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Product Update – T499 High Temperature (+175°C) Tantalum SMT Capacitors

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The tantalum SMT capacitor in its solid-state structure is typically rated as capable of 125°C applications. The T498 tantalum surface mount capacitor introduced earlier this year has a maximum temperature rating of 150°C. Now with the introduction of the T499, the temperature range capability has been extended to +175°C. The difference between the T499 and the standard tantalum capacitor lies within its material set and design. The materials changed include the carbon, the silver epoxy, the silver paint, the plastic molded encapsulant, and the leadframe. These materials also differ from those changes incorporated with the T498. These materials still contain no lead and are fully RoHS[1] compliant. The standard finish on the leadframe is a matte tin plating over nickel, and the device is capable of the 260°C reflow profiles as defined in J-STD-020C[2]. A gold or tin-lead finish is also available by changing the part number designation.

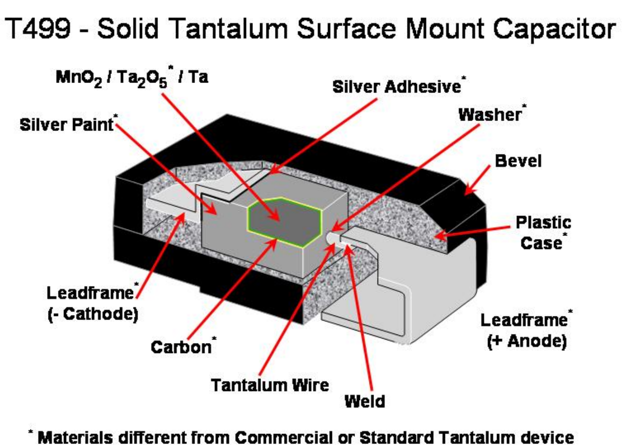

Figure 1. Structure of new T499 tantalum capacitor.

Though similar to the earlier T498, the appearance of this device is radically different from the previous SMT tantalum capacitors from KEMET, in that the color is no longer gold with brown lettering. The gold material has a heat activation of color change from yellowish gold to brown created in the presence of a controlled surface temperature rise. A laser flash through a mask is used to create the polarity and identifying marks on the gold plastic. Using this material and process in the presence of higher heats created an effect where the entire surface of the package was turning brown, and the markings became indiscernible.

The black compound has no discernable change in coloration when exposed to extended temperatures above 125°C. The marking on the package for the polarity stripe, capacitance code, voltage rating, the KEMET logo, and the print week code (PWC) are still created with a laser in a dot matrix pattern. The effect does not create a coloration change, but creates a surface abrasion as the laser removes the reflectivity of the plastic surface in the desired pattern.

Figure 2. Depiction of "D" case, T499 SMT capacitors.

The unique marking (H+) is shown in Figure 2. An explanation for the pattern with the markings is shown in Figure 3.

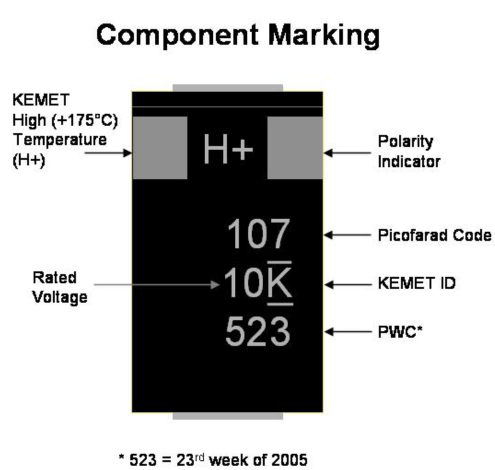

Figure 3. Component marking diagram for T499 capacitor.

The carbon, conductive epoxy, and the silver paint materials were chosen for the best offerings that would allow the device to exist in the 175°C environment without degradation. The tantalum anode structure, the tantalum-pentoxide, and the MnO_2 cathode system have been proven to withstand this temperature exposure without degradation.

Voltage Rating

The voltage rating of a component is fixed so as to create an acceptable failure rate at accelerated life conditions. Inability of a device to meet that criteria may cause the voltage rating of the component to be reduced, or the component to be redesigned (thicker dielectric) to allow for that failure rate to be achieved.

Accelerated life testing of this component at 175°C and with 50% nameplate voltage applied has shown the failure rate to be less than 0.5% per thousand-piece-hours. Failures were designated by positional fuse failure or parametric shifts beyond the initial limits.

For tantalum capacitors, a temperature related voltage derating is required to maintain that acceptable failure rate. The temperature-voltage derating of this device is slightly different from the standard tantalum SMT capacitor. These devices were created using thicker dielectrics for the voltage ratings than is required for the standard product line.

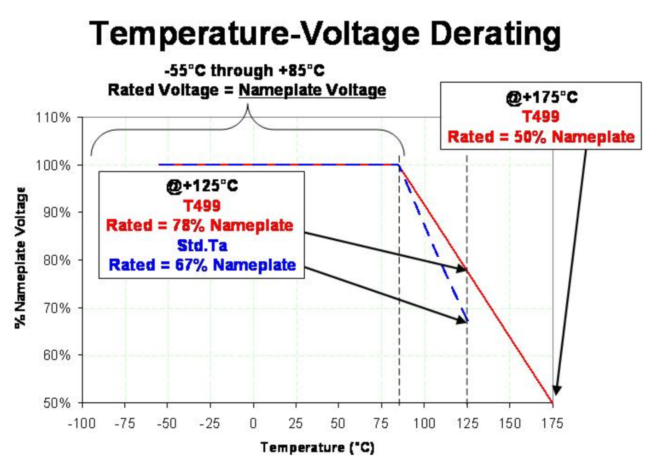

Figure 4. Voltage-temperature derating for standard and T498 capacitors.

For the T499, T498 and the standard tantalum capacitors, the voltage rating up through 85°C is the same as the nameplate voltage for the capacitor. For the standard capacitors above 85°C, the voltage rating is linearly reduced from 100% of nameplate voltage at 85°C, down to 2/3rd (67%) of nameplate voltage at 125°C. For the T499, the voltage rating is linearly derated from the 100% rating at 85°C, down to 50% of nameplate voltage at 175°C. This allows the 125°C rating to be at 78% of nameplate voltage, and the 150°C rating to be at 64% of rated voltage.

Application Derating

We will use the guidelines established with the long history of the commercial tantalum product to fix the recommended application at no more than 50% of the rated voltage. For a T499 rated at 50 VDC, this would create a recommended application of 25 VDC. This application would then apply up to 85°C, at which point the temperature-voltage derating requirements effectively lower the voltage rating of the part. At 175°C, this 50 VDC has a temperature-voltage derated rating down to 25 VDC, and following the 50% application guides, the recommended maximum application is the 12.5 VDC.

It is very important to consider the failure rate at rated voltage and 175°C is listed as 0.5% per thousand-piece-hours; but that application derating will allow for an appreciably reduced failure rate. Actual testing has revealed a failure rate less than 0.1% per thousand-piece-hours at 175°C and at the full rated voltage (50% of nameplate voltage).

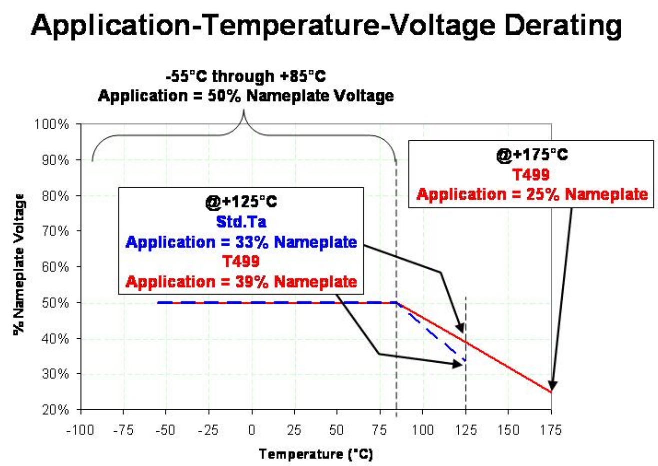

Figure 5. Recommended application voltages versus temperature.

Using the voltage factor calculations from MIL-HDBK-217F[3], at rated voltage the multiplying factor for the failure rate is 5,909. Compared to "50% of rated" factor of 1.045, then the improvement in failure rate at 175°C would be down from the 0.5% level stated for the T499 to 884 parts per billion-piece-hours. Remember though, the rated voltage is changing with temperature as shown in Figure 4. At temperatures up through 85°C, the recommended application voltage is 50% of nameplate voltage. Above 85°C, the recommended application voltage is 50% of the temperature-voltage derated level. For a standard tantalum at 125°C, the recommended application voltage is 50% of 67%, or 33% of the nameplate voltage. For a T499 at 125°C, 150°C, and 175°C, the application becomes 39%, 32%, and 25%, respectively, of nameplate voltage (Figure 5).

Power Rating

The power rating for capacitors is reflective of the allowable heat generated in the device and there is a direct correlation between these two. Without a standard temperature rise defined, the majority of manufacturers use the +20°C internal rise as an arbitrary figure in defining the power capability for these devices. This arbitrary rise added to the ambient temperature creates the absolute internal temperature of the component. Since capacitors are life tested under DC or static stress, there is no temperature rise at the maximum rated temperature of the device. Only by using the positive tolerance of +2°C at this temperature, can we define a "tested capability" at this temperature extreme. We then need to look at the difference between the temperature extreme and the assigned or arbitrary rise of +20°C, to calculate the point at which a power derating is applied. For 175°C ratings, and an allowable rise of +20°C, the power derating must begin above 155°C. The power capability (allowing a +20°C rise) for this device is the same from -55°C through 155°C. If the case power is defined as 150mW, then the power capability is defined as 150mW for this temperature range. There is a linear reduction in that power capability then applied from 100% at 155°C, down to 15 mW (10% or 2°C/20°C) at 175°C. Figure 6 shows this delineation.

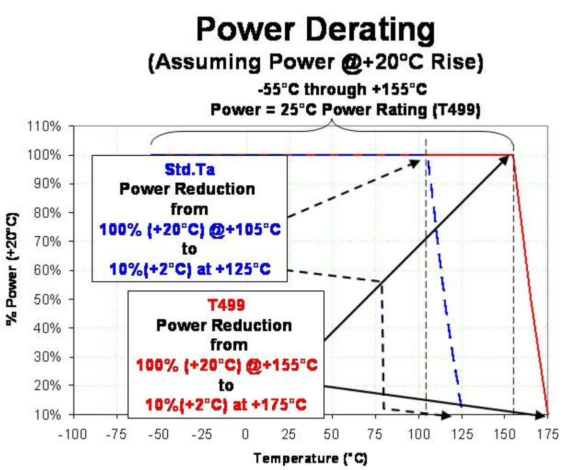

Figure 6. Power derating to maximum temperatures.

The allowable temperature rise is arbitrary and two considerations must be weighed when choosing this figure. First, the internal temperature rise plus the ambient must never exceed the maximum temperature plus 2°C. To do so would create an environment in which there is no reliability data to justify this application. Second, the rise must be considered as a potential thermal shock condition when the device is at ambient temperature and immediately after power is applied. Deltas in excess of +50°C may lead to thermal gradients that could induce stresses high enough to cause an internal fracture and failure.

It is evident from the plot of Figure 6 that the difference in these two types of capacitors create entirely different power capabilities between 105°C and 125°C. For example, the power dissipation for the standard tantalum at 125°C is down to 10% of the case defined power capability, while the T499 shows a capability at this temperature of 100% of the case defined power. Consider that these are two "D" case units and the actual power capability here is 15 mW for the standard and 150 mW for the T499. For devices of equal capacitance and ESR, the ripple capability for the T499 would increase by a factor of 3.16 (square root of 10).

The T499 also has advantages over the T498 (+150°C rating)[4]. At 150°C, the T498 power capability becomes 10% of the 25°C rating, whereas the T499 maintains the 25°C capability up through 155°C (for standard +20°C rise).

Application Areas

The ideal applications for these components begin where the standard products' end. At temperatures between 125°C and 170°C, these applications would still allow a 5°C margin or better, between the rating and the application. For new under hood, down-hole, and life-test systems, these applications may be considered with the T499 that were previously thought to be too precarious for the standard tantalum.

References:

1. RoHS –"Restriction on the use of certain Hazardous Substances in Electrical and Electronic Equipment" (European Union directive 2002 / 95 / EC)

2. J-STD-020C – IPC/JEDEC Joint Industry Standard – Moisture/Reflow Sensitivity Classification

3. MIL-HDBK-217F – Notice 2, Reliability Prediction of Electronic Equipment, Department of Defense, December 2, 1991, Washington, DC.

4. "Product Update – T498 High Temperature (+175°C) Tantalum SMT Capacitors", KEMET Electronics Corp., Unpublished, KEMET Distributed, May, 2005