vPolyTan™ Polymer Tantalum Capacitors, Hi-Rel COTS, Ultra Low ESR

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INTRODUCTION

Avionics, military, and space (AMS) applications are experiencing high growth due to the need for new and advanced equipment to replace the old systems that have outgrown their usefulness. These new systems are being designed to meet next-generation air, battlefield, and space requirements. Systems like Identify Friend or Foe (IFF) and phased array radar for tracking and target detection, avionics controls and displays, and power systems are designed for extreme environmental and electrical characteristics, like those in MIL-STD-704. The need for AMS customers to maintain their competitive edge is what's driving market growth.

A byproduct of this modernization effort is the need for capacitors with higher volumetric efficiency, reliability, voltage ratings, and bulk capacitance. To meet this need, engineers have been turning to Vishay Intertechnology's vPolyTan™ solid polymer tantalum capacitors.

WHAT ARE POLYMER TANTALUM CAPACITORS?

Unlike most capacitor technologies, solid polymer tantalum devices do not utilize plates for the anode and cathode. The anode is composed of a tantalum powder that is sintered into a tantalum pellet. This pellet is then anodized to form a tantalum pentoxide (Ta_2O_5) dielectric layer on the entire surface of the anode. The oxidized pellet is then impregnated with highly conductive polymer to act as the cathode.

At this point, the conductive polymer layer is then coated with graphite, followed by a layer of metallic silver, which provides a conductive surface between the capacitor element and the outer termination (lead frame or other).

Molded chip polymer tantalum capacitors encase the element in plastic resins, such as epoxy materials. The molding compound has been selected to meet the requirements of UL 94 V-0 and outgassing requirements of ASTM E-595 (see Fig. 1).

After assembly, the capacitors are tested and inspected to assure long life and reliability.

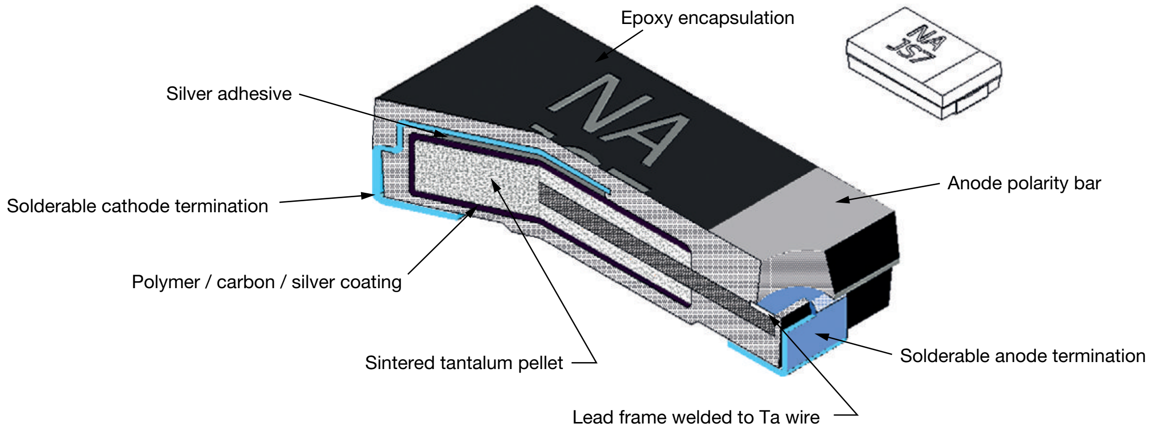

Fig. 1 - Example of a Molded Polymer Cross Section

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CONDUCTIVE POLYMER VS. MANGANESE DIOXIDE (MNO_2) TANTALUMS

The construction of conductive polymer capacitors is similar to that of manganese dioxide (MnO_2) tantalums. The major difference is in the material used to create the solid electrolyte. Standard MnO_2 capacitors have the conductivity of typical semiconductors. For conductive polymer capacitors, inherently conductive polymer (ICP) materials are used, which have an electrical conductivity several orders of magnitude higher. As a result, conductive polymer capacitors have a much lower equivalent series resistance (ESR) and require lower levels of voltage derating than MnO_2.

NO PYROTECHNICS / IGNITION FAILURE IN POLYMERS

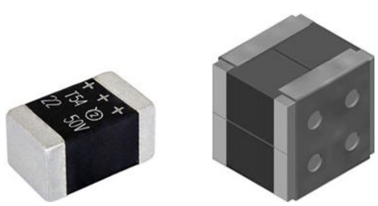
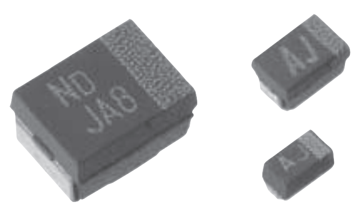
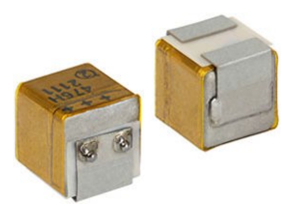
Another feature of conductive polymer capacitors is the absence of an ignition failure mode due to less oxygen content in the material.

Impurities in a capacitor's dielectric can result in a high current leakage point. The self-healing mechanism at work in MnO_2 tantalum capacitors is based on a thermally induced transformation of MnO_2 molecules into a more resistive Mn_2O_3 + O. If the leakage current causes a temperature rise that's high enough, the Mn_2O_3 forms and insulates the fault from further current flow, or "self-heals". If the free oxygen molecules that are created in the process interact with the tantalum at a high enough temperature, it can ignite and perform pyrotechnics.

If the same impurity occurs in the dielectric of a polymer capacitor, there is no oxygen available for combustion and hence no ignition failure. Self-healing will occur, resulting in a highly resistive material forming around the imperfection.

VISHAY'S HI-REL PRODUCT OFFERING

TABLE 1 - HIGH VOLTAGE RATED POLYMERS

T54	T56	T27
Lead frameless molded stacked polymer, Hi-Rel COTS	Molded case polymer, Hi-Rel COTS	Hermetically sealed polymer
		
16 V to 75 V	2.5 V to 50 V	16 V to 75 V
15 μF to 2800 μF	10 uF to 470 uF	15 uF to 470 uF
5 mΩ to 150 mΩ	25 mΩ to 200 mΩ	25 mΩ to 100 mΩ
DLA 20021	DLA 04051	-

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VOLTAGE DERATING

As discussed, the increased voltage tolerance of polymer technology allows for lower voltage derating requirements. In addition to a significantly lower ESR, the conductive polymer cathode features a benign failure mode (discussed above), so additional derating is not required for the safety concerns associated with MnO_2.

In Fig. 2 below, we see that for a rated voltage (V_R) of 10 V or less, only 10 % derating is required, while for V_R >10 V, 20 % derating is suggested. These guidelines are consistent up to 105 °C. After 105 °C, we see a linear decline of the recommended derating to 40 % for V_R. 10 V at 125 °C. Likewise, capacitors with a V_R >10 V will see a decrease to a recommended derating of 46 %.

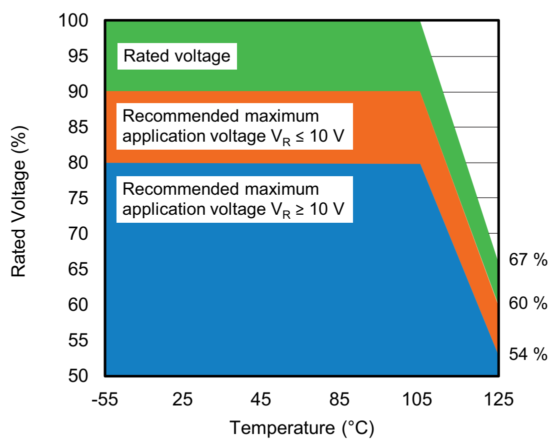

Fig. 2 - Voltage Derating

HIGH VOLTAGE

Better derating guidelines mean higher working voltages and in turn, higher volumetric efficiency. Typical polymer capacitors have a voltage rating of 50 V, but Vishay Sprague vPolyTan™ technology currently achieves ratings up to 75 V. This allows polymers to be used in MIL-STD-704, 28 V_{DC} bus (22 V_{DC} to 29 V_{DC} steady state) applications where voltage derating is required up to 125 °C.

These high voltage ratings, combined with the low derating required for polymers, give them a big leg up for volumetric efficiency over other capacitor technologies.

LOW ESR

Because the construction of the cathode is an inherently conductive polymer that has high conductivity, polymer capacitors have very low ESR, typically 10 % lower than MnO_2 tantalum capacitors. This makes the devices particularly suitable for high frequency and high ripple current applications.

HIGH RELIABILITY

Because polymers use a solid electrolyte, they are not susceptible to drying out like liquid or gel electrolytic capacitors. This drying process is a common mode of failure in aluminum electrolytics and can result in overheating. As the liquid evaporates, pressure can build up, causing it to leak, bulge, or even burst / explode. Solid polymer capacitors do not exhibit this failure mechanism and as such are much more reliable and have a longer life. Unlike aluminum electrolytics, polymer capacitors can operate for extended periods at higher temperatures without issue.

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MAP TECHNOLOGY

Vishay’s multi-array pckaging (MAP) technology packs maximum capacitance in a given volume. It achieves this by minimizing the lead frame and allowing more volume to be occupied by the actual capacitor (see Fig. 3).

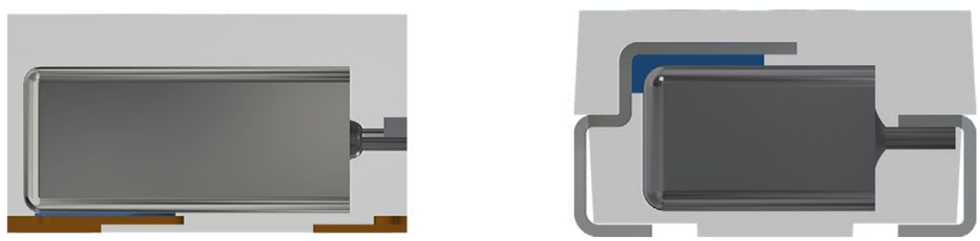

Fig. 3 - MAP vs. Molded

The Hi-Rel T54 family utilizes MAP technology to improve volumetric efficiency. Combining MAP with a dual-anode design allows for even lower ESR ratings (see Fig. 4 below).

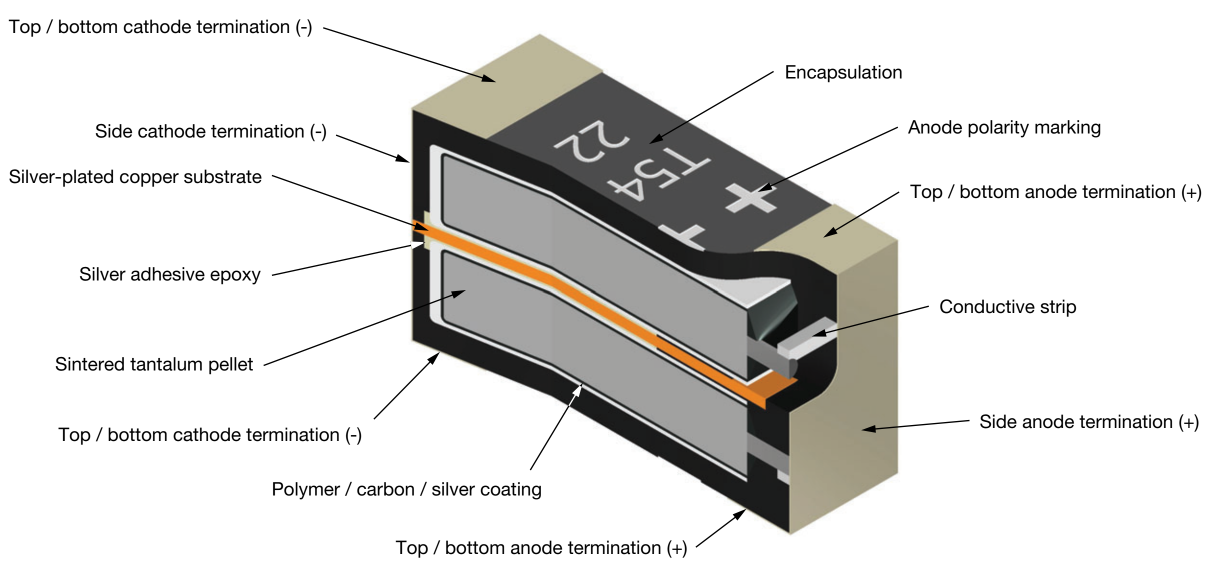

Fig. 4 - T54 MAP Technology With Ultra Low ESR, Dual-Anode Design

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STACKED CAPACITORS

Leveraging the MAP technology, Vishay has added a stacked option to the T54 family for applications needing high capacitance in a small footprint. With stacks, multiple capacitors are clamped together in parallel arrays. As the capacitors are configured in parallel, the capacitance increases with a reduction in ESR. The stacked options are 1 x 2 (one capacitor wide, two tall), 1 x 3, 2 x 2, 2 x 3, and 3 x 2. Ratings available range from 130 μF at 75 V_{DC} to 2800 μF at 16 V_{DC}. Custom arrangements can also be accommodated. These stacked bulk-capacitance configurations can save significant real estate on the designer's PCB.

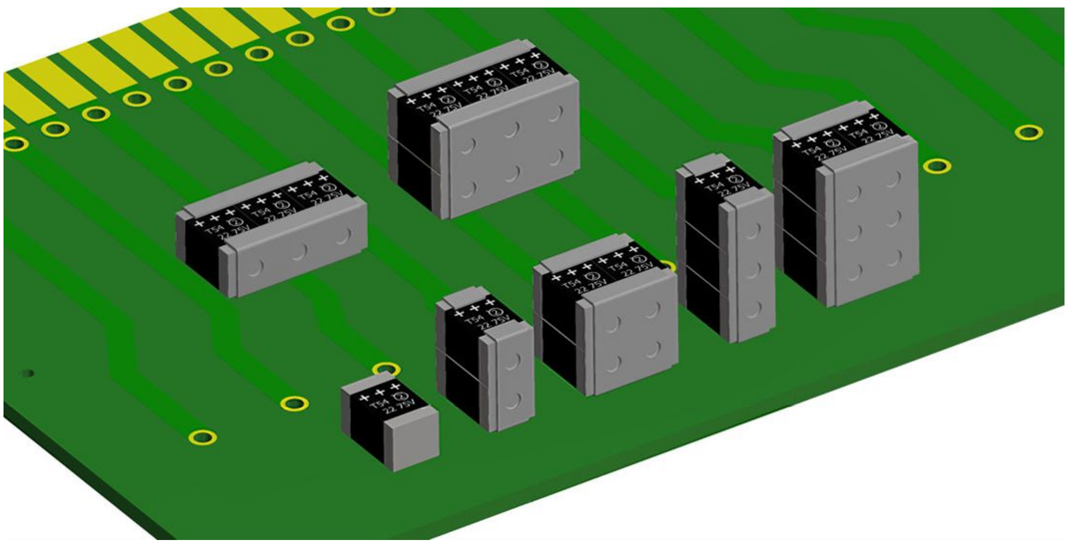

Fig. 5 - T54 Stacked Polymer Array

ENERGY STORAGE / BULK CAPACITANCE

Vishay's MAP and stacked array technology enables greater volumetric efficiency. This improvement in bulk capacitance makes polymers a good choice for applications that may require energy storage and / or rapid charge and discharge cycles, like pulsed radar, lidar, hold-up, and others.

Given the equation for energy stored in a capacitor of

$E = ½ \times CV^2$

where,

E is the energy in joules,

C is the capacitance in farads, and

V is the rated voltage in volts,

the T54 series can pack up to 5 J/in^2 in the E6 package (2 x 3 array), based on ideal conditions using the 900 μF / 35 V_{DC} rated stacked polymer solution.

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LONG TERM RELIABILITY

Unlike competing technologies like multilayer ceramic or aluminum electrolytics, polymer capacitors exhibit a no wear-out feature due to the features discussed above. This enables the long term reliability required for Hi-Rel military and space applications. Fig. 6 displays the kind of long term stability seen in polymer technology, with very little change in capacitance, leakage current, and ESR over time.

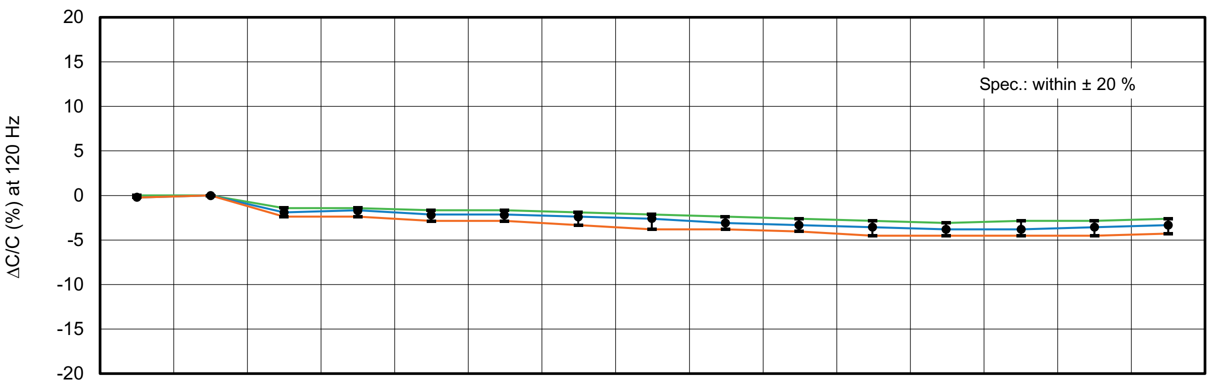

Fig. 6 - Capacitance Change

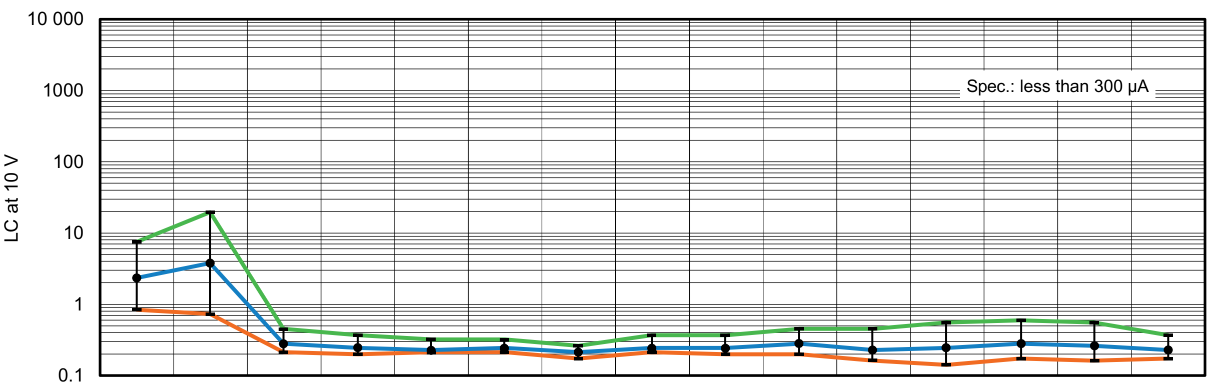

Fig. 7 - Leakage Current

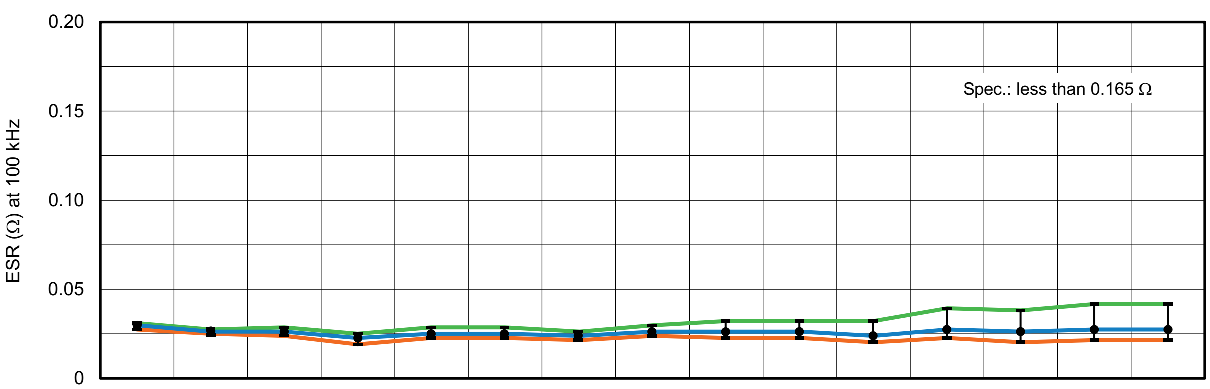

Fig. 8 - ESR

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APPLICATIONS

High end server motherboards, MIL-STD-704 power supplies, phased array radar, IFF, network infrastructure, energy storage, power conditioning, decoupling, smoothing, filtering, hold-up, and others.