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While tantalum capacitor performance is usually described in the context of various constant voltage, constant temperature tests, the capacitors themselves perform creditably under conditions of repetitive current surges and high ripple currents. This edition of Tech Topics describes the development of KEMET's T495 tantalum chip, which is designed specifically for low impedance and repetitive surge applications.

The authors, who shared the development responsibility, are members of KEMET's Tantalum Technology Team.

Vice President - Technology
Dr. John Piper

T495: A Low ESR, Surge Robust Tantalum Surface Mount Capacitor

by John J. Moore and Jim Marshall

Introduction

Since the introduction of electronic equipment and appliances, users have demanded reductions in price and size, both for consumer goods (such as radios and TVs) and industrial products (computers and instrumentation). The response from the electronics industry has been tremendous. Computers that 30 years ago filled rooms now easily rest on desktops. One of the most significant developments in the past 10 years to reduce price and size is surface mount technology. This advance comes just in time to meet consumers' growing demand for the next step beyond size reduction — portability. Desktop computers can now be carried in our briefcases or coat pockets; cellular phones and pagers are mobile. The electronics industry continues to meet these challenges by developing products that are smaller and smaller, and operate faster and faster.

Small size and increased operating speeds require a reduction in overall circuit impedance. Therefore, it is no longer feasible to add series resistance for surge protection. Components in these circuits encounter much higher turn-on current and voltage spikes than in older, slower designs. Low circuit impedance also dictates a decrease in component ESR, to prevent the component from limiting circuit speed and to minimize battery drain in portable products.

Tantalum capacitors, along with other components, must withstand the surface-mount process and then survive in low impedance circuits without contributing significantly to total circuit resistance. To satisfy these requirements, KEMET developed a surface mount tantalum capacitor that was both robust to current surges and low in ESR. This article describes the development and features of that capacitor, which became KEMET's T495 product line.

Background

The first two applications for the proposed T495 product were as output filters on switch-mode power supplies or DC-to-DC converters, and as input filters on battery-to-ground circuits. These applications demand very low component ESR and put the components in low impedance circuits where the possibility of a current surge is very real. However, most development efforts in the tantalum capacitor industry involve increasing the capacitance within a given size, often at the expense of ESR and surge robustness. To meet the needs of the target applications, the T495 needed to develop in a different direction.

Development

The causes of surge current failures in low impedance circuits had been studied for years at KEMET. Special surge current testing equipment was built using huge capacitor banks that could dump over 100 A of current into a tantalum capacitor through 0.3 ohms of circuit resistance over multiple cycles. A four-second charge and discharge cycle was used in order to allow the test equipment's cap bank to recover. Benchmark testing included KEMET and competitive product. As a result of this long-term study, the following factors were determined to contribute most significantly to surge robustness:

Dielectric Quality — Dielectric quality reflects the concentration of defect sites that exist in the tantalum oxide layer. As the number of defects increases, surge performance deteriorates.

Dielectric Thickness — Increasing the dielectric thickness in-creases the dielectric breakdown voltage and results in better surge performance.

Component ESR — Lower ESR reduces the internal heating that occurs with ripple and with DC leakage, which improves surge robustness.

Lead Wire Stability — Thermally induced increases in DC leakage current can be minimized by increasing lead wire attachment strength. Lower component parametric DC leakage improves surge current performance.

The other half of this technical challenge was to lower the component's ESR. The equation below defines the resistance of a wire: $R = \rho L/A$

R = resistance (ohm)

ρ = resistivity (ohm-cm)

L = length of the wire (cm)

A = cross-sectional area (sq. cm)

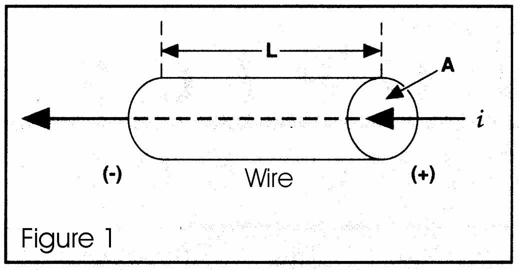


Figure 1

This same model applies to a capacitor, except that the Land A are a little different, as shown below:

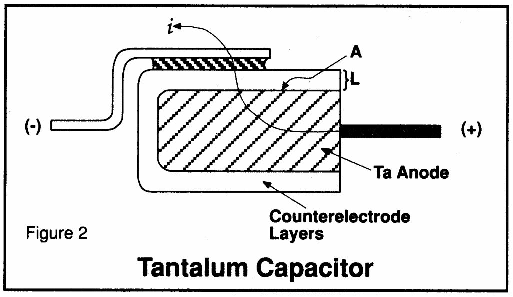


Figure 2

Tantalum Capacitor

The A (cross-sectional area) is the surface area of the anode. A larger slug increases the A term of the equation and reduces the ESR. The L (length term) is actually the thick-ness of the counter-electrode layers of the capacitor (MnO_2, Carbon and Silver). A thinner layer reduces the L value and hence, lowers the ESR. The term ρ (resistivity) is a physical characteristic of the tantalum anode and each counter-electrode layer. It is desirable to select materials and an anode structure with very high conductivity, to make the ρ term in the equation as small as possible.

Deployment

Based on the development studies, and with the objectives of the product in mind, the following systems were incorporated into the T495 product to improve its ESR and surge robustness:

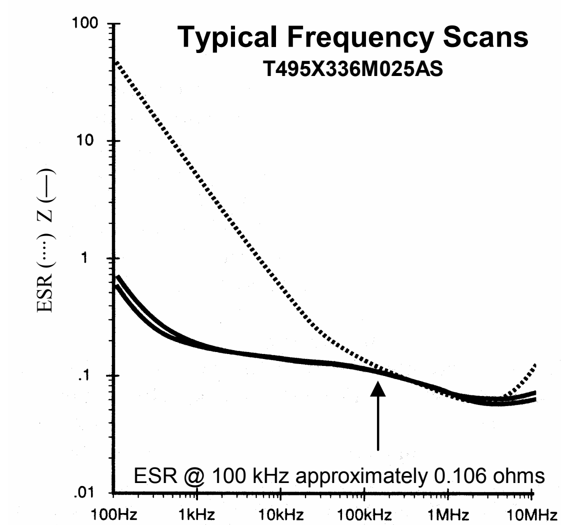
PROCESS VARIABLE	EFFECT	IMPROVEMENT
Coarse Tantalum Powder	Large internal particle connections Larger pore size for better MnO_2 coverage	ESR ESR and Surge
Maximum Anode Size	Largest possible surface area	ESR
High Form Voltage	Thicker dielectric	Surge
Modified Impregnation	Denser, more conductive MnO_2 More complete MnO_2 coverage	ESR ESR and Surge
Modified Silver	Improved conductivity (lower ρ) and coverage	ESR
Surge Screening	Removal of potential surge failures from the population	Surge
Modified Formation Parameters	Reduced number of defects per square area of dielectric	Surge
Moisture Barrier	Reduction of ionic migration during moisture exposure	Surge
Welded Tantalum Riser Wire	More stable connection to the sintered tantalum pellet	ESR and Surge

TEST	DESCRIPTION
Pulse Life	1 million cycles @ 25°C, VR, 0.3 Ω maximum circuit Z, 0.1 second charge/0.1second discharge per cycle
Steady Step Stress	85°C @ V_R Increase by $0.1V_R$ per hour through 1.6 V_R 0.3 Ω maximum circuit Z
Surge Step Stress	25°C @ VR, 0.3 Ω maximum circuit Z Increase by $0.1V_R$ every 5th cycle until at least 63% fail.
Ripple Life	85°C @ VR, 2000 hours 1.6 time maximum allowable ripple current, 40 kHz

To differentiate between standard product and the T495, some special tests were developed to demonstrate the improved performance of the new product:

Performance

A battery of tests was performed to qualify the new product and establish its specifications. In addition to the very low ESR levels, the test data also supported a reduction in DF and DC leakage limits. The T495 also has superior ripple current capability, excellent cap stability with frequency, and improved ability to withstand high inrush currents.



Conclusion

The T495 product line consists of 15 part types in D/7343 and X/7343H packages. Its capacitance and voltage ratings, coupled with the unique combination of low ESR and surge robustness, make the T495 a composite of customer driven characteristics. Some of the processes that were developed for the T495 can be incorporated in the standard T491 line as part of KEMET's continuous improvement process. Others cannot be incorporated because they would adversely limit the T491 capacitance range. The T495 development is one example of KEMET's continuous efforts to provide innovative products designed to satisfy the most challenging application requirements.

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