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Advanced Test Methods for Up-screened Tantalum Capacitors

COTS-Plus Discussion

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Commercial-off-the-shelf capacitors are designed and tested for non-critical applications. AVX has developed a range of “COTS-Plus” tantalum capacitors with testing and reliability grading done in accordance with MIL-PRF-55365 and AVX proprietary methods to provide improved reliability on commercial ratings by removing weaker components within the populations. This paper will describe the criteria for selecting ratings appropriate for up-screening and describe the various tests that are standard and optional to demonstrate the improved reliability that results from these screening methods. Standard and “Space Level” options are described and compared to illustrate the scope of the COTS-Plus system.

Introduction:
The term Commercial-off-the-shelf (COTS) refers to the standard catalog components which are available for commercial and industrial applications. This level of component allows for a large amount of flexibility in component design producing capacitors with high capacitance/voltage (CV) ratings with very low ESR characteristics. However; these families are designed and tested in a mass production setting and are generally not geared towards applications which require established reliability. These extended ratings and low ESR options are attractive to designers, but in order to utilize these components in high reliability settings, additional testing needs to be incorporated.

AVX has developed a range of “COTS-Plus” tantalum capacitors with testing and reliability grading done in accordance with MIL-PRF-55365 and AVX proprietary methods to provide increased reliability on commercial ratings. This COTS-Plus methodology has been applied to several different product series over time including standard solid tantalum capacitors (TBJ), multi-anode solid tantalum capacitors (TBM), and niobium oxide capacitors (NBS).

There are many aspects in which the commercially designed ratings differ from the components contained in the military specification MIL-PRF-55365. For starters, the powders used in commercial ratings have much finer particle sizes which translates into higher CV/gram capability. For reference the MIL-PRF-55365 designed components typically utilize powders less than 50kCV/gram, while commercial parts routinely use powders up to 200kCV/gram. Smaller particle size allows for some significant downsizing of existing ratings and a general extension of the capacitance available at a given voltage level. The drawback to these higher CV/gram powders is related to the reduced strength of the connection between particles due to smaller “necks”, and an increased difficulty to depositing the counter electrode material due to small internal pore structures. In addition, the use of high CV powders restricts the thickness of the dielectric layer which may be formed. Commercial components typically have formation ratios which do not exceed 2:1 meaning a 50V component will be formed at 100V. Military components on the other hand will typically approach a 4:1 ratio resulting in a thicker dielectric providing greater reliability in terms of surge current and electric field handling capabilities. This also means that the 50% de-rating recommendation is even more important for commercial grade components since the applied voltage is a higher percentage of the formation voltage.

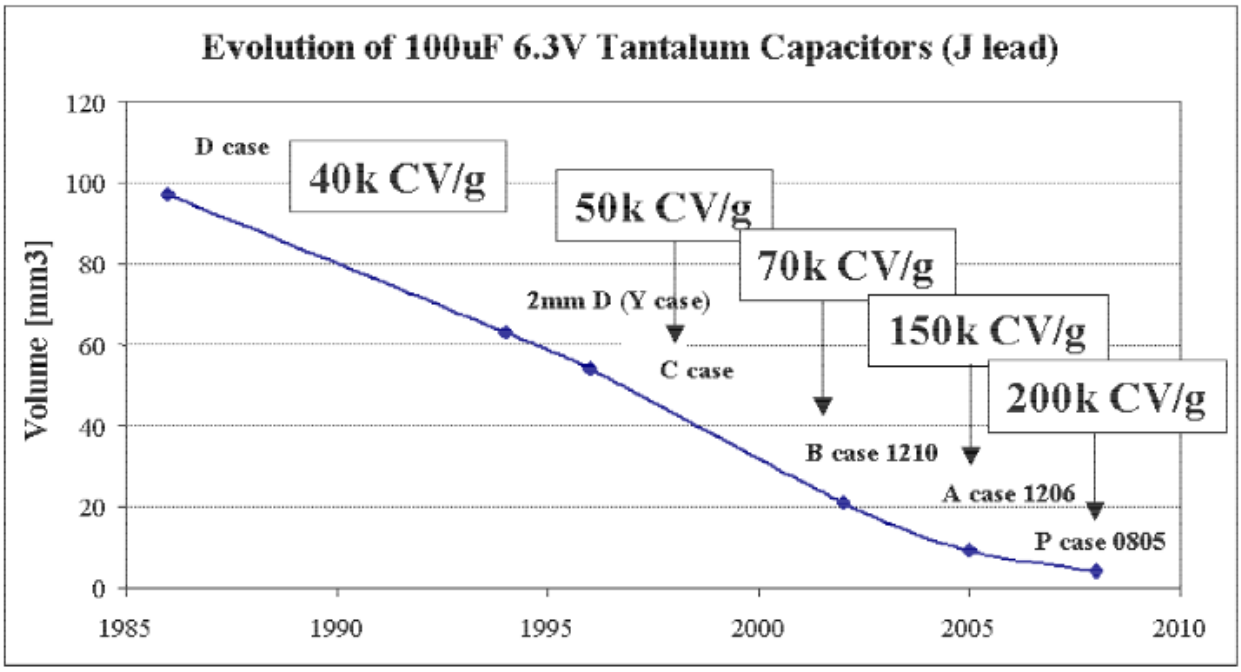

Figure 1: Evolution of CV/g Usage

There is also a difference in the overall philosophy for components built for consumer electronics compared to those supplied against a military specification. In general a commercial facility may change the materials used to build parts at will in order to achieve cost savings or utilize a readily available material supply. Also there may be many different internal anode designs used for the same rating which can be supplied under a single part number at the option of the manufacturer, and not all designs are created equal in terms of inherent reliability. Improved traceability and change control may be available on COTS-Plus components for specific ratings upon request in a source control drawing. For military QPL components the rating design is strictly controlled and certain changes must be qualified and submitted to DLA for approval.

COTS-Plus Screening:

Within the COTS-Plus series there is a standard level of up-screen testing incorporated with every batch of product produced. This includes some of the basic process steps such as reflow conditioning and thermal shock along with sample mechanical/visual inspection and 100% statistical electrical screening. There are options built into the part number to specify Weibull grading reliability and surge current testing, along with the MIL-PRF-55365 Group A tests, temperature stability and solderability.

GROUP A TEST OPTIONS

TEST	Group A Testing comparison			
	AVX COTS-Plus	MIL-PRF-55365 QPL		AVX SRC9000
		MIL Weibull B, C, D	MIL T Level	Space Level
100% Reflow	✓	✓	✓	✓
100% Thermal Shock	✓	✓	✓	✓
100% Weibull	Optional	Mandatory	Mandatory-Grade C min	Mandatory-Grade C min
100% Surge Current	Optional	Optional	Mandatory - C Level	Mandatory - C Level
100% Electrical Testing	Custom Test Limits Available	To Specification Limits Only	+3 Sigma Limits	+3 Sigma Limits or Custom
Visual & Mechanical	Sample	Sample	100% - 20X	100% - 20X
Simulated Mounting, Rework and Lot Conformance (Sample)	Optional			✓
Solderability Test* (Sample)	Optional 75% Coverage	Mandatory 95% Coverage	Mandatory 95% Coverage	Mandatory 95% Coverage
100% X-Ray	Optional		✓	✓
DPA - 1580 Destructive Physical Analysis	Optional		✓	✓
Surge Voltage (Sample)	Optional			✓
Hot DC Leakage (Sample)	Optional			✓
Temperature Stability (Sample)	Optional	Mandatory	Mandatory	Mandatory

*Only Mil QPL ratings receive the steam age portion of solderability testing unless otherwise specified by the customer

Figure 2: Group A Testing Comparison

Weibull grading is currently the industry standard for establishing the reliability of solid tantalum capacitors. During this burn-in capacitors are subjected to accelerated voltage and temperature (typically 1.3 to 1.5 x Rated Voltage @ 85C) for a minimum of 42.25 hours. The number of failures on a 300 piece sample is monitored after 15 minutes, 2 hours, and 40 hours, then the distribution of those failures is used to calculate a failure rate (B, C, or D) for that frame. While the calculation is based on a sample, the entire batch is subjected to these conditions which provides a reliability grade with a 90% confidence interval. Commercial components typically specify a 1%/1000 hour failure rate with a 60% confidence since the burn-in performed is typically only 2-3 hours and no calculation is required per batch. Ultimately the purpose of the Weibull grading burn-in is to remove infant mortalities from the frame and improve the inherent DC leakage characteristics. However; in recent time there has been some debate regarding the efficacy of this process which we will discuss when reviewing our alternative burn-in methods under the Q-Process.

Failure Rates /1000Hrs	
Commercial	**1%**
B	**0.1%**
C	**0.01%**
D	**0.001%**

Figure 3: Weibull Reliability Levels

Surge current screening is also a test which most high reliability customers require. This is essentially a conditioning where components are subjected to a peak current charge in order to remove parts which are not able to handle the required current. Commercial grade parts receive a 100% in line single unit surge at room temperature during production (Typically 2 to 4 times). The COTS-Plus options allow for surge testing to be conducted at additional temperatures (-55C and 85C) which is recommended if the application operates near these temperature extremes.

An additional benefit to COTS-Plus components is the statistical screening implemented on every batch we produce. The catalog limits are often conservative in nature and do not always reflect the actual capability of the parts under test. Screening to a catalog limit allows for distributions which contain parts that are statistically different from the vast majority of the population which calls into question the inherent reliability of these outliers. Any COTS-Plus component tested utilizes a minimum 6 sigma limits for DCL and ESR providing a more normalized population. However for mission critical or space level applications electrical testing to 3 sigma limits is recommended.

Conformance testing is another area where military grade parts differ from commercial components. Each quarter a representative group of components from all of the military grade shipments is placed on Group C conformance testing. While COTS-Plus components do not require this testing, it can often be specified on a lot by lot basis in a source control drawing (SCD).

TABLE X. Group C inspection (ER only).

Inspection	Requirement paragraph	Method paragraph	Number of sample units to be inspected	Number of failures allowed
Subgroup I Thermal shock (mounted) 1/	3.15	4.7.12	12	1
Subgroup II Resistance to soldering heat Moisture resistance	3.16 3.18	4.7.13 4.7.15	18	
Subgroup III Life (2,000 hours at +125°C)	3.22	4.7.19	24	
Subgroup IV Life (10,000 hours at +85°C) FR (exponential only)	3.22	4.7.19.1	25 minimum per style	See 4.4.4.1
Subgroup V Resistance to solvents 2/	3.25	4.7.22	8	0

Figure 4: MIL-PRF-55365 Group C Conformance Testing

In order to standardize the COTS-Plus options for high reliability users there are two DSCC drawings (07016 and 95158) for users to pick from. These drawings contain ratings cap/voltage combinations and ESR levels outside those available in the military grade range, but include the standard COTS-Plus testing with options for additional screening.

Ultimately all of these testing and conditioning options help remove suspect components from the population and demonstrate certain capabilities, but they do not improve the inherent reliability of the base design. Each batch supplied is qualified as

meeting the specified standards, but not every batch meets requirements. This introduces some risk in terms of delivery where it may require the testing of several batches in order to achieve a suitable Weibull grading or pass a specified life test. This differs from the military grade components which were specifically designed around these requirements.

COTS-Plus SRC9000 Space Level:
The COTS-Plus component offering does not stop with military style burn-in and surge current testing. AVX has offered SRC9000 space level COTS-Plus components for many years which includes several additional tests in order to ensure the reliability of these products. In 2014 AVX made a significant update to the component we offer and recommend from the COTS-Plus SRC9000 space level range. Moving away from up-screening strictly commercial level components, the range was redefined using the professional grade TRJ/TRM series for the SRC9000 TBJ/TBM series. The professional grade range incorporates more conservative designs and formation ratios and includes some important enhancements during its original manufacture including addition burn-in, improved inherent reliability to 0.5%/1000 hours with a 60% confidence, and stricter controls on the changes that may be made to the product.

As a standard, the entire population of SRC9000 space level product is tested to C Weibull reliability and C surge current screening per MIL-PRF-55365 along with 100% visual inspection at 20x magnification, 100% X-Ray inspection, and 100% electrical screening to 3 sigma limits for DCL and ESR. Components also have a 5 piece DPA sample pulled for evaluation of the components construction. In addition we perform sampling for lab testing which includes surge voltage testing, hot DCL leakage (85C), temperature stability, and solderability. Lastly, any COTS-Plus component that is not included in a military QPL specification receives a 1000 hour life test where the results are projected out to 2000 hours. If any of the components do not pass the 1000 hour measurement, or the projected 2000 hours value, the frame of components does not meet the SRC9000 requirements and will not be shipped.

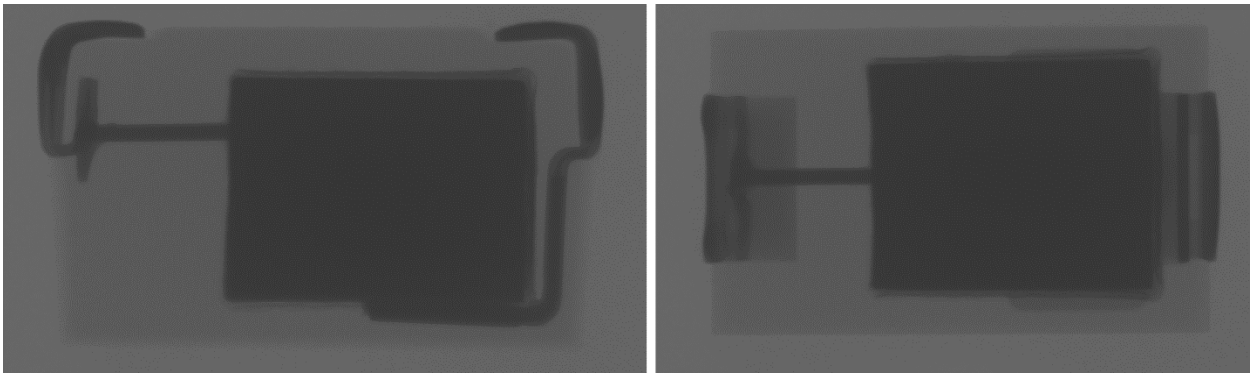

Figure 5: Example 2 Plane X-Ray

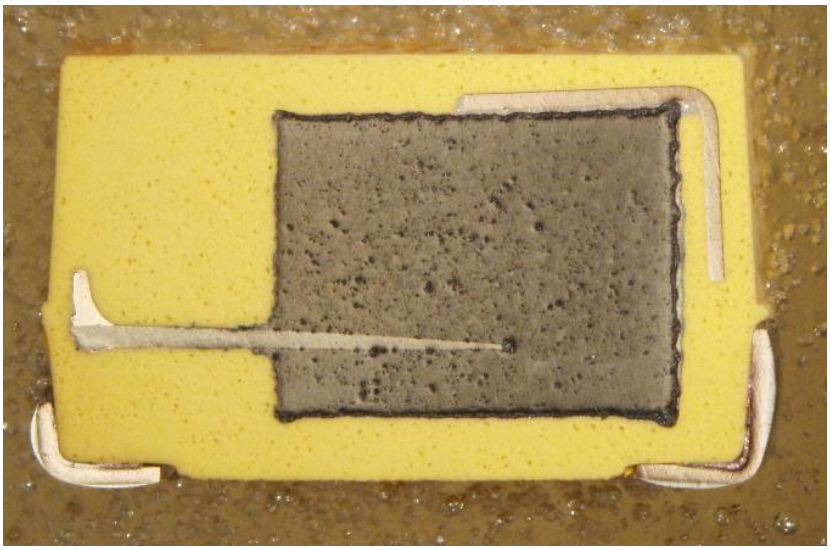

Figure 6: Example TBJ DPA Cross Section

In addition to standard COTS-Plus and SRC9000 screening we are very receptive to customer defined specifications requiring further testing for their intended application. Drawings may be submitted to AVX at any time through our local representatives or to the factory directly.

Q-Process:
One of the more recent initiatives from AVX on high reliability tantalum capacitors has been updating the burn-in process and procedure. Weibull grading has been the standard for several decades, but recent evidence suggests that this process may have some adverse effects on the parts under test. This is even more prevalent in commercially up-screened components since their lower formation ratios and thinner necks make them less suitable for the over voltage requirements of Weibull grading.

- With Weibull, it is possible to leave parts in the population that have healed, but which are mechanically weak typically resulting in early time failures during customer production.
- Because the Weibull calculation needs failures, better parts need higher voltage acceleration, which can degrade leakage current performance.
- Proper screening before Weibull grading is discouraged because the need for early time failures is required to do the calculation.

In order to improve the performance of our parts through customer processing and handling we have developed a new burn-in procedure. This new burn in process, along with a test regime that incorporates an additional reflow and statistical 3 sigma screening at 125C pre and post burn-in, allows us to identify and remove units which display elevated leakage characteristics. This process removes high leakage parts prior to the burn-in process which prevents them from healing and shifting back into the normalized population resulting in mechanically sensitive parts. In addition the burn-in has been updated to occur at 125C at a voltage based on the design of the components under test. Any rating qualified to the Q-Process goes through a series of DOE’s to

determine the optimum burn-in time and voltage to produce the lowest leakage highest reliability components possible per design.

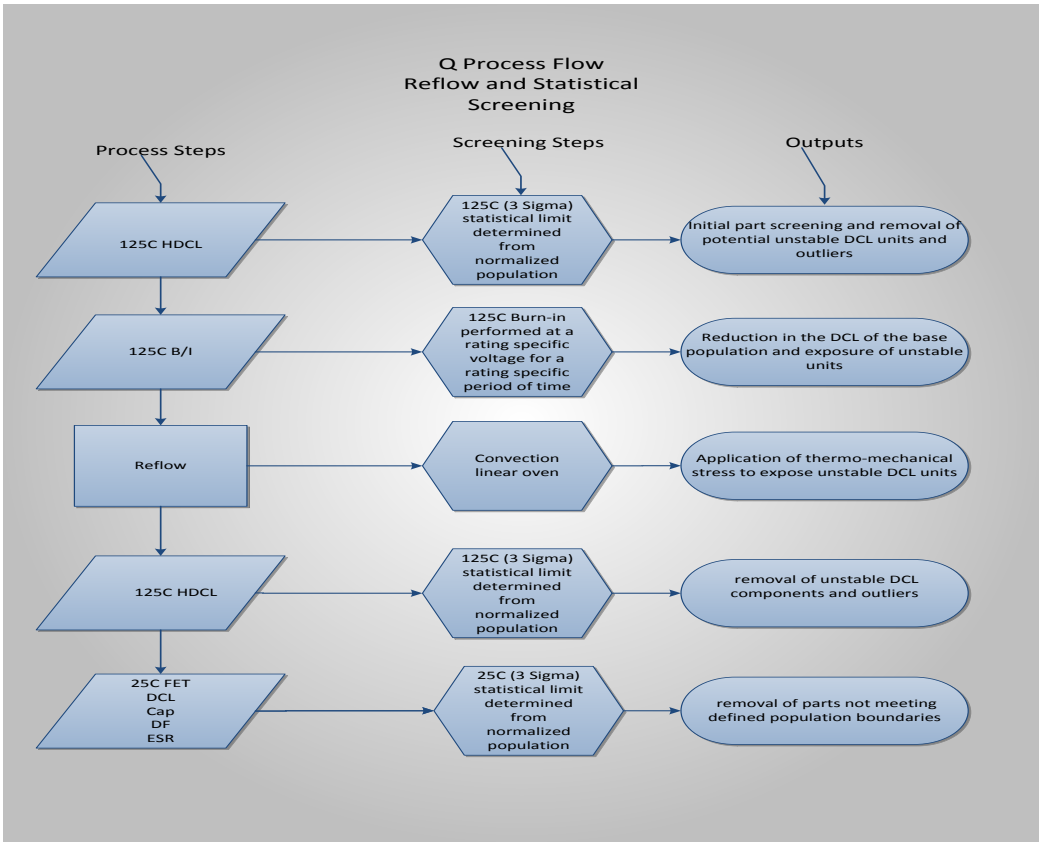

Figure 7: Q-Process Testing Flow

One drawback of the Q-Process is the loss of a reliability grade number which customers are accustomed to seeing for Weibull graded components. Due to the early removal of suspect components, it restricts the ability to provide a reliability grade based on early life failures. As an alternative we have developed a Product Level Designator lot acceptance test for Q-Process parts. Unlike Weibull, which is tested before the components are actually finished, the Product Level Designator lot acceptance test is done after all processing is completed. At a minimum, each frame will have a 30 piece sample mounted and subjected to a simulated manufacturing process flow which ends with an abbreviated life test at 125C with no failures allowed. The results of this test, based on the Arrhenius model, chi squared model, and MIL-HDBK-217, provide components which exceed the 0.1%/1000 hours failure rate most commonly used in the industry.

The main focus for Q-Process up to this point has been for the medical implantable life support industry, but current activities include offering COTS-Plus components with Q-Processing which is incorporated into our new T4J and T4C series. In addition we are actively seeking to incorporate this test protocol into a military specification.

For more information on the Q-Process please refer to the paper titled "Reaching the Highest Reliability for Tantalum Capacitors" on our website.

Conclusion:

The AVX COTS-Plus system offers designers a much wider range of tantalum capacitor options compared to MIL-PRF-55365 while retaining the ability to source product with established reliability and military testing. The methodology has evolved to include Space Level options and additional construction types, and is now offered with the AVX Q-Process as an alternative to Weibull grading. The system has been proven to be effective and is widely adopted for applications including space flight.

References:

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