Commercial vs. Hi-Rel Tantalum Capacitors in Space Application

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Space applications require electronic components with long-term stability and reliability, capable of working in harsh environment under severe mechanical shock and vibration like those at launch. Besides electrical and mechanical performance, cost also plays a significant role when choosing electronic components for space application between the commercial, automotive, COTS, and MIL-grade products.

One of the ways to determine the optimal grade of Tantalum capacitors that combine acceptable quality and lower price, is direct testing of the samples of the capacitors by the end-users. When failure rate is compared for the same type of Tantalum capacitors from different manufacturers and impact of the end-user processes on the failure rate is verified, the results of the investigation provide very valuable information on possible applications.[1] Comparison of ac and dc characteristics and mechanical stability in different types of Tantalum capacitors with the same capacitance, working voltage, and size, like Polymer Hermetic Seal (PHS) vs. Wets in [2], is also very informative. At the same time, there are several factors that limit the usage of the results of the end-user testing.

One of these factors is technology. There is broad range of materials, first of all tantalum powders, and processes used in manufacturing of the same type and grade Tantalum capacitors. Working voltage and related formation voltage and thickness of the dielectric are the major reasons for these variations. Besides that, the technology varies with specific manufacturer and the capacitor grade for the same manufacturer. The size of tantalum anodes with the same CV/g tantalum powder and formation voltage also adds variations to the technology because it influences impregnation efficiency for the MnO_2 or polymer cathode. All these variations in materials and processes have strong effect on performance and reliability of Tantalum capacitors and, thereby, the results of the end-user testing. Even the name of the technology can be confusing. For instance, presented by KEMET flawless technology (F-Tech), which provides defect-free dielectric even at highest formation voltages, comprises many processes and analytical steps. Some of them are known to industry and described in open publications [3], while others are trade secrets and not disclosed. Taking some of the steps and missing others won't make it F-Tech unless proven directly on every production batch.

Another limiting factor is end-of-line (EOL) screening. Increasing voltage well above working voltage and/or bake-out at temperatures significantly exceeding normal operating temperatures will "kill" weak parts; however, these extreme conditions can also provoke hidden defects in the dielectric of the good parts making them potentially unreliable. These parts with hidden defects in the dielectric typically are not detected by traditional DCL testing and can fail during the field application. Only BDV test can detect hidden defects in the dielectric, but it's destructive test. At

the same time, simulated breakdown screening, SBDS, allows screening and removal of unreliable parts with low BDV without any harmful effect on the population of the capacitors.[4,5]

One more limiting factor affecting the end-user testing results relates not to the actual capacitor under test, but to the specific conditions used in the testing. In some cases, HALT type conditions can cause failures that never occur at normal operation conditions. For example, according to Catalog T550 series PHS Tantalum capacitors have maximum operating temperature 105 ^{o}C. Exceeding this temperature can cause delamination of the external layers of the capacitor element inside the hermetic can and/or loss of hermeticity. As a result, AC and DC characteristics change during the testing and failures occur. The technology is different in T551 series PHS Tantalum capacitors, allowing long-term application at temperatures up to 125 ^{o}C. At the same time, testing of these capacitors at temperatures exceeding maximum temperatures specified in the Catalogs will damage the whole population of the good parts.

It is assumed, that sufficient de-rating will address reliability issues and allow usage of practically any grade of Tantalum capacitors in space applications. It is true that de-rating reduces failure rate in finished capacitors; though, the effect of de-rating depends strongly on actual technology.[1] At the same time, de-rating approach to Tantalum capacitor technology can be harmful to the capacitor performance and reliability. For example, 50% de-rating requires about double formation voltage and almost 10x increase in the volume and weight of the capacitors in comparison to these without de-rating. Thicker Ta_2O_5 dielectrics produced by higher formation voltage are more prone to crystallization of their amorphous matrix, which is the major reason for catastrophic failures of higher voltage Tantalum capacitors. Much larger size of the de-rated capacitors slows down heat dissipation and can cause thermal run-away and catastrophic failure, while no failures occur in smaller, not de-rated capacitors with better heat dissipation. The way of making reliable and volumetrically efficient Tantalum capacitors is low or no de-rating while combining F-Tech and SBDS.[1]

High-reliability grades of Tantalum capacitors undergo rigorous electrical and mechanical tests during qualification like these in MIL-PRF-55365 for surface mount MnO_2 Tantalum capacitors, while automotive and commercial grades can be qualified with much more limited testing. Additionally, each manufacturer designates their own qualification plans for these capacitors. Besides that, high reliability grades must meet special requirements for every production batch to prove their quality while there are no special requirements for commercial grade Tantalum capacitors. As an example, the Table below shows different special requirements for different grades of surface-mount MnO_2 Tantalum capacitors produced by KEMET.[6]

	MIL-PRF-55365 T-Level	MIL-PRF-55365	COTS	Commercial
KEMET Series	**409/419/429/492**	**409/419/429/492**	**497***	**490/491**
DPA	X			
100% X-ray	X			
Group C Testing	X			
+3 Std Dev Screening	X			
Established Relaibility	B, C, D	B, C, D	B, C	
Surge Current	X	X	X	
Mil Maintenance	X	X		
F-TECH			optional	
SBDS			optional	

*Several COTS series, but 497 has F-TECH and SBDS options.

The PHS Tantalum capacitors are manufactured according to DLA 13030B with F-Tech and SBDS technologies, qualification tests similar to these in Wet Tantalum capacitors according to MIL-PRF-39003, and 5% Percent Defective Allowable (PDA) for Thermal Shock, 240 h Life Test, and Gross Leak (bubble test). Besides that, any new materials and processes introduced to these capacitors require re-qualification. This is an important protection against unchecked changes in technology for the sake of cost reduction or better productivity.

In conclusion, finding high quality Tantalum capacitors for reasonable cost is a challenge. High-reliability COTS, combining the best technology and screening techniques, rigorous qualification tests, thorough quality verification on every production batch, and protection against unchecked changes in materials and processes, can be a good solution for the space application. Usage of the relatively new types of Tantalum capacitors, like PHS instead of Wets, can provide high reliability – low total cost space solution. In comparison to Wet, PHS Tantalum capacitors have similar DCL, BDV, maximum working voltage, and size for given CV, which is unprecedented for any solid Tantalum capacitors developed earlier, but also much lower ESR and, thereby, much higher capacitance stability with temperature and frequency. These differences allow usage of 2-8 times fewer PHS capacitors than Wets for the same electronic solution. Besides that, each PHS Tantalum capacitor has about 25% lighter weight in comparison to the weight of Wet Tantalum capacitor with the same CV. Fewer and lighter components are especially beneficial in space applications where the load weight is a critical part of the total cost. PHS Tantalum capacitors have already been used in space for several years and their numbers in this application are increasing rapidly. No PHS field failures have ever been reported.

References

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