Performance and Reliability Study of 50V and 63V Tantalum Polymer Capacitors

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Introduction

Since their introduction, tantalum polymer capacitors have been sought after as a welcome complement to traditional tantalum MnO_2 capacitors. Their advantages of improved ESR, benign failure modes, improved voltage derating and higher ripple handling have become well known by designers throughout the industry who need to consider such characteristics in their design. While the release of tantalum polymer capacitors has addressed most of the needs designers were seeking, one item had remained unresolved until recently, higher voltage ratings for power input rails.

For designers working with common 24V input rails as well as 28V avionics rails, the use of tantalum polymer solutions remained out of reach due to voltage limitations with this technology. Designers working with the traditional commercial grade tantalum MnO_2 versions of these capacitors were seeking a product with a much improved turn on failure rate. This was needed to address issues with increased cost due to rework and circuit board damage that was being observed by the board manufacturing facilities.

In late 2008, the industry introduced the first 35V rated tantalum polymer capacitor targeted for the 24V input rail. In 2009, the recommended derating was increased to allow for the use of this device on 28V power rails as well. However, the reduction in derating did not give designers the level of comfort they were seeking. Many designers questioned how a 35V polymer design could be substituted for a 50V MnO_2 design when they felt that the 50V design was still not an adequate enough voltage rating to ensure good reliability.

To address this concern, tantalum polymer capacitor manufacturers continued their pursuit of higher voltage rated capacitors throughout 2009 to 2011 and introduced a series of higher voltage releases including 50V and 63V rated designs.

This paper will focus specifically on the performance characteristics of these newly released higher voltage ratings. Assessments of the electrical characteristics, long term reliability and surge handling capabilities of these components will be demonstrated. In addition, direct comparisons of these new product offers to their MnO_2 counterparts will be made.

Electrical Characteristics of 50V and 63V Tantalum Polymer Capacitors

Impedance

The primary objective for removing MnO_2 from the tantalum capacitor design was to improve the overall impedance of the component. Since MnO_2 represented most of the impedance within the tradition component design, the use of a material that was 1,000 times more conductive than MnO_2 was a logical step in improving performance.

The initial release of the first 50V tantalum polymer designs included ESR values ranging from 35 to 90mOhms compared to similar MnO_2 capacitance/voltage offerings that today range from 90 to 300mOhms. While the polymer devices do demonstrate a much improved ESR with these initial release offerings, it should be noted that further advancements will likely continue to drive down these ESR values as improvements in high voltage processing continue.

Capacitance

Following the initial release of 50V tantalum polymer capacitors, slight gains in capacitance offerings were observed with polymer product offerings vs MnO_2. Today, the industry offers up to 18uF of capacitance in a polymer design packaged in a 7343-43 (7.3mmL x 4.3mmW x 4.4mmH) case size compared to 15uF of capacitance for the MnO_2 product offerings. Much of this advantage in capacitance relates to the types of tantalum powders used for polymer processing vs MnO_2 processing. As with ESR, it is likely that further advancements will lead to even higher capacitance offerings with the polymer designs in the near future which will result in a wider capacitance gap between the two technologies.

Case Size (mm)	Voltage	Cathode	Capacitance	ESR
7.3L x 4.3W x 4.3H	50V	MnO_2	15uF	90mOhms
		Polymer	18uF	35mOhms
	63V	MnO_2	10uF	1000mOhms
		Polymer	15uF	150mOhms

Table 1: Component Selection for Performance Comparison of Maximum Capacitance 7343-43 Case Size

Break Down Voltage Testing of Polymer and MnO_2 Designs

In comparing these two technologies with regard to power on performance, perhaps no characteristic is more important to consider than the Breakdown Voltage (BDV) capabilities of these devices. Unlike many of the lower voltage power rails, higher voltage input rails such as 24V and 28V inputs can experience a higher degree of voltage transients. One such example is the 28V avionics power rail which requires that components be capable of withstanding as much as 50V of transient voltage per MIL-STD-704F.

It should be noted that this comparative analysis was based on commercial grade MnO_2 devices which did not incorporate many of the special processing steps used for military grade and other high reliability 50V MnO_2 devices. The use of certain specialized process steps for 50V MnO_2 products specifically designed for high reliability will demonstrate a much different level of power on performance compared to common commercial grade products. A comparison of such high reliability designs was not conducted during this analysis.

During this evaluation, 50V and 63V components were selected from a series of manufacturers and processed through the same mounting and testing conditions. Component selection was based on capacitance and voltage rating with test groupings based on product with the same capacitance and voltage ratings. When similar matches were not possible, the higher capacitance/voltage ratings for the two technologies were selected.

Sample sizes ranged from 10 to 30 pcs depending on component available. Board mounting included two reflow passes using a common Pb-Free reflow profile. Voltage stress conditions were applied at .5Vr, .8Vr, 1.1Vr, 1.4Vr, 1.7Vr, 2.0Vr, 2.3Vr and 2.6Vr. By using these larger step increases in voltage stress, we could minimize the effect of "aging in" the devices that would come from using lower step voltage increases.

BDV Testing of 50V Designs

In assessing the performance of 50V designs, a 10uF/50V design was selected from each of the two technologies. Included in the MnO_2 family was a 7343-43 case configuration compared to a 7343-31 case configuration selected from the polymer family. As shown in Figure 1, a comparison of the two 50V designs demonstrates that the MnO2 design has the potential for breakdown just above the rated voltage of the device. In this particular sample step, the earliest failures were detected at 55V. While not included in this analysis, earlier assessments of commercial grade 50V MnO_2 devices commonly found the potential for breakdown at voltages below rated voltage following board mount.

While in this evaluation the MnO_2 design demonstrated breakdown activity at 55V, the polymer design did not achieve a BDV until reaching 85V. At that voltage, much of the polymer population experienced breakdown indicating a tighter distribution in BDV compared to MnO_2 with no evidence of low BDV maverick parts in the polymer mix as was observed with MnO_2.

Finally, it was observed that both designs topped out at 115V indicating that the maximum potential BDV between the two designs may remain uniform due to the fact that the dielectric construction is similar between the two designs.

Conclusions from this analysis indicate that the potential did exist for a low percentage of MnO_2 devices to breakdown at or near the rated voltage of the device while polymer designs do not demonstrate the potential for breakdown near rated conditions. This conclusion has been reached not only through this analysis but also through a series of additional tests on much larger sample sizes and a mix of production lots. This has given manufacturers great confidence in the reliability of 50V polymer designs.

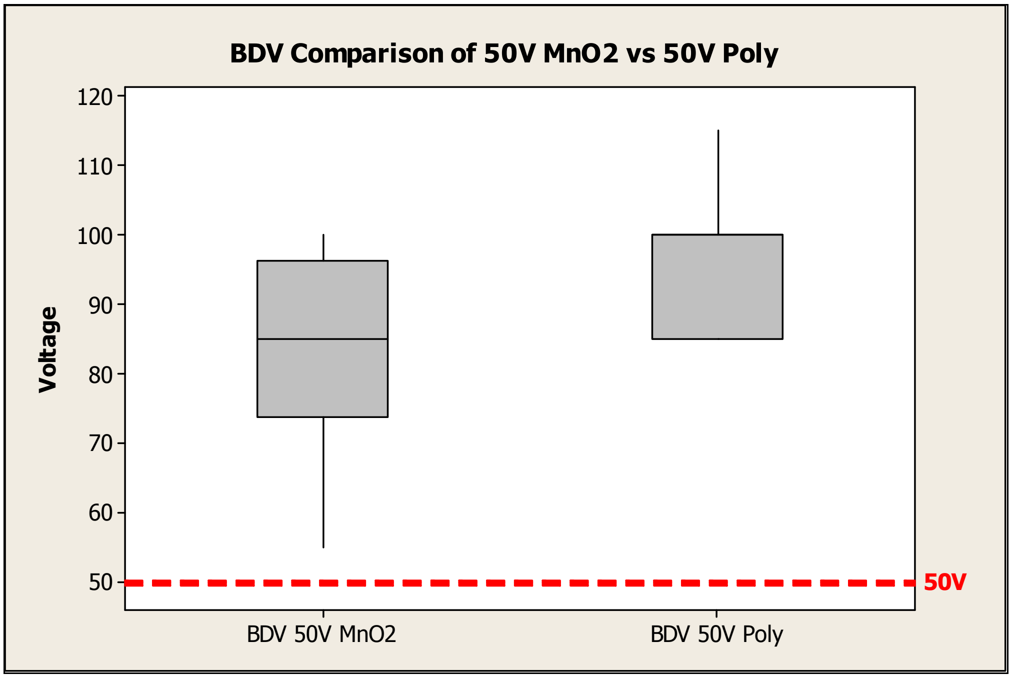

Figure 1: BDV Comparison of 50V MnO_2 and 50V Polymer Designs

BDV Testing of 63V Designs

Figure 2 compares the two technologies with the construction of a 63V design. For this analysis, a 4.7uF/63V design was selected for both the MnO_2 and polymer design. Both case sizes were identically matched with a 7343-31 configuration. As with the 50V analysis, the earliest BDV was observed with the MnO_2 design which demonstrated a BDV starting at 69.1V. As the voltages were increased, additional break downs with the MnO_2 design were observed at 88.2V and 107V. With 80% of the MnO_2 parts having fallen out at 107V, the polymer design demonstrated its earliest failure at this voltage level. At 126V, the remaining MnO_2 components achieved their highest BDV while most of the polymer components remained active. With an applied voltage of 145V, the remaining polymer devices achieved their maximum breakdown voltage.

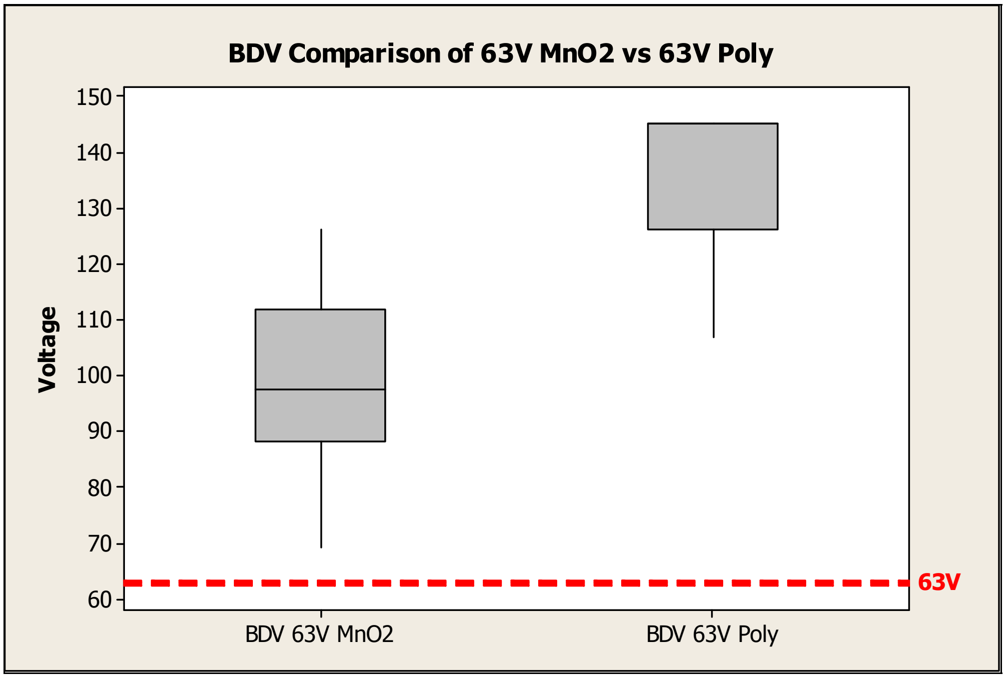

Figure 2: BDV Comparison of 63V MnO_2 and 63V Polymer Designs

Given these high BDVs for polymer designs, an analysis of 75V MnO_2 designs was incorporated into the analysis. While higher in capacitance (22uF) and voltage, the objective of the analysis was to establish a baseline for 75V MnO_2 products.

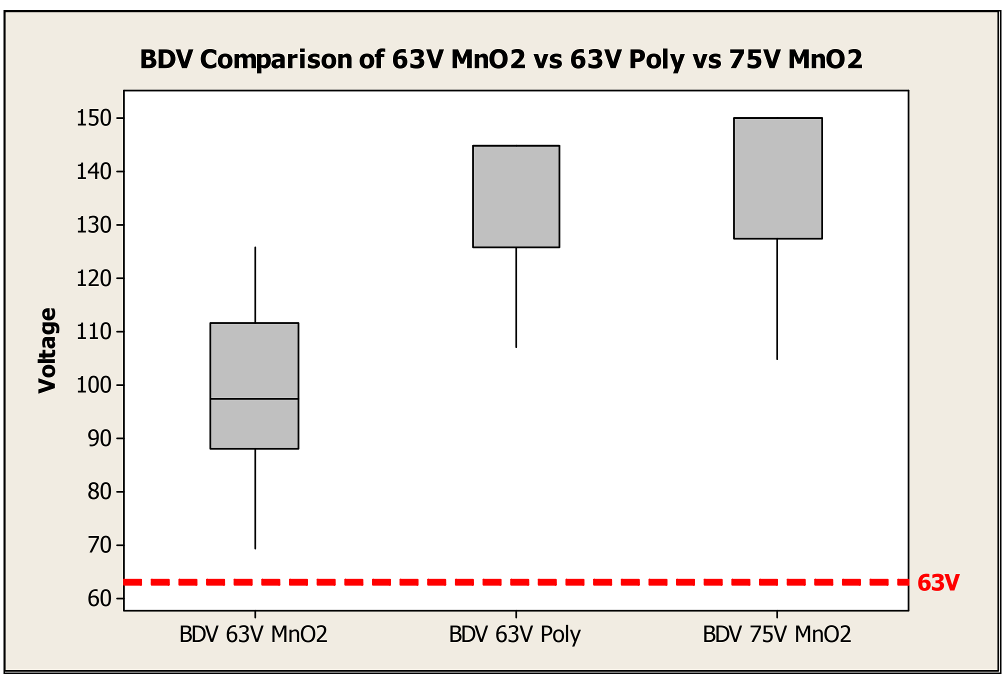

Figure 3: BDV Comparison of 63V MnO_2, 63V Polymer and 75V MnO_2 Designs

Demonstrated in Figure 3, it can be observed that the 75V design produced its earliest BDV at about the same voltage stress level as the 63V Polymer (105V for the 75V MnO_2 vs 107V for the Polymer). While a larger sample size would be needed to further establish a more precise variation between the two designs, the results suggest that the 63V Polymer and 75V MnO_2 designs would most likely demonstrate similar minimum BDV behaviors. As the voltages were increased, the BDV of the 75V design followed a similar trend to the 63V polymer design, with its highest BDV reaching 150V.

The conclusion of these BDV studies demonstrates that the polymer tantalum devices maintain a higher BDV when compared directly to a similarly rated MnO_2 design. The results also show that the breakdown distributions of the MnO_2 devices demonstrated much greater variation means. Therefore, as larger populations are tested with the MnO_2 designs, there is a much greater likelihood of observing breakdowns at or below the rated voltage compared to polymer, which demonstrated a tighter distribution. While larger sampling sizes would be desirable, the above information does establish a BDV baseline for the two technologies.

Analysis of both of the 50V designs has shown that the MnO_2 design will demonstrate a BDV at as little as 1.1Vr while the polymer design will begin to experience BDVs at around 1.7Vr. The 63V designs followed a similar trend with MnO_2 designs observing a BDV at as little as 1.1Vr while the 63V polymer designs reached their earliest BDVs at 1.7Vr. Finally, it was observed that a 75V MnO_2 design would follow a similar BDV trend to the 63V polymer based on the data collected during this assessment.

Reliability of Tantalum Polymer Designs

A life test was conducted to establish a baseline for the long term reliability of these higher voltage polymer designs. Testing was conducted at 105˚C at rated voltage for 2000 hours and included 200 pieces of a 10uF/50V design with a maximum ESR limit of 90mOhms post mount. Test measurements were collected at 0, 250, 500, 1000 and 2000 hours. Critical areas of performance included the rate of ESR decay and stability of Leakage throughout testing.

As shown in Figures 4, the ESR of each device remained stable through 1000 hours of testing. From 1000 to 2000 hours, approximately twenty percent of the population experienced a shift in ESR ranging from 3 to 19 mOhms. This shift in ESR is commonly associated with slow oxidation of the polymer over time at high temperature conditions. While this shift in ESR is commonly observed under such conditions as a 105˚C and 125˚C life test, applications operating at 85˚C or less will typically observe little to no noticeable shift in ESR throughout the life of the application.

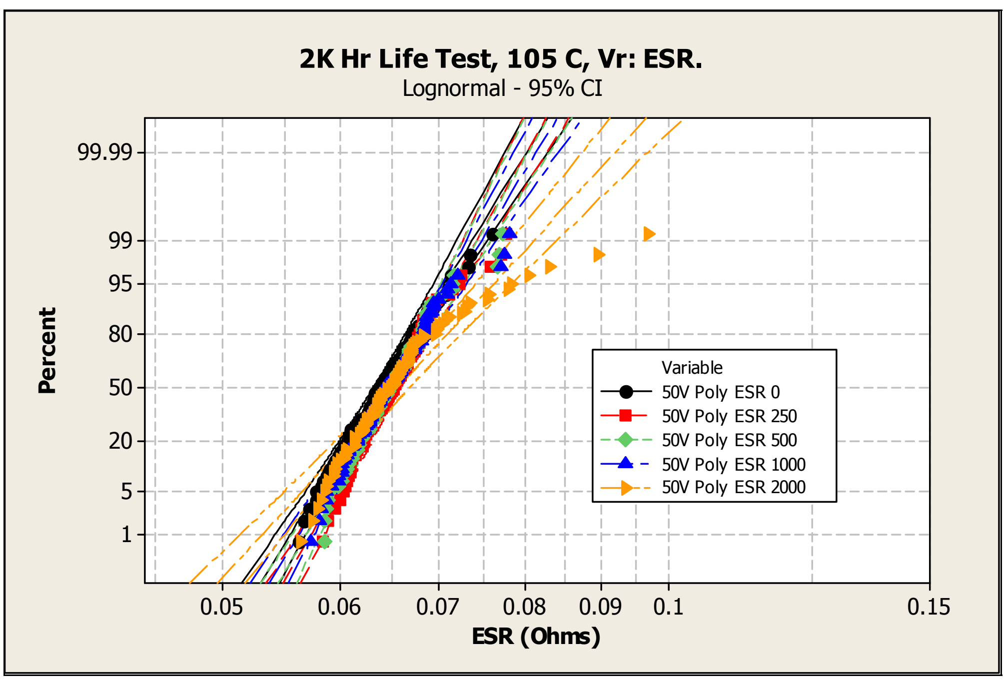

Figure 4: 50V Polymer Post 2000 Hours Life Test ESR Performance.

Figure 5 demonstrates the long term leakage performance of the 50V polymer design. Leakage performance indicates how stable and robust the dielectric construction is over an extended usage time. The decreasing leakage behavior observed during testing is the result of continuous localized polymer oxidation brought on by the localized heating of the leakage sites within the device. As the polymer in contact with the leakage site oxidizes due to heating, its resistivity continues to increase over time. This continued increase in resistivity at the leakage site will restrict the flow of current and reduce the total leakage value over time.

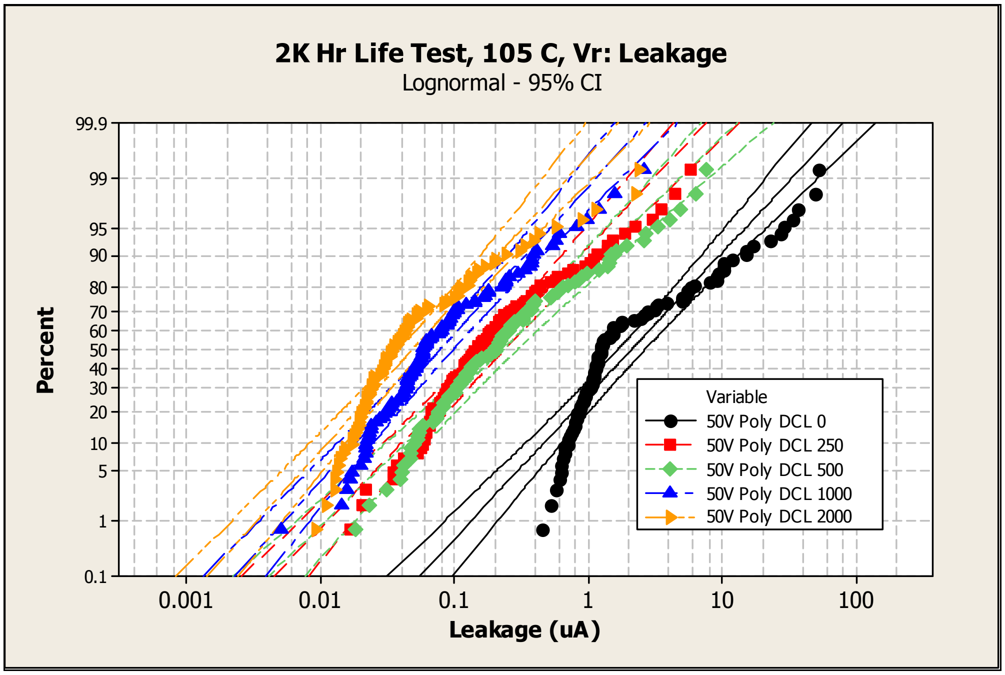

Figure 5: 50V Polymer Post 2000 Hours Life Test Leakage Performance

Tantalum polymer capacitors are associated with having a higher leakage value than their MnO_2 counterparts. However, it has been observed in recent years that the new high voltage polymer process has routinely demonstrated a comparable or even lower leakage value than similarly matched MnO_2 designs at the end of long term testing.

To assess this behavior with these most recent high voltage offerings, a comparison of the above 10uF/50V polymer design was made for an identically rated commercial grade MnO_2 capacitor. Test conditions were identical to the above with a 2000 hours test time at 105˚C and rated voltage.

As shown in Figure 6, the leakage performance at the end of 2000 hours demonstrated a better overall leakage performance for the polymer design compared to the MnO_2 design. It is hypothesized that the reasons for this reduced leakage may be related to the differences in the quality of the dielectric between these two devices. While both devices were built with similar dielectric thicknesses, the MnO_2 design may have produced more dielectric defects due to the extreme temperatures and stresses applied to the MnO_2 devices dielectric during cathode processing. The details of these process differences are however outside the scope of this paper.

As stated above, this analysis was based on a commercial grade MnO_2 design and may not reflect the same behaviors that would be observed on a high reliability MnO_2 design or a low leakage MnO_2 series design.

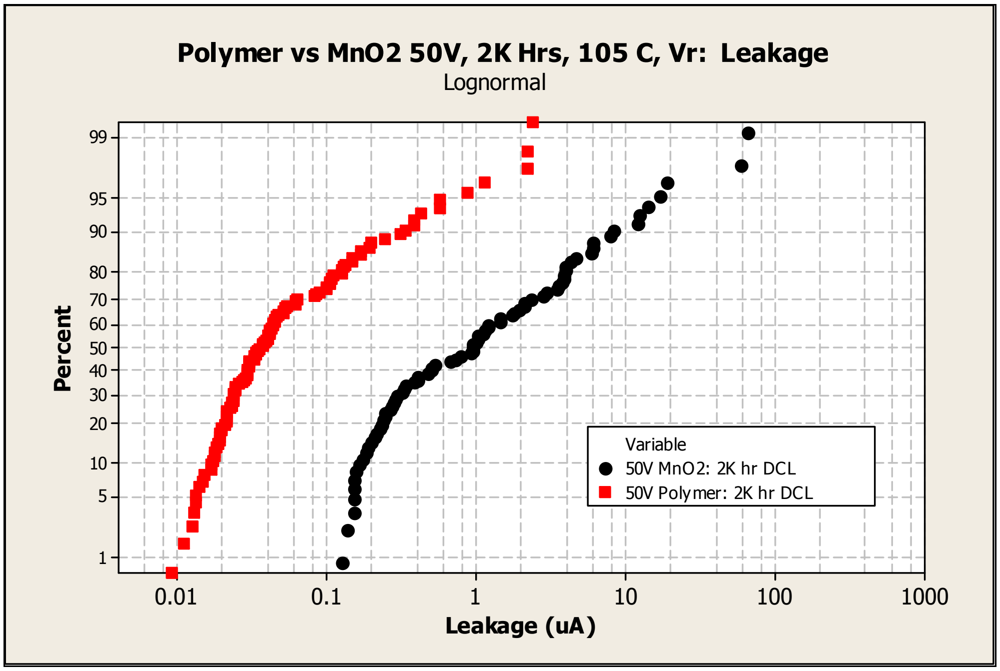

Figure 6: Leakage Performance of Polymer vs MnO_2 Tantalum Post 2000 Hrs Life Test

Summary

The continued development of higher voltage rated tantalum polymer capacitors has led to the recent release of 50V and 63V product offerings. The primary application for these devices is in the replacement of currently used commercial grade tantalum MnO_2 capacitors for common 24V input rails as well as the 28V avionics power rail. While the primary driver for replacing the current solution is most associated with initial power on performance and safety concerns, this paper demonstrates that there are also advantages in the overall performance of the tantalum polymer capacitor as well.

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