High Voltage Ceramic Capacitor Testing Protocols

INTRODUCTION

The level of reliability associated with capacitor selection is generally dictated by the intended application in which a capacitor will be used and the associated environmental conditions to which the part will be subjected. These applications can differ significantly, from basic commercial applications, to more demanding industrial, military / aerospace or automotive programs, to system critical space applications. Ensuring that the chosen capacitor matches its intended application is critical to achieving long term success. This application note reviews the more common applications and presents testing protocols most often associated with the governing specifications that exist.

OVERVIEW

Ceramic capacitors are considered to be highly reliable components, which offer a number of advantages compared to other capacitor technologies, and as such, are often employed in a wide variety of extremely demanding applications. That said, like all manufacturing environments, there tends to be a certain amount of variation inherent to the process that will result in differences in the performance characteristics and reliability of each device. In truth, even though a lot of capacitors may have been manufactured at the same time, using the same batch of material, tooling and equipment, no two capacitors within that lot are “exactly” the same. Fortunately, their differences tend to be inconsequential and certainly well within the acceptable limits of the system or application for which they are intended.

So if manufacturing operations for ceramic capacitors tend to produce highly consistent results, why test at all? There are in fact several reasons, not the least of which would be to ensure that the theoretical design meets customer expectations. Secondly, it is important to ensure that some unintended process variable has not inadvertently been introduced to the system, which could alter the anticipated result. Finally, depending on the application to which the capacitors are intended, one may need to consider long term reliability as a factor when contemplating testing options.

For example, commercial applications are much more inclined to weigh cost above all other factors, and as such, might limit inspection to a basic outgoing quality test sequence. On the other hand, Space level, system critical applications are much more inclined to emphasize reliability over price and consequently, these types of requirements often include an extensive inspection sequence complete with In-Process examination, Pre-production Qualification testing, Group A acceptance testing, and ongoing Group B or C retention testing. Other test sequences have been developed for those applications where the required level of reliability lies somewhere between.

This application note outlines industry recognized inspection and test sequences commonly associated with Commercial, basic High Reliability, Military / Aerospace and Space / System Critical applications in which ceramic capacitors are utilized. It should be noted that these recommendations may not be applicable to all situations, and as such, it becomes the engineer’s responsibility to confirm results and make adjustments where necessary to accommodate specific conditions. Additional details can be found by referring to the following specifications which form the basis for this Application Note:

- **AN109-6 –** CalRamic Technologies Capacitor Basics VI – Testing / Screening Requirements
- **MIL-PRF-49467** - Capacitor, Fixed, Ceramic, Multilayer, High Voltage (General Purpose), General Specification for
- **MIL-PRF-123** - Capacitors, Fixed, Ceramic Dielectric, (Temperature Stable and General Purpose), High Reliability, General Specification for

- **GSFC S-311 / S-311-P-829G** – Capacitor, Ceramic, Multilayer Chip, Space Applications
- **EIA-RS-469** – Standard Test Method for Destructive Physical Analysis (DPA) of Ceramic Monolithic Capacitors
- **GSFC S-311 / S-311-M-70** – Specification for Destructive Physical Analysis Capacitors

Common Product Classifications

- **Commercial Grade** – Capacitors intended for Commercial applications usually receive a very basic level of testing, which is intended to insure that there is not an inherent issue within the lot that might otherwise result in a major recall of the OEM's end products. Faced with an extremely competitive market and the need to keep costs to a minimum, acceptability is generally gauged through inspection and test of a small representative sample. Consideration is given to the fact that a small percentage of the capacitors delivered may be faulty, but supplier selection is generally limited to those manufacturers that have a recognized quality system in place and a proven track record for reliability. Typical test requirements for Commercial Grade products include Dielectric Withstanding Voltage, Room Temperature Insulation Resistance, Capacitance, Dissipation Factor and Visual / Mechanical Inspection.

- **Standard High Reliability** – For those customers that require a level of reliability beyond Commercial Grade, capacitor manufacturers will typically recommend a test sequence that now includes Thermal Shock and Voltage Conditioning. This test sequence is performed on 100% of the production lot and has proven to be an effective means of addressing concerns with infant mortality. Capacitors are first subjected to a combination of temperature extremes and elevated voltages, and this additional stress followed by a basic battery of tests, has proven to be a much more effective screen than if the supplier were to simply perform the Commercial Grade test sequence at 100%.

- **Military / Aerospace Grade –** Although Standard High Reliability testing can be an effective means of reducing the risk of infant mortality and enhancing the overall reliability of the capacitors being utilized, the recommended testing protocols are governed by the individual supplier. Selection of a Military / Aerospace Grade device that has been screened to an established DSCC specification levels the playing field by ensuring that the selected supplier meets a minimum industry standard requirement for testing. In addition to an expanded Group A inspection test sequence that incorporates a PDA limit (Percent **D**efective Allowable), these specifications also provide requirements for Qualification testing, and Qualification retention testing (Group B / C).

- **Military Qualified –** Whereas Military / Aerospace Grade products allow the customer to select those tests that they feel are appropriate for their application, selection of a Mil Qualified part takes that decision out of the customer's hands. All MIL grade capacitors which are registered on the Qualified Products List (QPL), are mandated to have been subjected to and passed a preliminary qualification test sequence and once in production, representative samples are selected from subsequent lots of capacitors and subjected to Qual retention testing on a periodic basis. Qualification, through a variety of electrical and environmental tests, establishes that the capacitor meets a baseline level of reliability and periodic Group B / C testing ensures that there have been no changes in design and / or the processing of the capacitor since qualification that might otherwise affect the reliability of the device.

- **Space Level / System Critical Grade** – Space Level Grade capacitors take the reliability of a Military Grade / Military Qualified product a step further. Additional test requirements are intended to provide for an extra assurance that the production build will continue to operate as intended for an extended period of time that could conceivably last for 15 years or longer.

Common Test & Inspection Requirements							
Test Requirement		Commercial Grade	Standard High Rel	MIL / Aero Grade	MIL M49467	MIL M123	Space Level
In-Process	Dielectric Withstanding Voltage	X	X	X	X	X	X
	Insulation Resistance @ +25ºC	X	X	X	X	X	X
	Capacitance	X	X	X	X	X	X
	Dissipation Factor	X	X	X	X	X	X
	Ultrasonic Examination					X	X
	Destructive Physical Analysis					X	X
	Visual Inspection	X	X	X	X	X	X
	Mechanical Inspection	X	X	X	X	X	X
	Terminal Strength					X	X
Group A Inspection	Thermal Shock		X	X	X	X	X
	Voltage Conditioning		X	X	X	X	X
	Insulation Resistance @ +125ºC		X	X	X	X	X
	Dielectric Withstanding Voltage	X	X	X	X	X	X
	Insulation Resistance @ +25ºC	X	X	X	X	X	X
	Capacitance	X	X	X	X	X	X
	Dissipation Factor	X	X	X	X	X	X
	Partial Discharge (Corona)				X		X
	Radiographic Inspection (Encapsulated)				X	X	X
	Visual Inspection	X	X	X	X	X	X
	Mechanical Inspection	X	X	X	X	X	X
	Destructive Physical Analysis					X	X
	Solderability				X		X
Qualification	Low Temperature Storage				X		X
	Solderability				X	X	X
	Marking Legibility (Laser Marking)				X		X
	Voltage – Temperature Limits				X	X	X
	Vibration – High Frequency				X	X	X
	Immersion				X		X
	Shock – Specified Pulse				X		X
	Terminal Strength				X	X	X
	Resistance to Solder Heat				X	X	X
	Moisture Resistance				X	X	X
	Resistance to Solvents				X	X	X
	Humidity, Steady State, Low Voltage					X	X

Common Test & Inspection Requirements							
Test Requirement		Commercial Grade	Standard High Rel	MIL / Aero Grade	MIL M49467	MIL M123	Space Level
Qualification	*Life Test*				X	X	X
	Partial Discharge (Corona)				X		X
	Reverse Polarity						X
	Vibration, Random Frequency						X
	Breakdown Voltage						X
	Equivalent Series Resistance						X
Group B / C Periodic Inspection	Terminal Strength				X	X	X
	Resistance to Soldering Heat				X	X	X
	Moisture Resistance				X	X	X
	Voltage Temperature Limits				X	X	X
	Low Temperature Storage				X		X
	Marking Legibility (Laser Marking)				X		X
	Resistance to Solvents				X	X	X
	Humidity, Steady State, Low Voltage					X	X
	Solderability					X	X
	Vibration, Random						X
	Thermal Shock					X	X
	Life Test				X	X	X
	Partial Discharge (Corona)				X		X