Automotive Polymer Tantalum Capacitors with capabilities beyond AEC-Q200

48V Application Voltage Adoption in LEO Satellite Industry

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Abstract

From ground stations to satellite payloads, every segment of the Low Earth Orbit (LEO) satellite industry seeks reliable component technologies combined with mature manufacturing processes and controlled costs.

These applications have challenged the capacitor industry during the last years. New materials and manufacturing processes enabled polymer tantalum capacitors to fulfill capabilities beyond AEC-Q200 stress test requirements, demonstrating higher performance levels during screening and LAT testing protocols on low voltage DC/DC output power rails. In addition, new evaluations progressed in 48V input power rails.

In this presentation, the 75V polymer Tantalum capacitors, used on the 48V power rails, long-term test results such as endurance and storage life are presented and discussed.

Market and Applications Considerations

The satellite industry is in a profound transformation. As the market for low earth orbit (LEO) satellites accelerates, engineers and procurement teams alike are rethinking the very building blocks of space hardware.

A disruptive pivot from traditional, space-qualified components to automotive-grade electronics is a shift that is redrawing the competitive landscape and redefining the economics of space access. This may raise concerns, given the stringent requirements for space, but there is a real revolution happening under the hood. Unlike the geostationary or deep-space predecessors, LEO satellites are designed for short mission, often three to five years.

LEO satellites, operating at altitudes below 450 km, offer unique advantages: ultra-low latency, sharper imaging and reduced signal delay. These attributes are fueling demand across defense, disaster response and the rapidly expanding Internet of Things (IoT). This growing market demand stimulates investment in LEO satellite constellations. The global small satellite market is projected to reach $207B by 2030, growing at CAGR of 11.8% from 2025 to 2030 [1].

Tantalum Polymer Automotive-grade parts, qualified under AEC-Q200, are engineered for reliability in harsh terrestrial environments so they can withstand longer mission profiles, shock, vibration and thermal cycling. They are also produced in high volume manufacturing facilities, readily available and cost a fraction of their space-qualified counterparts. For LEO missions, where cost, speed and agility are significant, these attributes are irresistible.

The transition is not without risk. Space-grade components, built to MIL-PRF standards, remain the gold standard for radiation tolerance, long-term reliability and mission-critical performance. For human spaceflight, deep-space probes or high-risk defense missions, failure is not an option—and neither is compromise.

To reconcile cost and reliability, some LEO constellations are adopting "up-screen automotive capacitors," which subjects commercial or automotive parts to additional testing to meet more stringent standards.

As LEO satellites are redefining the economics and engineering of space, the message for electronics engineers is clear. The embrace of automotive-grade components reflects a broader trend toward cost-efficiency, rapid deployment and risk-based decision-making.

Tantalum Polymer Automotive Grade Advantages

Size and weight are two key factors while designing small satellites. These requirements lead the designers to high volumetric efficient capacitors, such as tantalum polymer surface mount devices. Since the extreme usage application conditions in space require highly reliable bulk capacitance, tantalum polymer capacitors are increasingly considered due to performance benefits:

(a) lower ESR equivalent series resistance with improved power delivery and reduced heat generation;
(b) small size and weight;
(c) self-healing capability under low energy transients and
(d) enhanced frequency response compared to old legacy tantalum MnO_2 technology.

The tantalum polymer SMD capacitors have been mainly used in power management conversion, from POLs to DC/DC conversion with voltages ≤ 5V, Fig 1. The 540/T541 High Reliability Polymers Series (DLA 04051/04052) has been adopted successfully during the last decade, and the YAGEO Group was the first to market with the QPL Tantalum Polymer MIL-PRF-32700, T581 Series [2] [3]. The significant increase of small satellites triggers the high demand for automotive grade products, with extra surge current screening. To support customers, YAGEO Group includes the T598 Automotive Grade Polymer Up-screen [4] [5].

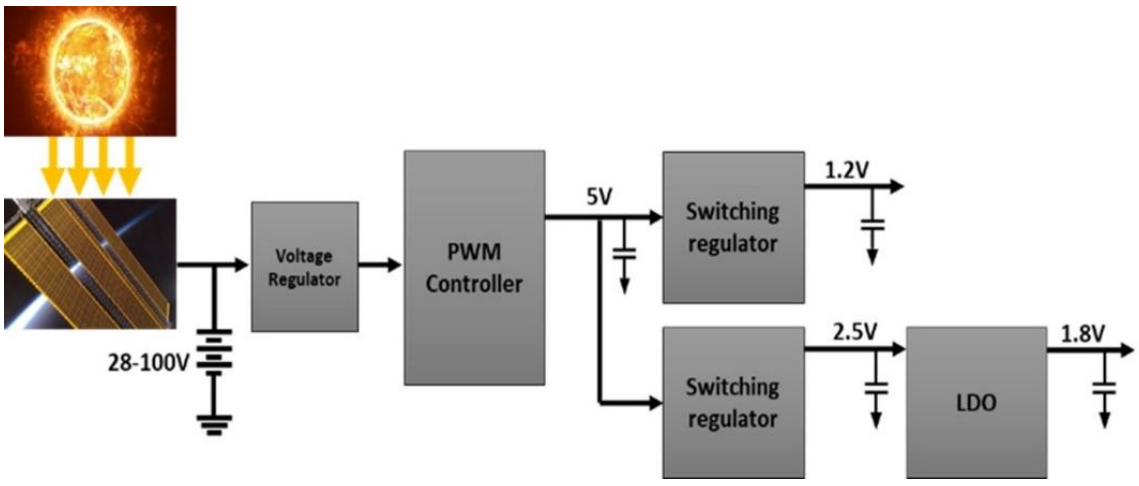


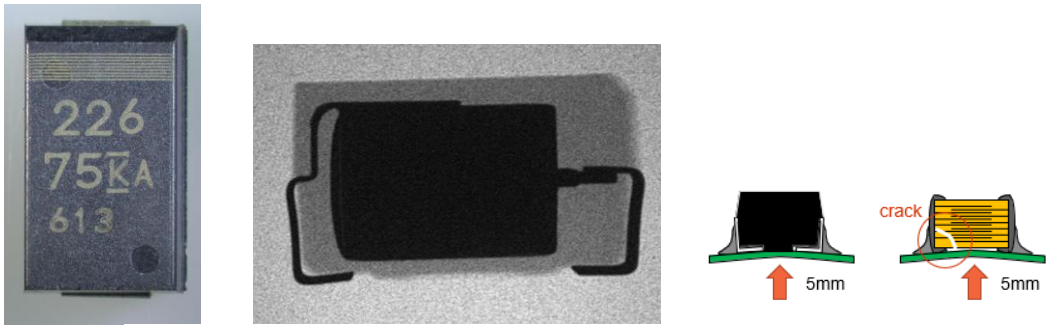
Figure 1. Schematic Example: Space POL with typical application use of tantalum polymer SMD capacitors

In the input side, at 28V or 48V, Class II Multi-Layer Ceramic Capacitors (MLCCs, like X7R or X5R) are widely used, but they present performance penalties and mechanical failure modes. The Tantalum Polymer Automotive-grade parts serve as a direct, highly effective solution to these specific limitations.

Class II MLCCs utilize ferroelectric materials (like Barium Titanate). When an operating DC voltage is applied, the internal crystal structure saturates. This causes the effective capacitance to drop. To maintain steady voltage rails on data-heavy payloads, engineers are forced to parallel dozens of MLCCs, wasting massive board space. Tantalum polymers are non-ferroelectric and exhibit an insignificant DC bias effect. Their capacitance stays essentially flat across the entire operating voltage range. A single tantalum polymer capacitor can replace a whole parallel bank of MLCCs. MLCCs are also inherently brittle. The intense acoustic vibrations, mechanical shocks, and pyrotechnic separation

events during launch create tremendous physical board flexure. Large-case MLCCs (like 1210 packages) frequently develop microscopic internal cracks. In orbit, these cracks lead to immediate short circuits or catastrophic thermal runaway

Tantalum polymers utilize a molded epoxy resin enclosing a porous metal pellet structure with external terminals. This configuration is highly resilient against board flexure and mechanical shocks, making them structurally robust against harsh launch vehicle environments, Fig 2.



(a) (b) (c)

Figure 2. Construction Difference: MLCC vs Tantalum Polymer – crack mitigation

Tantalum Polymer Automotive Grade 48V challenge

Tantalum Polymer Automotive-grade T598 Series capacitors are specified with 105ºC rated temperature and rated voltage Ur, 125ºC category temperature and category voltage 0.67Ur. A voltage derating recommendation should be applied. A minimum 75V rated voltage capacitor is recommended for the 48V input line.

YAGEO Group is addressing Class II MLCC 1210 10uF50V challenges with the development of the new **T598X226M075AH up-screen** solution. In this work we include:

(a) comprehensive package of electrical characterization;
(b) mechanical performance analysis and
(c) life endurance, storage and vacuum test result in combination with ACC (anomalous charging current)

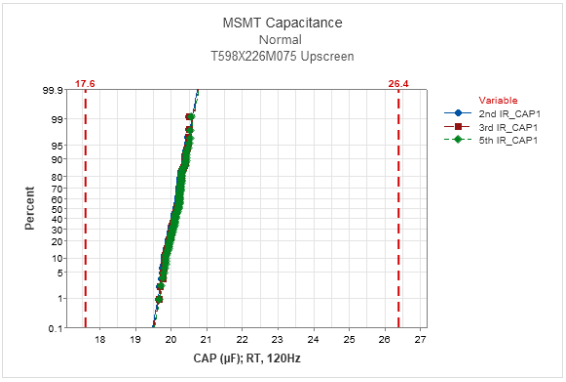
This new X case size EIA 7343-43 capacitor, **T598X226M075AHW100** is specified in Table 1

Rated Voltage (V)	Capacitance µF	Case Code/ Case Size	YAGEO Part Number	DC Leakage µA at 25°C max/ 5 minutes	DF% at 25°C 120 Hz Max	ESR mOhm at 25°C 100 kHz Max	Maximum Allowable Ripple Current (rms) mA at 45°C 100 kHz	MSL Reflow Temp ≤ 260°C	Max Operating Temp (°C)
75	22	X/7343-43	T598X226M075AHW100	165	10	100	2,240	3	125

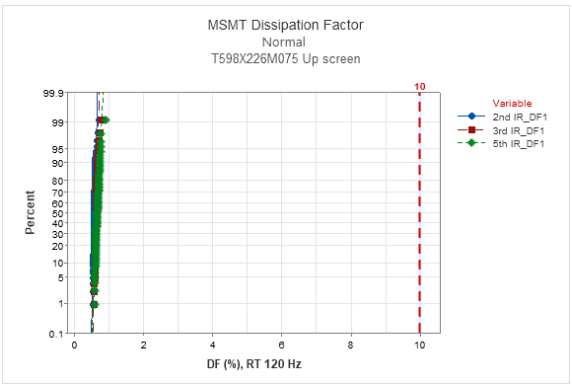
Table 1. Electrical Specification Parameter for the new T598X226M075AH up-screen

ELECTRICAL CHARACTERIZATION

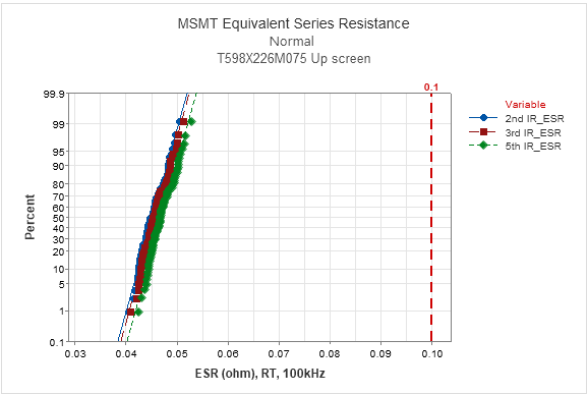
Electrical parameters of capacitance (120Hz, RT), Dissipation Factor (120Hz; RT), ESR (100kHz, RT) and Leakage Current (rated voltage, RT at 270sec) in capacitors subject to five times 260ºC reflow soldering were investigated. All the parameters are well inside initial limits under these multiple harsher conditions, Fig 3.



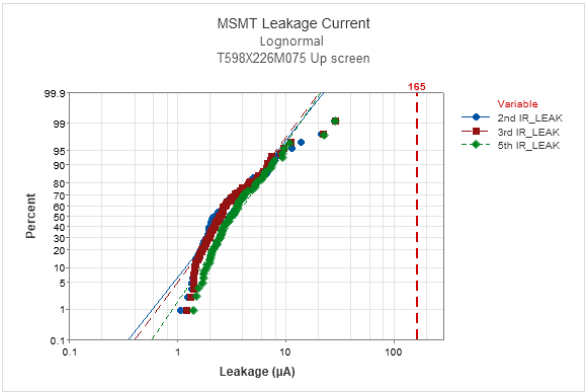
(a) M-SMT Capacitance (uF, 120Hz, RT)



b) M-SMT Dissipation Factor (%, 120Hz, RT)



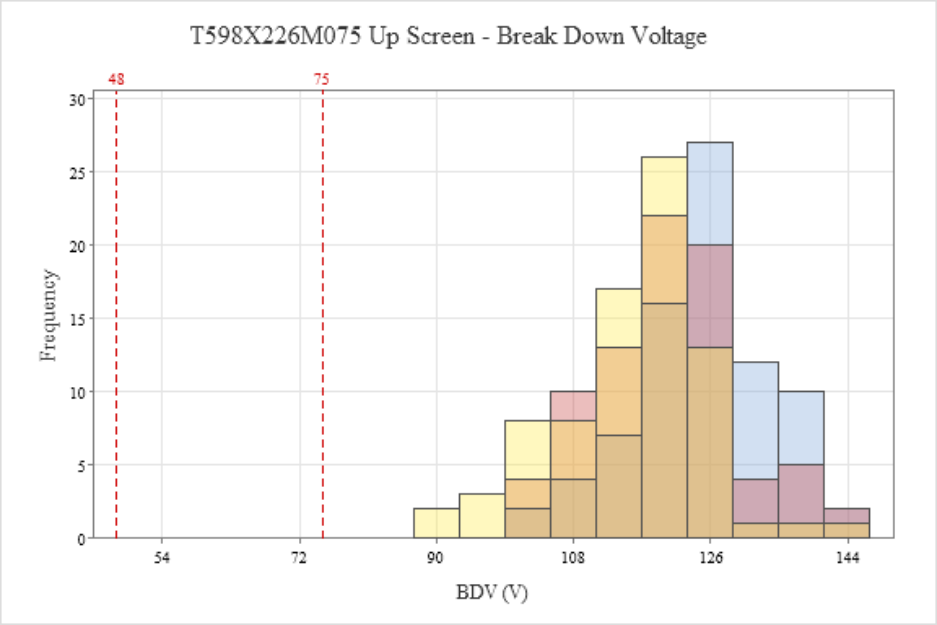
c) M-SMT ESR - Equivalent Series Resistance (Ohm, 100kHz, RT)



d) M-SMT Leakage Current (uA, 75V, 270seconds, RT)

Figure 3 Electrical parameters performance at multiple 260ºC Reflow Soldering

Specifically for the leakage current and the tantalum pentoxide dielectric studies, 100 samples from three different manufacturing batches were subject to BDV (break down voltage) at 90ºC with a ramp voltage 3.3V/sec, Fig 4. The destructive failure occurs at BDV higher than the 75V rated voltage, and with large safety margin for the 48V application voltage.



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Figure 4 Break Down Voltage (V) from 3 different manufacturing batches

The temperature characterization of the electrical parameters determines that capacitance varies with temperature (positive temperature coefficient) with typical variation between -5% at -55ºC up to +20% at 125ºC, Fig 5. The polymer counter electrode bulk material contributes for the ESR variation with temperature, with polymer technology revealing significant lower variation than the old legacy MnO2 counter electrode, typically the ESR variation is within 15% from -55ºC up to 125ºC.

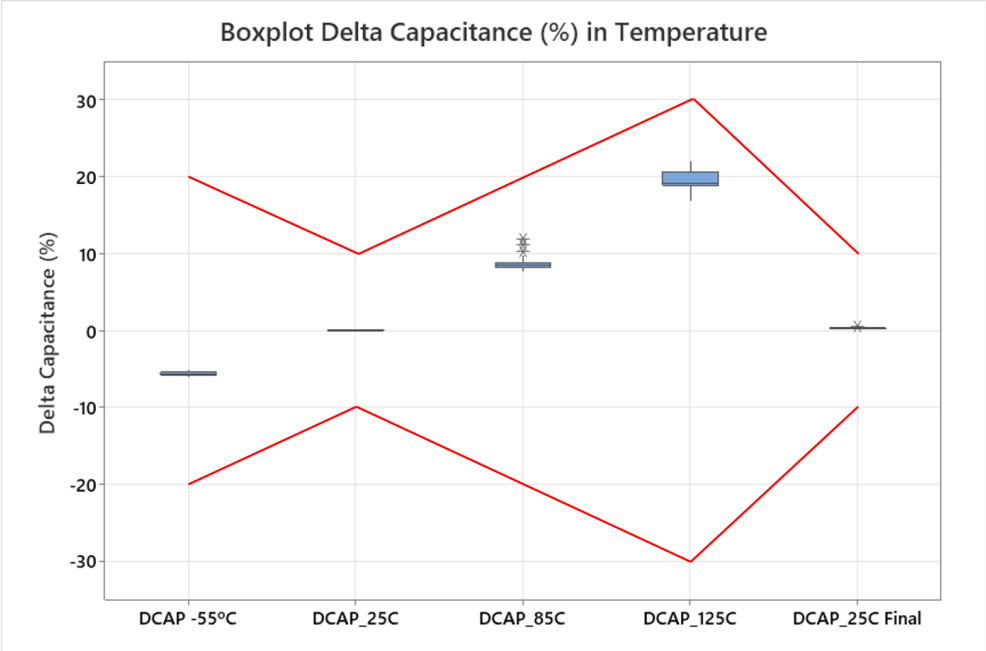


Figure 5 Capacitance Characterization in Temperature

MECHANICAL PERFORMANCE

Evidence of non-susceptible flex cracking is shown with an extended flex boarding test up to 5mm displacement for 60 seconds, Fig 6 and Table 2.



Figure 6. Board Flex Testing (5mm / 60 sec)

T598 EIA 7343-43 Board Flex Capacitance Stability Investigation	DELTA CAP (%)
Mean	-0.200
Std. Dev.	0.666
Maximum	0.275
Minimum	-2.964

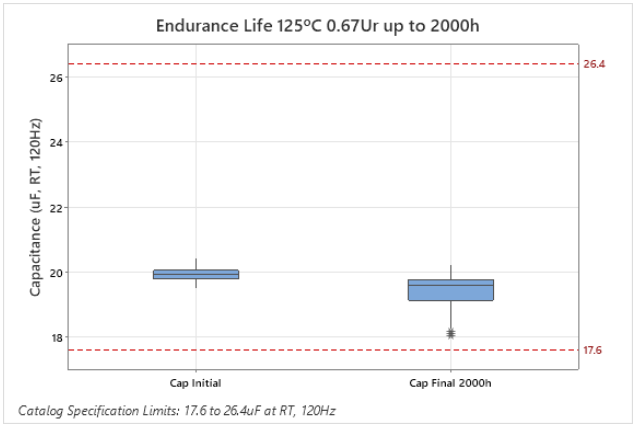
Table 2. Capacitance drift % before and after Board Flex Testing EIA7343-43 Tantalum Polymer Automotive Grade

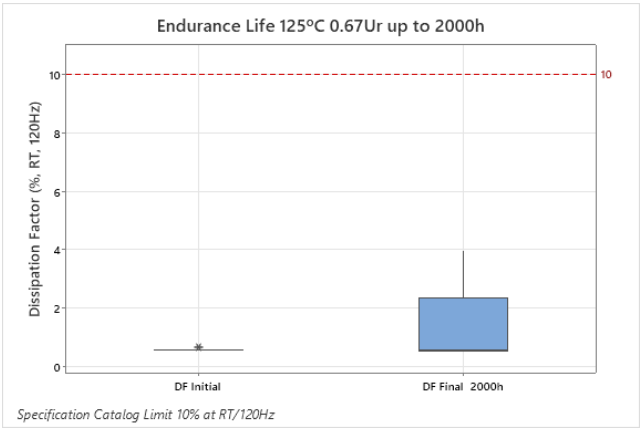
Electrical parameters stability after 60 sec with 5mm board flex test revealed almost no change in capacitance (uF, RT, 120Hz) with 0.2%. The tantalum polymer mechanical construction, Fig 2, deliveries a robust performance in extreme mechanical stress.

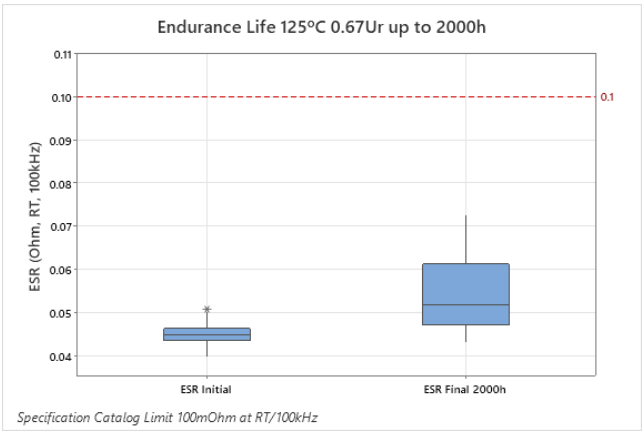
LIFE ENDURANCE, STORAGE AND VACUUM RESULTS

One of the most important benefits of tantalum polymer capacitors in comparison of the 'old legacy' MnO_2 counter electrode is the significant reduction of the ESR (Equivalent Series Resistance). This reduction improved the efficiency of the capacitors for filtering in power lines and decreased self-heating resulting in lower operating temperatures and probability of failures. Extensive characterization investigations during last decade reveal one of major limitations of tantalum polymer capacitors compared with MnO_2 is the limited long-term stability. Significant enhancements have been introduced to optimize package integrity and new materials [5, 6, 7].

Endurance life and Endurance Storage results with the new 75V rated capacitor are presented. The AEC-Q200 specifies a 1000-hour requirement at 125ºC, while the T598 Series YAGEO specification meets the testing for 2000 hours. The data demonstrates a high safety margin when the capacitors are tested for up to 2000 hours, Fig 7 and 8.
The electrical performance graphics include the initial specification catalog limits described in Table 1 and reveal high capability results.







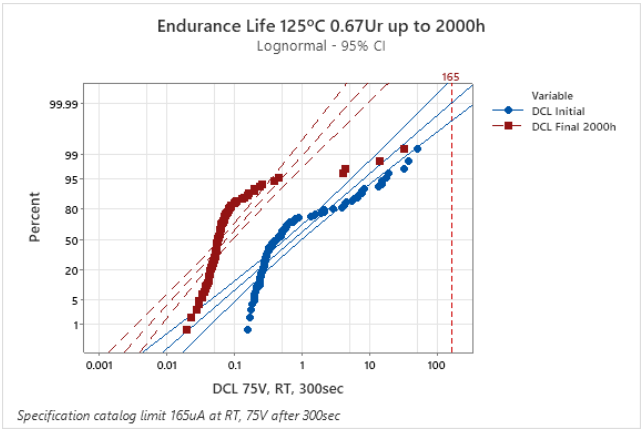
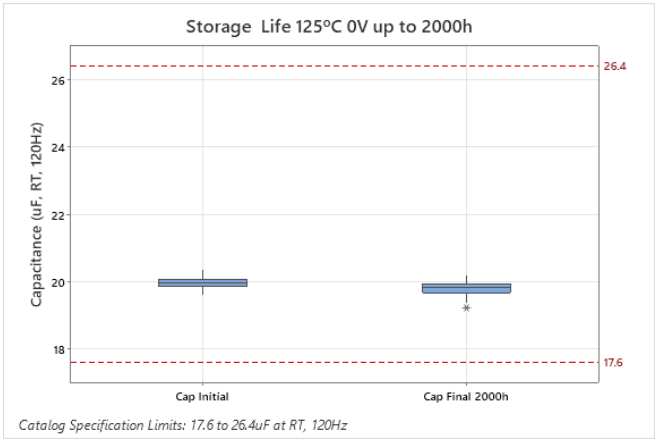
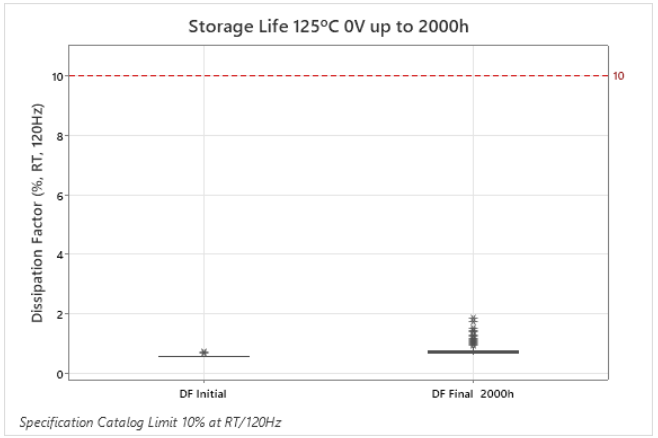
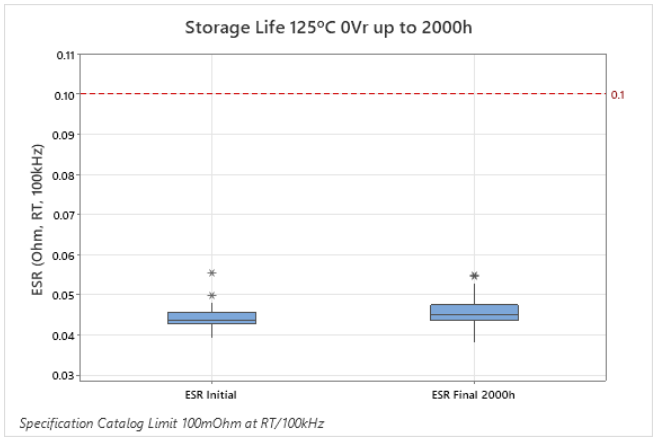


Figure 7. Endurance Life Test Results – 125ºC 0.67Ur extended up to 2000h







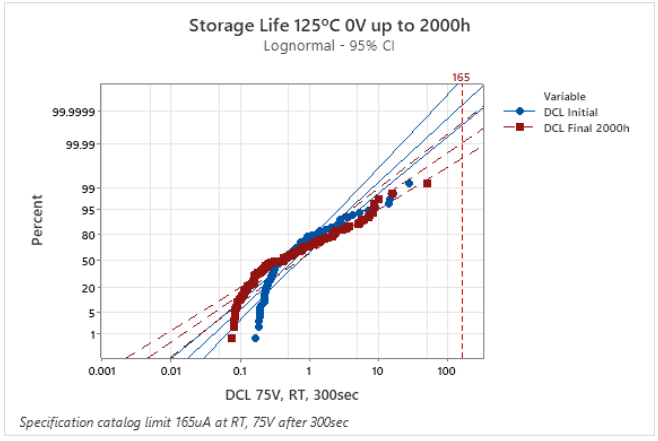


Figure 8. Endurance Storage Test Results – 125ºC 0V extended up to 2000h

Anomalous charging current (ACC) after step voltage application in discharged and dry parts is a peculiar phenomenon in tantalum polymer capacitors that has been extensively studied during the last years. This high transient current was first discovery by Dr. Yuri Freeman [8, 9].

ACC is a higher amount of current flowing into a capacitor while charging than would be predicted by formula I = C*dv/dt. ACC is measured relative to the theoretical charge current at a given voltage. Although ACC does not pose a reliability risk to the capacitor itself, it can pose risk to applications. To minimize this effect when using tantalum polymer capacitors in an extremely dry and cold environment, such as space vacuum, 50% derating is recommended. This drastically reduces the likelihood of experiencing the ACC phenomenon.

An investigation with 75V rated voltage tantalum polymer capacitors was performed comparing samples stored in vacuum oven at 0°C, against control under laboratory ambient condition. The laboratory step up equipments used is presented in Fig 9.

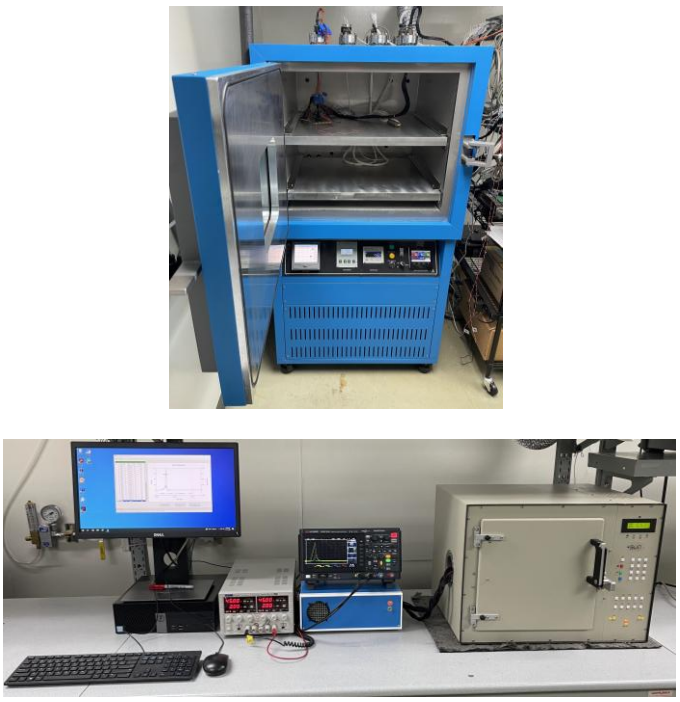


Figure 9. Vacuum Oven and ACC Ramp Voltage Tester

Electrical measurements of capacitance and ESR were done at room temperature, after mounting the capacitors applying two times the 260ºC reflow, and after post 480 hours testing. The ACC characterization was done on the test and the control samples, post-mount and post 240 and 480 hours.

The capacitance drift % results is shown in Fig10. The control samples reveal a minimal favorable drift of capacitance between 0.3 to 0.4% related to moisture. The capacacitors subject to 480h in 0ºC vaccum shown a sligth reduction of capacitance between -0.5 to -0.6%.

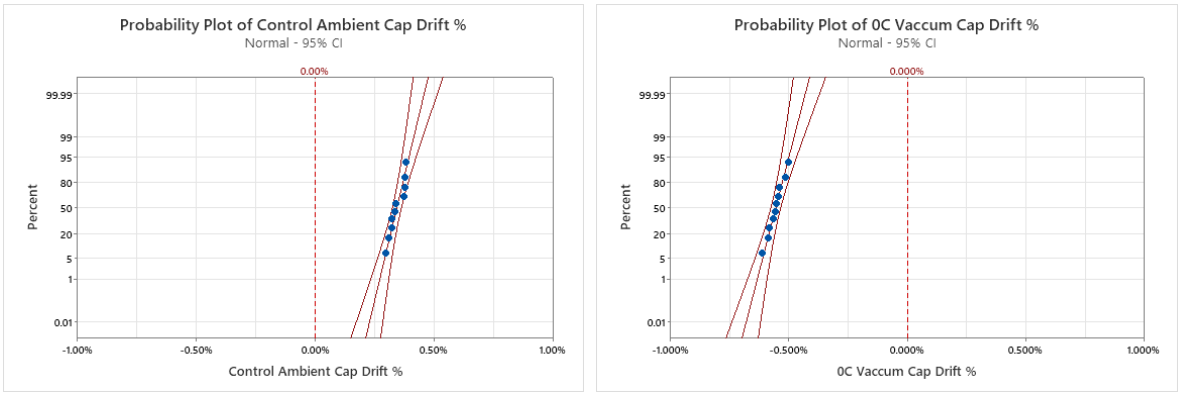


Figure 10 . T598 75V capacitors capacitance drift (%) comparison: Control and Test (480h, vaccum, 0ºC)

Results of the ESR are reported in Figure 11. The drift for equivalent series for the 75V polymer technology is negligible.

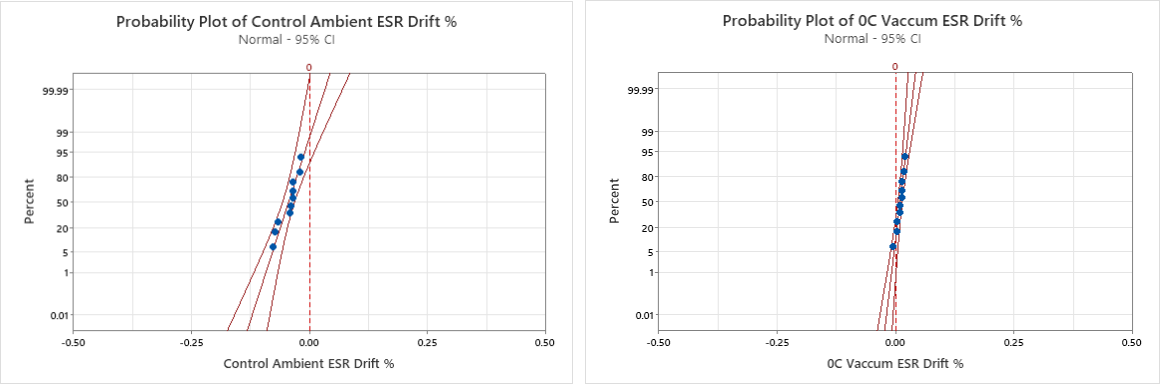


Figure 11 . T598 75V capacitors ESR drift (%) comparison: Control and Test (480h, vaccum, 0ºC)

The ACC characterization performed after mounting and after 240 and 480h, testing control and 0ºC vacuum conditions were done at 60V and 40V to compare and higher and lower voltage. The results are reported in Fig 12 and 13 and in summary we conclude:

1. ACC at 40V tested at ambient conditions is significantly lower than at 60V;

2. ACC at 60V after post mount reveal similar behavior, although the control samples presented an ACC reduction when stored in the laboratory environmentally. Small amounts of moisture have positive influence. And the 0ºC vacuum samples show an increase.

3. ACC at 40V after post mount reveals similar behavior but within 4 theoretical current and support the relevant derating voltage factor to mitigate the application risk.

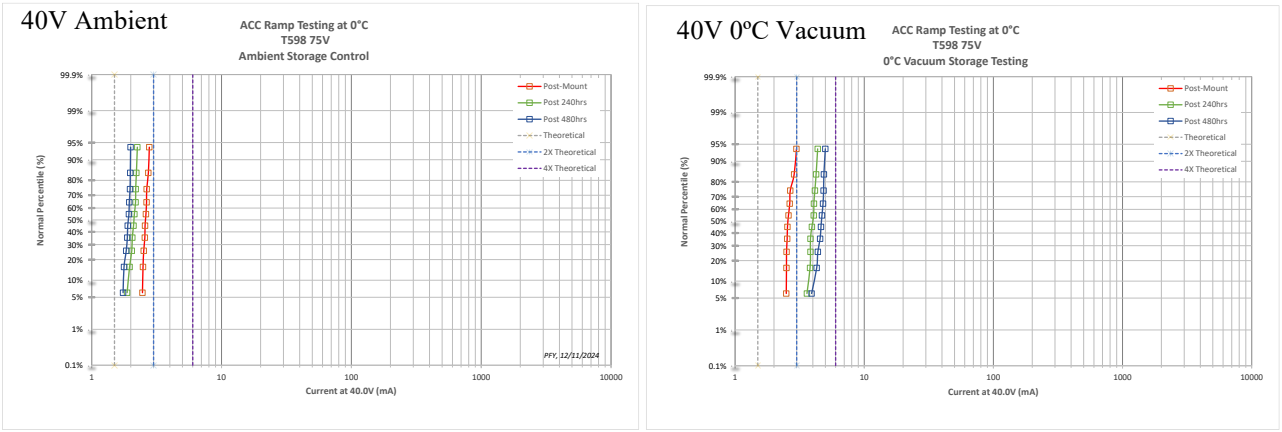


Figure 13 . T598 75V capacitors ACC 40V: Control and Test (240h 480h, vaccum, 0ºC)

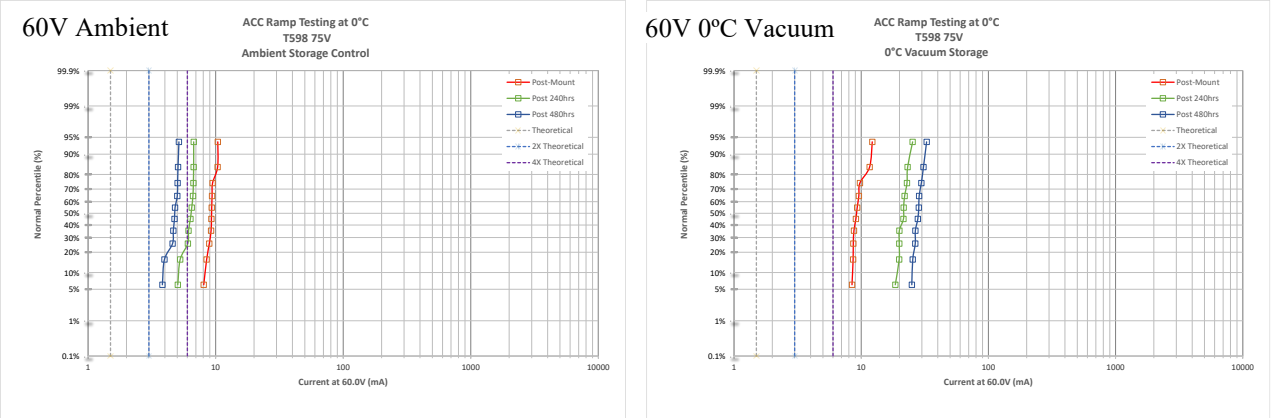


Figure 12 . T598 75V capacitors ACC 60V: Control and Test (240h 480h, vaccum, 0ºC)

Conclusion

Overall, we show strong performance characteristics of the tantalum polymer automotive grade capacitors. The next 75V rated voltage capacitors extension with up-screen surge capability option per MIL-PRF-55365, combined with the Sn-Pb termination (H option), opens new opportunities for the double-digit growth market of small satellites in Low Earth Orbit constellations.

Acknowledgment

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