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Space-Grade Tantalum Polymer Caps Deliver Lower ESR And Better Current Handling For Bulk Capacitor Applications

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Possibly no sector has experienced such massive fundamental changes as that of space-based systems in the past few decades. A balance of public and private partnerships worldwide now reflects this sector's growth. This is quite a departure from developments that were once exclusively dominated by government agencies.

The need for end services is growing exponentially from demands as traditional as space exploration to accelerating space-based defense concerns. If those needs were not enough, the demand for further accessibility is turbo charged by the needs of telecommunications, financial services, earth observation and navigation sectors to name a few.

Completely new launch platforms now deliver payloads ranging from traditionally sized satellites to picosats and everything in between. Production methods have expanded to include additive manufacturing processes that reduce cost, weight and time to market for end payloads.

Advances in flight electronics have delivered just as amazing performance from innovation in both active and passive electronics. Discussions of active electronic components are commonplace. Active device discussions are dominated by topics such as FPGA processing improvements or GaN efficiency impacts.

A summary of passive component evolution is harder to find. But typically, advanced actives require higher power quality, better decoupling, broader frequency dc blocking and better filtering/bypass. Advanced performance passive components are required to meet the ICs' expanded requirements and allow optimum performance. In response to these requirements, advances in material systems for capacitors have been applied to capacitors targeting space applications.

Multilayer ceramic capacitors (MLCCs) have had a major new product offering in the acceptance of established reliability (ER) base metal electrode (BME) devices that provide high capacitance/unit volume (Hi-CV) in small case sizes (see the reference). These miniaturized devices also have low inductance options available, which exhibit circuit efficiencies so high that fewer capacitors are needed to achieve a given function. NASA, ESA and Defense Logistics Agency (DLA) all have accepted this technology and generated flight-grade specifications for designers to utilize.

Modern space electronics has a similar need for advances in *bulk capacitors*. Solid tantalum capacitors using MnO_2 cathodes are used in space applications because of their large capacitance in a small size and their infinite useful life. Significant advances are occurring in traditional tantalum capacitors. Among traditional MnO_2 tantalum capacitor trends are lowered ESR, increased CV, higher voltage rating and smaller case sizes.

This article provides an update on advances beyond the traditional MnO_2-based tantalum capacitors. Specifically, we will discuss tantalum polymer capacitors and outline their electrical performance relative to traditional MnO_2 tantalum capacitors. The article will also provide an update on tantalum polymer agency qualifications.

Tantalum Polymer Capacitors: Features And Construction

Tantalum polymer capacitors are miniature bulk capacitors that are available in a variety of quality levels and case sizes. A key feature of tantalum conductive polymer capacitors is improved ESR over traditional MnO_2 tantalum capacitors. Polymers exhibit approximately one-eighth the ESR of standard tantalum devices and therefore can handle about 8x the current of MnO_2 devices.

Polymers also exhibit improved energy density. This feature creates a flexibility for designers to find reasonably sized bulk capacitors in small case sizes with reduced component height. Currently, case size dimensions can range from 0402 to 2924 and heights can be as low as 0.50 mm.

From a mechanical point of view, such small sizes translate into the capability of tantalum polymer bulk capacitors to withstand the high levels of shock and vibration associated with automotive and flight applications. Electrically, the smaller case sizes allow designers to place these capacitors at ideal PCB locations—typically close to the load with minimized loop inductance for maximum circuit efficiency.

The wide number of different-sized cases available allows designers to utilize the ideal physical device in most applications. The capacitor's inductance is primarily a function of the length, width and height of the capacitor. The case dimensions drive the mounting pad layout and the combination of capacitor plus PCB mounting pads determines the loop inductance exhibited by the capacitor in circuit. The important thing to realize is that the tantalum polymer case sizes vary by a letter call-out code and not all letters are sequentially larger than the prior one. A summary of tantalum polymer capacitance inductance is shown in Table 1.

Table 1. Tantalum polymer Inductance (nH) by case size.

A = 1.8	G = 1.8	P = 1.4	V = 2.4	4 = 2.2
B = 1.8	H = 1.8	R = 1.4	W = 2.2	5 = 2.4
C = 2.2	K = 1.8	S = 1.0	X = 1.8	8 = 2.2
D = 2.4	L = 1.0	T = 1.0	Y = 2.4	
E = 2.5	N = 1.4	U = 2.4	Z = 1.8	

Tantalum polymer capacitors have the added advantages of:

- Wide capacitance range with low inductance in small-case face down/undertab package
- Wide voltage range of 2.5 V to 125 V
- Lower derating required:
  - 90% rated voltage/10% voltage derating for products rated up to 10 V
  - 80% rated voltage/20% voltage derating for products rated 16 V and higher
- Benign failure mode if shorted
- No dc bias voltage effects, no piezo effect
- High reliability—space-flight-qualified and automotive-grade families are available.

Tantalum polymer capacitors are created by utilizing a conductive polymer in the cathode of the tantalum capacitor as shown in Fig. 1. 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 Ta_2O_5 dielectric is formed. A conductive polymer layer is deposited onto that structure and with added processing a tantalum conductive polymer capacitor is formed.

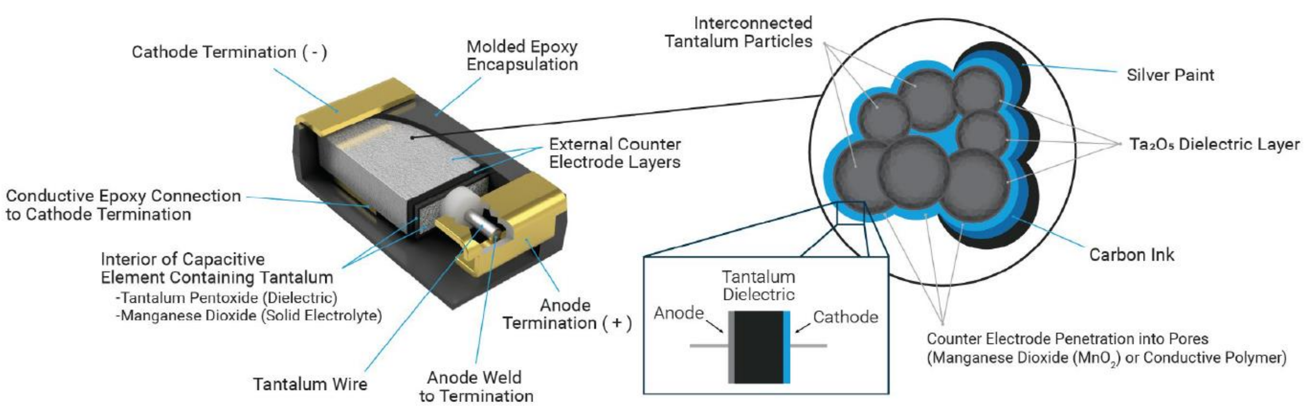

Fig. 1 Conductive polymer capacitor cross section.

This results in very low ESR devices compared to traditional tantalum devices. ESR reductions of up to eight times are reasonable to expect and they translate into up to eight times the current capability compared to traditional tantalum capacitors.

Parameters To Consider

Conductive polymer tantalums differ from traditional tantalum capacitors in several ways worth considering when selecting an end device.

First, conductive polymers have a sensitivity to moisture and carry a moisture sensitivity level (MSL) rating of 3 or higher. A level 3 rating means the parts are supplied in dry pack and need to be processed within 168 hours after opening, or dried at 40°C for 168 hours prior to use. For reflow processes, AVX recommends following JEDEC 020 requirements. A maximum of three reflow cycles with a peak of 260°C for a total duration of 30 seconds are recommended.

Moisture affects polymer performance in two ways. One is that, during the reflow process, moisture presence (steam) creates internal pressure on polymer layers throughout the reflow mounting process and immediately impacts device performance and, in extreme cases, reliability.

The other effect is that, with long-term exposure, excess moisture initiates a degradation of the polymer cathode material, which accelerates with increasing levels of temperature and voltage. This can result in a drop in conductive polymer conductivity (increased ESR) and create a shift in capacitance, which is generally non-recoverable. However, hermetic-case tantalum polymers sufficiently isolate the polymer material system where this characteristic is of little concern.

Anomalous charging current (ACC) is a temporary increase in the dc leakage of conductive polymers that occurs during initial charging, typically when a device has experienced excessive drying. Anomalous charge currents can be detrimental to circuits, which need rapid charging immediately after reflow or at low/ambient temperatures. ACC effects can return to normal leakage current range within hours of initial appearance. The magnitude of ACC is part-number dependent and reducing ACC requires selection of a specific part family.

Tantalum polymers cannot make use of Weibull grading due to a lack of infant mortals and a more latent failure mode created by wear out and parametric shifts. Tantalum polymers exhibit acceptable reliability when compared with aluminum electrolytics and tantalum MnO_2-based devices. The effect of wear out of cathode material from humidity and oxidation is shown in Fig. 2.

It must be stressed that adequate selection of tantalum polymer devices—from fully hermetic series to enhanced moisture/humidity isolation greatly expands the useful life of these components. For example, fully hermetic parts shift potential cathode wear out to well beyond the useful life of even the longest mission requirements.

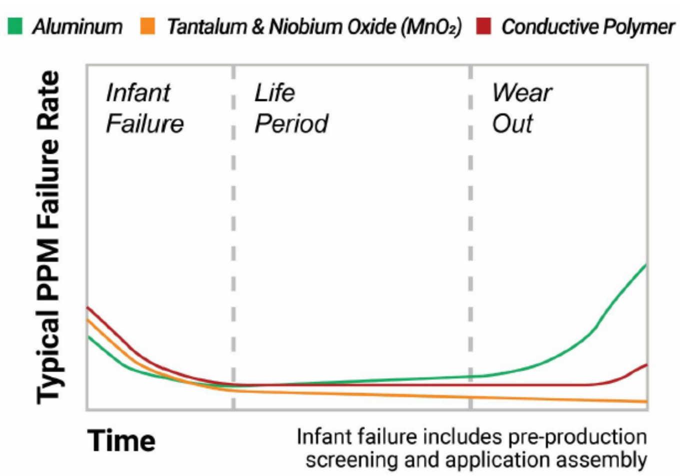

Fig. 2. Solid electrolytic capacitor relative FIT rate vs. time comparison.

A high-level comparison of tantalum polymer to MnO_2 tantalum is shown in Table 2. As expected tantalum polymers exhibit dramatic ESR (and therefore RMS current) capabilities. Other parameters are manageable based on careful selection of end-device package and styles.

Table 2. High-level comparison of tantalum polymer versus MnO_2 capacitors.

Feature/performance	Tantalum polymer	MnO_2 tantalum
High-temperature storage	Possible ac characteristic degradation	No concern
Moisture sensitivity level	MSL 3 – 5	MSL 1-3
Humidity sensitivity level, post mounting	Wear out accelerated by temperature and voltage	No concern
Anomalous transients	Occur under dry conditions	No concern
Oxidation	Wear out accelerated by temperature	No concern
ESR	Ultra-low ESR	Low to moderate ESR
DCL performance	Medium to high	Ultra low

ESA, NASA And Mil Status

Currently, the Defense Logistics Agency (DLA) has multiple drawings for tantalum polymer capacitors. Additionally, there is a DLA effort underway to create a tantalum polymer specification. The specification will be created to provide the requirements and quality assurance provisions for non-established reliability (non-ER) and established reliability (ER) conductive polymer, surface-mount capacitors.

The ER capacitors will have calculated failure rate levels (FRLs) based on a reliability assessment performed on each production lot. The first slash sheet will be MIL-PRF-POLY/1. This slash sheet will cover molded single-anode capacitors.

The second slash sheet will be MIL-PRF-POLY/2. It will cover molded multiple-anode capacitors. MIL-PRF-POLY is the working name for these specifications and a five-digit specification number will be assigned upon final approval from DLA Document Services.

Next, NASA has tantalum polymer under review for flight use.

Finally, the ESA has already recognized two different AVX tantalum polymer capacitors for flight system use. The first AVX tantalum polymer capacitor that the ESA has approved is the TCS series of capacitors. It is described in the ESA 3012/006 specification as a polymer multi-anode tantalum capacitor based on the TCS type. This family of parts has a maximum rated voltage of 50 V.

These parts have multiple uses but one very common use could be as a negative-gate-bias capacitor for a GaN transistor. Among the spectrum of parts available is a 10-µF device with a rated voltage of 35 V. In fact, 35-V rated ESA 3012/006 capacitors are approved in values up to 33 µF, which may also potentially be used on low-voltage drain-bias filtering lines.

Hermetic encapsulated tantalum polymer capacitors are available as well in the TCH series—ESA3012/00*. As discussed previously, this hermetic package was developed for extreme-use applications and successfully suppresses the impact of humidity and oxidization on the tantalum polymer capacitor.

The TCH capacitor series is ideal for flight gate and drain bias banks with voltage ratings as high as 100 V. Common values of use are 22 µF at 100-V rating, 33 µF at 75-V rating, 47 µF at 50-V rating and 150 µF at 35-V rating. These devices are also recommended for flight power conversion and distribution applications. TCH series devices are also offered as a COTS-plus grade, making them suitable for flight electronics accepting COTS plus hardware.

Summary

Space flight electronics is rapidly evolving through the use of novel active components thus impacting the need for advanced performance passives to insure optimal IC performance. Ceramic capacitors have responded to the needs of advanced actives and more demanding architectures with the MIL-PRF-32535 BME specification. Tantalum capacitors have responded with optimized size/weight MnO_2 SMT capacitors such as MIL-PRF 55365/12. The slash 12 spec calls out CWR15 devices available in 0603, 0805 and 1206 EIA case sizes.

Beyond that, tantalum polymer capacitors can be considered to be low ESR/higher-current devices for use in a variety of end flight applications. Tantalum polymer devices come in multiple families intended to optimize the device performance in end applications. Agency approval of tantalum polymer capacitors is increasing across DLA, NASA and ESA specifications. Proper selection of the tantalum polymer family will insure long-term reliable use in end applications.

Reference

"Base Metal Electrodes Reduce Size And Weight Of MLCCs In Satellites**"** by John Marshall and Ron Demcko, How2Power Today, March 2019.

About The Authors

Currently an AVX Fellow, Ron Demcko manages the TSG team at AVX headquarters in Fountain Inn, SC. This role centers on projects ranging from simulation models for passive components to product support/new product identification and applied development. Prior to that Ron was the EMC lab manager for AVX in Raleigh N.C. This lab concentrated on subassembly testing and passive component fixes for harsh electrical and environmental applications. Before the EMC lab work, he held an application engineering position at AVX. Product work included integrated passive components, EMI filters and transient voltage suppression devices.

Previously Ron worked as a product engineer and later as a product engineering manager at Corning Glass Works' electronics division. In this role he supported production, sale and development of pulse-resistant capacitors, high-temperature capacitors and radiation-resistant capacitors. He developed high-frequency test methods and co-developed high-temperature test systems. Ron received a BSEE from Clarkson College of Technology. He can be reached at ron.demcko@avx.com.

Slavomir Pala has worked at AVX in various technical positions for the past 20 years. Currently, Slavo works as a technical marketing manager in AVX's tantalum division. In this role, he provides a bridge between production R&D and the customers' latest capacitor needs, which requires detailed interaction with customers across all market segments.

Prior to AVX, Slavo spent two years at SONY TV as a production engineer. He graduated from the military aviation university in Kosice, Solvakia with a specialization in airborne radio and airborne radar equipment. Slavomir can be reached at slavomir.pala@avx.com.

For more information on capacitors, see How2Power's Design Guide, locate the Component category and click on "Capacitors". For information on power design for space applications, see How2Power.com's Space Power section.