is the ability of these materials to achieve a higher K, along with their capability to increase electrode overlap area thru multilayer designs that allow the device to attain reasonable capacitance levels and compete with other technologies on SMPS applications.

The method for manufacturing these type capacitors requires that the device be fired at high temperatures in a ceramic kiln. Once fired, ceramic is characterized as being an extremely strong material in compression, but with limited strength in tension and as such they may be susceptible to damage when exposed to high mechanical stress conditions. In addition, inherent variations in the coefficient of thermal expansion for materials used to manufacture the ceramic capacitors themselves and differences between the capacitor and the substrate to which it is mounted can, in certain situations, make these types of capacitors susceptible to thermal shock. Acknowledging that these potential concerns exist, there are a number of design and process considerations at the engineer's disposal that can greatly reduce the possibility of introducing thermal and / or mechanical shock to the device.

For SMPS applications the ceramic dielectrics most commonly utilized are EIA-STD-198 defined Class II, stable materials. The most common choice is X7R and properties of these materials do present additional performance considerations that the engineer should be aware of as follows:

- Class II materials exhibit piezoelectric characteristics

- Class II dielectrics exhibit a characteristic called aging, whereby the capacitance value measured after exposure to temperatures above the materials Curie point (~ +125ºC) will decay logarithmically with time. Dielectric aging is generally expressed as a percent per decade hour (i.e. 1 – 10 hours, 10 – 100 hours, 100 – 1000 hours, etc.) and typical values for Class II, X7R materials are in the range of 2% or less. Manufacturers will routinely incorporate a design margin that compensates for aging of the device thereby ensuring that capacitance values for delivered product are sufficiently above the minimum allowable value.

- Class II, X7R materials are sensitive to DC voltage whereby the dielectric exhibits a decrease in dielectric constant and subsequent loss in capacitance when exposed to DC bias. The amount by which voltage can affect the capacitance value can be minimized thru a reduction in the allowable volts per mil loading of the device.

- Class II, X7R materials exhibit dissipation factor readings in the 1.5 to 2.5% range and as such may pose a concern when operated in an AC application.

- Taller capacitor stacks, especially those where their height exceeds the minimum base dimension, or those that exhibit significant mass, may be susceptible to damage in high vibration and shock environments. If exposure to these conditions is anticipated, the engineer may want to consider the use multiple smaller capacitor stacks, an alternate design whereby the height is limited and the footprint is increased and / or the use special mounting techniques.

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Assuming that the mechanical and thermal shock concerns have been properly addressed, ceramic capacitors offer a number of key advantages when compared to alternative technologies as follows:

- Ceramic capacitors exhibit extremely low levels of ESR, which is especially critical for higher frequency applications and generally allows the design engineer to utilize a lower capacitance value when compared to electrolytic, tantalum or film capacitor options
- Ceramic exhibits comparatively low levels of ESL when compared to other technologies

- Class II, X7R materials are non-polar devices and can be connected in any configuration

- Ceramic capacitors are designed for continuous operation at full rated voltage across their entire operating temperature range

- Ceramic capacitors are maintenance free, non-toxic and environmentally friendly

Performance Summary

Characteristic	Ceramic			Film		Electrolytic	
	NPO	X7R	Y5V	Polyester	Polypropylene	Aluminum	Tantalum
Operating Temperature	-55 to +125°C	-55 to +125°C	-30 to +85°C	-55 to +125°C	-55 to +105°C	-40 to +105°C	-55 to +125°C
Dielectric Constant	15 – 150	600 – 5200	7000 – 22000	3.1 – 3.3	2.1 – 2.3	7 – 10	24
DF	0.10%	2.50%	5%	0.35%	2%	8%	20%
•TC	±30 ppm / °C	±15%	+22 / -82%	±12%	±1%	±10%	±8%
ESR	Excellent	Good	Fair	Fair	Fair	Poor	Poor
ESL	Excellent	Excellent	Good	Fair	Fair	Poor	Poor
Frequency Response	Superior	Excellent	Excellent	Fair	Fair	Poor	Poor
Polar	No	No	No	No	No	Yes	Yes
Environmental Concerns	No	No	No	Yes	Yes	Yes	Yes

Summary

Compared to other capacitor options available, ceramic capacitors offer extremely low levels of ESR and ESL and predictable performance characteristics related to temperature, voltage and frequency, making them the preferred choice for high reliability, high frequency SMPS applications. In addition, unlike film and electrolytic options, ceramic capacitors offer a maintenance free environmentally friendly choice.

Please contact APITech Electromagnetic Integrated Solutions for additional information:

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