TECHNICAL PAPER

Tantalum Polymer vs Aluminum Polymer Performance as an Output Filter Capacitor for Miniature Switching Power Supplies

R. Demcko
A. Stanziola
D. West
KYOCERA AVX Components Corporation
One AVX Boulevard
Fountain Inn, S.C. 29644 USA

Abstract
Engineers have questioned the impact performance of converting Aluminum Polymer capacitors to Tantalum Polymer capacitors in applications where MLCCs are present on the output filter 'bank' of a small switching power supply. The reasons for designers to convert to Tantalum Polymer capacitors in the design ranged from long term reliability and stability to availability/delivery and company specific design guidelines.

This investigation is intended to compare the interchangeability of Tantalum Polymer Capacitors in a design with the original Aluminum Polymer capacitors. The data collected was the measured output voltage ripple on a highly utilized circuit/chipset under a specific conditions of an end user. Comparisons between Aluminum Polymer Electrolytic and Tantalum Polymer Electrolytic technologies are made.

TANTALUM POLYMER VS ALUMINUM POLYMER PERFORMANCE
AS AN OUTPUT FILTER CAPACITOR FOR MINIATURE SWITCHING POWER SUPPLIES

Ron.Demcko@avx.com Ashley.Stanziola@avx.com Daniel.West@avx.com

INTRODUCTION

A common theme present in electronic designs is smaller, lighter, more functionality, more reliability and lower costs. Power supplies have a difficult goal to deliver given that the semiconductor's load power requirements in the circuit have become more power hungry and tolerate less ripple since Vcc levels are constantly dropping though many times reverting to multiple Vcc rail levels.

Luckily the use of switching power supplies can deliver higher power conversion efficiency along with reduced size & weight when compared to other solutions. Its because of this that IC houses have concentrated efforts on creating chipsets intended to provide a simple switching implementation with a single chip or two.

Switchers can pose problems in terms of noise and output ripple but thanks to progress made in designs, simulations and capacitor technology – switchers are here to stay.

Many times the output filters consist of ceramic capacitors for high frequency noise filtering and bulk capacitors for low frequency filtering / large curent hold up functions. A typical schematic is shown in figure 1.

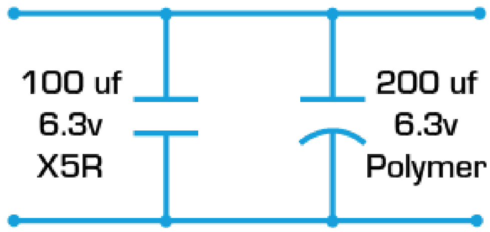


Figure 1 Output Filter Capacitor Schematic

This study concentrates on defining bulk filter capacitors performance & its impact upon ripple. As IC rail voltages decrease, the amount of acceptable ripple voltage decreases. Therefore output capacitor performance is an enabling feature to a successful low ripple switcher.

Bulk capacitors have made trememdous progress in recent years based upon demands from high volume end users across the spectrum of electronics. This comparison will only look at conductive tantalum polymer and conductive aluminum polymer capacitors.

Stacked MLCC capacitors were not considered in this investigation due to the end circuits small size and small power rating.

It is important to note that stacked ceramic capacitors do not necessarily exhibit excessive DC bias instability effects. This is a common misconception associated with stacked ceramic output filter capacitors. DC bias instability is a direct function of ceramic dielectric type chosen to build the ceramic capacitors. Class I ceramic dielectrics exist which exhibit zero DC bias characteristics to high DC bias instability. However, stacked ceramic capacitors were not considered due to the nature of the test circuit.

TANTALUM POLYMER VS ALUMINUM POLYMER PERFORMANCE

POLYMER CAPACITOR TECHNOLOGY

The introduction of conductive polymers in the world of bulk capacitors offers end users multiple advantages. First,conductive polymer technology reduces the ESR of the capacitor significantly. Reduced ESR allows the capacitor to handle higher currents with less heating.

Also, the use of conductive polymers improves the reliability/performance of the capacitor and shifts the failure modes into benign failure type category. A failure site occurs by a defect from either a problem in manufacturing or one that is introduced from end use miss applications. The failure site will experience heating which transforms and isolates the area via a "peel off" of the cathode. The failure is effectively isolated and results in a benign failure.

The predominant options for small to intermediate output bulk capacitor technology is either aluminum electrolytic or tantalum technology based. Both technologies have conductive technnology counterparts and many times the conductive polymer version of the output capacitor options is selected in small power switching supply design.

A comparison of the options follow.

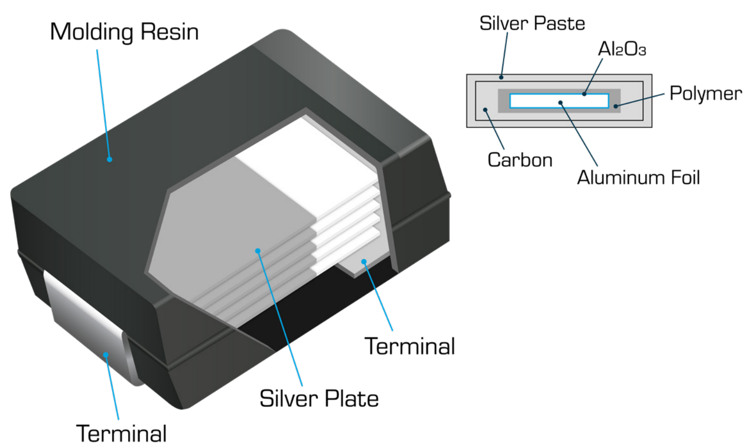
ALUMINUM POLYMER CAPACITOR

Aluminum conductive polymer capacitors come in either layered or wound styles.

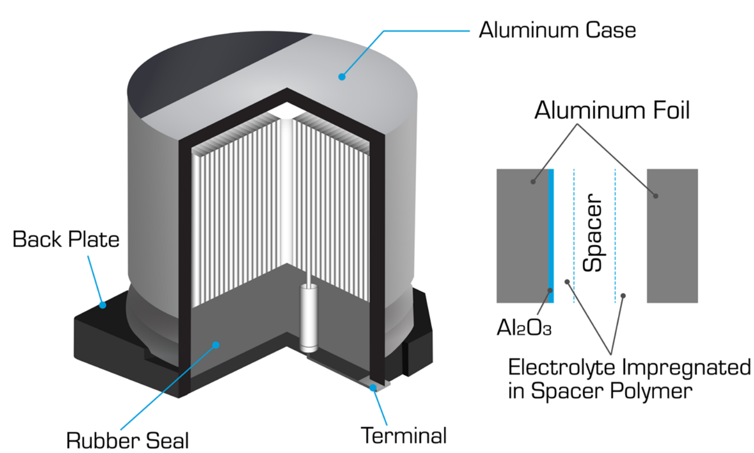
In the case of layered conductive polymer aluminum capacitors, a conductive polymer is the electrolyte. The layered devices have an aluminum cathode as shown in figure 2a.
Layered aluminum polymers tend to offer reduced inductance over wound aluminum polymers – thus extended frequency response.

Also layered aluminum polymers exhibit greatly reduced heights relative to wound aluminum polymers. Lowered height results in better shock and vibration performance as well as ease of implementation into height-constrained designs. The case of layered aluminum polymers is resin compound with J leads.

Wound conductive epoxy aluminum polymers are based upon a conductive polymer electrolyte but utilize a wound electrode structure vs stacked (as in the case of layered conductive polymers) shown in figure 2b. Wound aluminum polymers offer a larger capacitance range than layered aluminum polymers. In addition, wound aluminum polymers provide lower ESR than stacked Aluminum polymer technology.



Layered Aluminum Polymer - 2A



Wound Aluminum Polymer - 2B

Aluminum Conductive Polymer Capacitor Types Layered Figure 2A - 2B

TANTALUM POLYMER VS ALUMINUM POLYMER PERFORMANCE

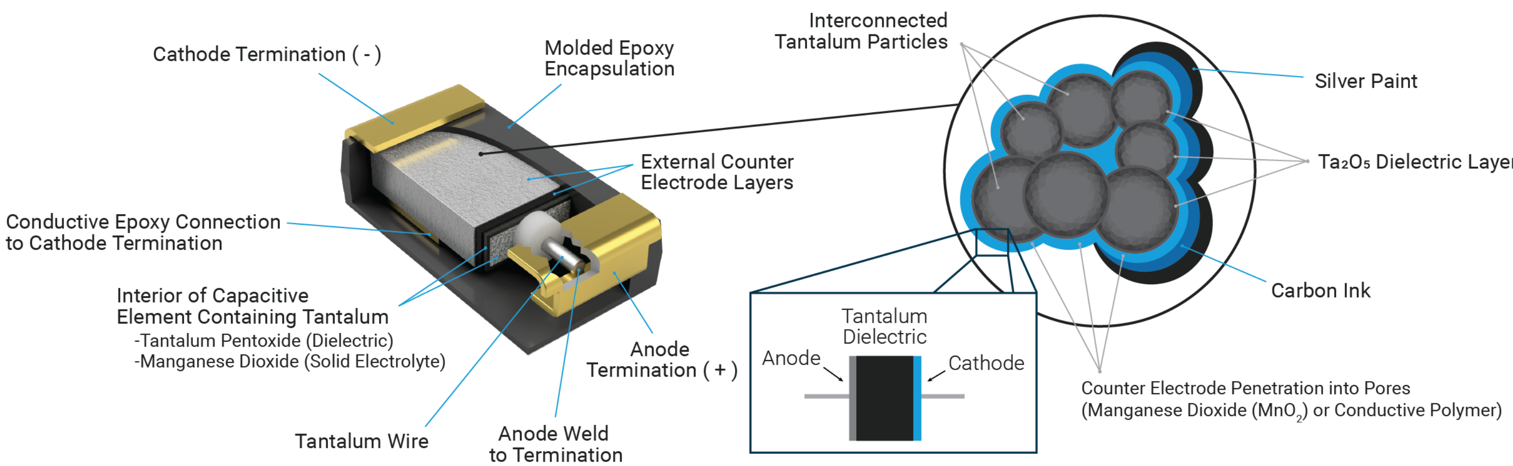
POLYMER CAPACITOR TECHNOLOGY

Tantalum conductive polymer capacitors are created by utilizing a conductive polymer in the cathode of the tantalum capacitor (figure 3). The anode wire is tantalum and a porous pellet of Tantalum powder is pressed onto the anode wire. The resulting structure is sintered into a monolithic block and a Ta2O5 dielectric is formed. A conductive polymer layer is deposited onto that structure and with added processing a tantalum conductive polymer capacitor is formed.

Tantalum conductive polymer devices are able to exhibit very low ESR and Equivalent Series Inductance as low as 1nH. These devices exhibit dramatically lower ESR over traditional tantalum capacitors and thus can withstand much higher ripple currents.

A general comparison of aluminum and tantalum conductive polymer technology is shown below. A key feature of Tantalum conductive polymer capacitors is the flexibility in case sizes and component height.

Currently case size dimensions can range from 0402 to 2924 and heights can be as low as 0.55mm. It is important to note the broad range of conductive tantalum polymer capacitor sizes allow designers to place these capacitors at ideal PCB locations for maximum efficiency. The below table provides a high level over view of polymer bulk capacitors and the blue text within figure 6 provide a more defined window on component options available.



Tantalum Conductive Polymer Cross Section
Figure 3

Conductive Polymer Bulk Capacitor Technology Comparison

Key: X Low; – Fair; ▲ Good; ● Best

Technology	Cap Range	Voltage Range	Temperature Range	Leakage Current	Size	Frequency Characteristics	AEC Q200	Life
Ta Polymer	▲	●	●	▲	●	●	▲	●
Layered AlEl Polymer	▲	▲	▲	▲	▲	▲	▲	▲
Wound AlEl Polymer	●	▲	▲	▲	X	–	▲	▲

TANTALUM POLYMER VS ALUMINUM POLYMER PERFORMANCE

TEST BOARD DESCRIPTION AND SET UP

The LMZ22005/03 evaluation board is designed to evaluate the capabilities of the SIMPLE SWITCHER® power modules from TI (fig 4). This evaluation board accepts input voltages between 6V and 20V and converts that to a selectable output voltage in the 0.8V to 6V range. The output voltage selected for this study was 3.0 volts.

The LMZ22005/03 design is based upon a control loop that requires the use of low ESR output capacitors.

Since the purpose of this test was to evaluate the impact of various bulk output filter capacitors, the capacitor at Co5 (fig 2) was chosen to be tested with two capacitor technologies – Layered Aluminum Polymer & Tantalum Polymer capacitors.

Specifically, AVX P/N: TCJD227M006#0015 was compared to a 220µF 6.3V 15 mΩ rated conductive aluminum polymer.

It is important to note that the original layered aluminum polymer capacitor used in the design was made obsolete and the customer sought suitable alternatives.

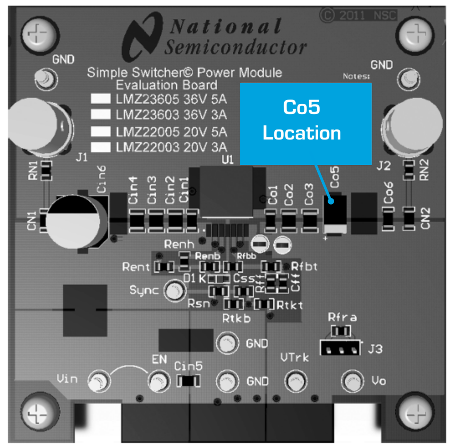


Figure 4 LMZ22005/03 Evaluation Board

TEST BOARD DESCRIPTION AND SET UP

The test configuration was a power supply driving the LMZ22005/03 board. An electronically programmable load was placed on the evaluation boards output and an oscilloscope was used to measure ripple voltage. This is shown graphically in figure 5 below.

In this figure, an HP3610A power supply set to 9 volts was used to power the evaluation board. An ITECH IT8511DC electronic load was placed upon the evaluation boards output terminals and ripple voltage was measured by an HP5464D.

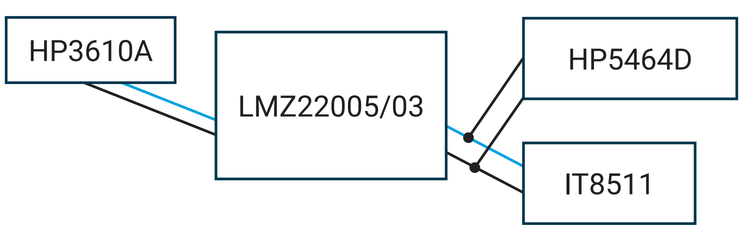


Figure 5 Test Configuration

TANTALUM POLYMER VS ALUMINUM POLYMER PERFORMANCE

TEST RESULTS

This test looks at comparing the output ripple voltage when using similar capacitance and rated ESR value Layered Aluminum Polymer capacitors and Tantalum Polymer capacitors. As stated previuosly – the origional layered Aluminum polymer capacitor used in the design was obsoleted and the request was made for a conductive tantalum polymer to be investigated for acceptable performance in the existing dsign. This particular test compared a 15 mΩ Conductive Tantalum Polymer capacitor to a 15 mΩ Layered Aluminum polymer. Basic part descriptions are shown in figure 6.

Figure 6 shows the exact comparison of the part tested. Note the small print blue comments within multiple cells which outline the envelope of options available for other conductive Tantalum polymer components. The blue comments show the boad range of conductive polymer tantalums that are available for other circuit designs.

The specific circuit involved for this test had a 100µF X5R capacitor is placed in parallel with the polymer part and it was assumed that the resulting ESR of the combination would result in acceptable ripple.

Part Type 220 µF @6.3v	Cap µF	Voltage VDC	ESR mΩ	Case Size mm	XY area mm^2	Part Volume mm^3	Unit Weight mg	Inductance nH
TaPoly	220	6.3	15	7.3x4.3x2.9	31.4	91	278*	2.4*
Available TaPoly part window	1 to 1500	2.5 to 125	As low as 6 milliohms	As low as 1.1x0.6x0.55mm	As low as 0.363mm^3	As low as 0.363mm^3	As low as 1mg	1.0 to 2.5 Range
Layered Al Polymer	220	6.3	15	7.3x4.3x2.9	31.4	60	130	1.41

Figure 6 Polymer Capacitor Description
*part as tested

Both capacitors were tested at 25°C with a 2amp load. The layered Aluminum Polymer provided a ripple of 9.84 mV compared to that of the Tantalum Polymer of 10.00mV (figure 7).

A delta of 0.16 mV is felt to be so small it is within the reasonable direct cross capability. Oscilloscope traces of measured data are shown in figure 7.

220 µF 6V TaPolymer TCJD227M006R0035E	220 µF 6.3V Aluminum Polymer
10.00 Millivolt Ripple	**9.84 Millivolt Ripple**

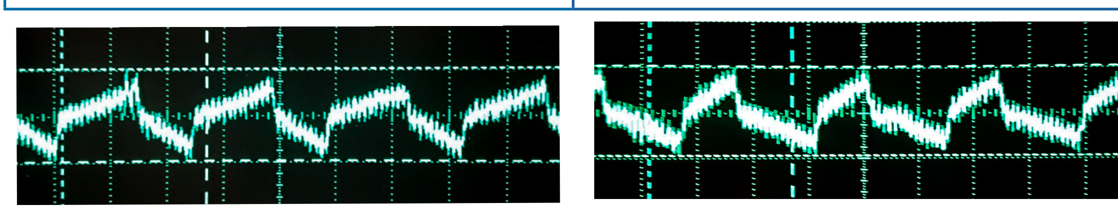


Figure 7 Tantalum Polymer vs Aluminum Polymer Ripple Voltage

SUMMARY

The testing performed proves that Conductive Tantalum Polymer capacitors can effectively compete with and replace Aluminum Polymer capacitors in output filter applications.

Conductive Tantalum Polymer capacitors offer designers multiple advantages ranging from ease of use due to wide case sizes and under-tab lead frame options to exceptional reliability.

Conductive Tantalum Polymer Capacitors have characteristics such as, case sizes as small as 0402, part volume as low as 0.363mm3, and weight as low as 1mg; which are ideal for weight sensitive applications. Modern day cores such as microcontrollers, microprocessors and FPGA frequently utilize these devices as miniature bulk filter caps.

Conductive Tantalum Polymer capacitors reliability is better than 1%/1000 hours at 85°C with 100mΩ series impedance at 60% confidence level. Additionally, several families of enhanced reliability devices exist such as AEC Q200 auto grade and European Space Agency qualified series.

Added information regarding AVX conductive Polymer Tantalum capacitors can be found in AVX simulation software found at: http://www.avx.com/design-tools/tantalum-capacitor-models/

NORTH AMERICA
Tel: +1 864-967-2150

ASIA
Tel: +65 6286-7555

CENTRAL AMERICA
Tel: +55 11-46881960

EUROPE
Tel: +44 1276-697000

JAPAN
Tel: +81 740-321250