Derating Guidelines for Surface Mount Tantalum Capacitors
Voltage and temperature derating guidelines are important factors to consider when selecting a tantalum capacitor. Understanding what conditions allow for optimal performance and reliability eases the complexity involved in selecting components that will meet the expectations of the end product.

In this session, we will explain the reasons for derating tantalum capacitors as well as provide guidance on how to follow KEMET’s derating guideline tables.
So, why do I need a 50V rated capacitor for my 24V power rail? The answer is that you can indeed use a surface mount tantalum capacitor at or near its rated voltage with the understanding that the failure rate at this voltage condition will typically be between 0.1 and 1.0% per one thousand hours of operation. In addition, the user can expect to see increases in initial power on failure rates following board mounting. Most applications cannot accept this rate of failure however. So, to improve the reliability of the device, KEMET recommends designers follow the derating guidelines outlined in this module.

So, why should I select a 50V Rated Capacitor for my 24V Power Rail?

Tantalum Capacitors used at or near their rated voltage typically experience a 0.1% to 1.0% failure rate per 1000 hours of operation.

Most Tantalum Capacitors fail during a “power-on” event, which is not included in the above failure rate!
Note that while factors such as temperature, circuit impedance, ripple, and mechanical stress can play a role in reliability, no single factor has more of an impact on the reliability of a tantalum capacitor than the applied voltage.

Derating will improve the long term reliability of the device as well dramatically improve the initial power on performance.

Let's review how derating improves these areas of performance.
Borrowing the FIT calculation from Mil-Handbook-217F, we see that the final failure rate is multiplied by several environmental and electrical factors. The most dominating is the voltage factor as in this calculation.

\[
\lambda_p = \lambda_b \pi_T \pi_C \pi_V \pi_{SR} \pi_R \pi_E \times 1000
\]

\[
\pi_T = \exp \left[ -\frac{0.15}{8.617 \times 10^{-4}} \left( \frac{1}{T_{40k}} - \frac{1}{298} \right) \right]
\]

\[
\pi_V = \left( \frac{S}{0.6} \right)^{17} + 1
\]

\[S = \frac{\text{Application Voltage}}{\text{Rated Voltage}}\]

\(\pi_T\) factors for specific temperatures:

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>(\pi_T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>1.00</td>
</tr>
<tr>
<td>50</td>
<td>2.31</td>
</tr>
<tr>
<td>85</td>
<td>3.66</td>
</tr>
<tr>
<td>105</td>
<td>4.58</td>
</tr>
<tr>
<td>125</td>
<td>5.62</td>
</tr>
</tbody>
</table>

\(\pi_V\) factors for specific Application/Rated Ratios (S):

<table>
<thead>
<tr>
<th>S</th>
<th>(\pi_V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%</td>
<td>1.00</td>
</tr>
<tr>
<td>50%</td>
<td>1.05</td>
</tr>
<tr>
<td>60%</td>
<td>2.00</td>
</tr>
<tr>
<td>70%</td>
<td>14.7</td>
</tr>
<tr>
<td>80%</td>
<td>134</td>
</tr>
<tr>
<td>90%</td>
<td>986</td>
</tr>
<tr>
<td>100%</td>
<td>5909</td>
</tr>
</tbody>
</table>

FIT = Failures In Time specified as parts per billion-piece-hours

Borrowing the FIT calculation from Mil-Handbook-217F, we see that the final failure rate is multiplied by several environmental and electrical factors. The most dominating is the voltage factor as in this calculation.

The calculation of the temperature and voltage factors are shown with tables for typical values. The highest factor for the temperature at 125°C is 5.62, or at 125°C, the failure rate is 5.62 times the failure rate at 25°C, because of the temperature.

For the voltage, because the exponential factor is 17, the failure rate multiplier increases exponentially as the voltage exceeds 60%. It still has a near unity factor at 50% rated voltage, but the failure rate doubles at 60%, jumping to a multiplier of 14.7 at 70%, 134 at 80%, and close to 1000 at 90%. For this capacitor type, exceeding the recommended derating voltage can lead to very high failure rates.
Now let us assess the impact of derating to improve initial power on performance.
Consider a distribution of breakdown voltage for a specific manufacturing lot of product that has been assembled. To ensure the best possible screening, KEMET’s components are 100% thermally and electrically surge stressed prior to 100% electrical screening. The application of thermal and electrical stresses to the device will alter the breakdown distribution. Our objective of applying these stresses to the components is to exercise the construction of each device in order to identify weaker parts that would not meet the minimum standards at 100% electrical screening.

During Kemet’s 100% electrical screening, a portion of the manufactured lot may not pass the screening limit.

The tail of the distribution that falls below the screening limit is removed from the lot.
Packaged components consist of product with a truncated distribution. In this current condition, the product can withstand voltages up to the screening limit (typically rated voltage).

However…
Board mounting will thermally stress the devices once more. This final exercising of the components will redefine the distribution once again, resulting in some parts with breakdown voltages that are below the initial screening limit. As the application voltage gets closer to the screening limit, an increase in failure rate may be experienced. However, by following Kemet’s voltage derating guidelines, this risk can be reduced or eliminated altogether.
Now that we understand the need for derating, let’s review the derating tables.

Shown here is one of KEMET’s derating guideline tables which compares the percentage of applied rated voltage to the temperature. This table can be found in most every KEMET surface mount tantalum specification sheet. Let’s take a few minutes to understand these tables by reviewing the terms and definitions for temperature and voltage derating.
First, let's define the rated temperature and rated voltage of a component.

The rated temperature of a component is the maximum temperature at which the device can be used without lowering the voltage rating of the component. It is often lower than the category temperature ($T_C$), but can be equal.

The rated voltage ($U_R$) is the maximum peak DC operating voltage for continuous operation, up to the rated temperature ($T_R$). Rated voltage is the labeled voltage of the device.

In this Example: A 50V rated cap would still be considered 50V up to 85C.
Next we will define the category temperature and category voltage.

The category temperature is the maximum recommended operating temperature of the device. To exceed the category temperature is to exceed the temperature capability of the component.

The category voltage is the maximum recommended peak DC operating voltage for continuous operation at the category temperature (TC).

In this Example our 50 volt rated cap would now be considered 33 volts at 125 degrees Celsius.
Now we will factor in a recommended voltage derating to optimize reliability up to the rated temperature.

A component’s recommended application voltage up to rated temperature is the recommended steady state operating voltage for continuous operation and optimal reliability at rated temperature ($T_R$).

In this Example: Our 50V rated cap has a recommended 50% derating.

So, the device is recommended for applications of ~25V up to 85C.
Next we will factor in a voltage derating up to the category temperature.

A component’s recommended application voltage up to category voltage is the recommended steady state operating voltage for continuous operation and optimal reliability at category temperature ($T_c$).

In this Example: Our 50V rated cap would be recommended for applications of ~16.5V at 125C.

In this Example our 50 volt rated capacitor would be recommended for applications of approximately 16.5V at 125 degrees Celsius.
In an effort to simplify derating tables, KEMET included two terms in its derating tables to assist designers in their product selection.

First, KEMET defined the recommended derating field as the “Recommended Application Voltage”. This field is viewed as the recommended steady state voltage.

Next, KEMET defines the “Maximum Transient Voltage”. This field is to assist designers who need to account for voltage spikes such as automotive designers who need to account for a potential load dump during the life of the automobile. These short transient conditions do not have an impact on the long term reliability of the device but can present some risk for failure if the components breakdown voltage was reduced during board mounting. To guard against this risk, KEMET recommends that the circuit be proofed to its maximum transient voltage during in-house testing.
Due to differences in the material structure of traditional tantalum capacitors vs. polymer tantalum capacitors, derating guidelines for these two capacitor types are quiet different. While the science behind these differences is outside of the scope of this presentation, we will review the differences in derating guidelines between each.
The traditional MnO2 tantalum capacitor technology follows a recommended voltage derating of 50%, up to the rated temperature of the device. For applications that exceed the rated temperature, a linear derating is applied from 50% of rated voltage at rated temperature down to 33% of rated voltage at category temperature. KEMET’s series of traditional MnO2 capacitors includes all T49x and T510 series products.

The same derating guideline is used for high temperature series products such as the T498 and T499 series. While the category temperature is much higher for these series, derating guidelines of 50% up to rated temperature and 33% of rated voltage at category temperature still applies.
Polymer tantalum capacitors use a different material set which does not experience the degree of distribution shift seen in traditional MnO2 tantalum capacitors. This difference in behavior allows for a significant reduction in voltage derating recommendations.

- Derating recommendations for polymer tantalum capacitors are:
  - 10% derating for rated voltages ≤ 10V
  - 20% derating for rated voltages > 10V.

- In addition, the rated temperature (TR) is typically higher (105C vs 85C).

Polymer tantalum capacitors use a different material set which does not experience the degree of distribution shift seen in traditional MnO2 tantalum capacitors. This difference in behavior allows for a significant reduction in voltage derating recommendations.

Derating recommendations for polymer tantalum capacitors are:

- 10% derating for rated voltages less than or equal to 10 volts
- 20% derating for rated voltages greater than 10 volts.

In addition, the rated temperature is typically higher (105 degrees Celsius vs 85 degrees Celsius).
Here we can see the derating advantages KEMET’s polymer tantalum capacitors have over traditional MnO2 tantalum capacitors.

As noted, voltage derating is divided into two classes according to voltage rating. For less than or equal to 10 voltage ratings, a 10% derating is recommended. For voltage ratings greater than 10 volts, a 20% derating is recommended.

Currently, polymer tantalum capacitors have two category temperature classes including 105 degrees C and 125 degrees C.

KEMET’s T520 and T528 Series have both a category and rated temperature of 105 degrees C. So, there are no temperature derating requirements.

Kemet’s T525 and T530 series has a category temperature of 125 degrees C but maintain a rated temperature of 105 degrees C (enter). So, derating of the voltage rating is required as the application temperature exceeds 105 degrees C.

Kemet’s T521 series currently consider of a mix of 105 degrees C and 125 degrees C category temperature products. (enter and pause)
Included in this table are common application voltages and the recommended voltage ratings by tantalum capacitor type.

Given the reduction in voltage derating requirements for KEMET's polymer tantalum capacitors, a lower voltage rating is recommended in comparison to traditional MnO2 tantalum capacitors.

<table>
<thead>
<tr>
<th>Application Voltage</th>
<th>Traditional MnO₂ Tantalum</th>
<th>Polymer Tantalum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0-2.0V</td>
<td>2.5-4V</td>
<td>2.5V</td>
</tr>
<tr>
<td>3.3V</td>
<td>6.3V</td>
<td>4V</td>
</tr>
<tr>
<td>5.0V</td>
<td>10V</td>
<td>6.3V</td>
</tr>
<tr>
<td>9V</td>
<td>20V</td>
<td>10V</td>
</tr>
<tr>
<td>12V</td>
<td>25V</td>
<td>16V</td>
</tr>
<tr>
<td>20V</td>
<td>35-50V</td>
<td>25V</td>
</tr>
<tr>
<td>24V</td>
<td>50V</td>
<td>35V</td>
</tr>
<tr>
<td>28V</td>
<td>63V</td>
<td>35V</td>
</tr>
</tbody>
</table>
Voltage derating offers the greatest improvement in long term reliability and initial power on performance.

While components are proofed to rated conditions during testing, thermal stresses from the customers board mounting process will alter the breakdown voltage distribution.

Understanding a components category temperature, category voltage, rated temperature, rated voltage and recommended application voltage will ensure optimal reliability and initial power on performance.

Surface Mount Tantalum Capacitors include both traditional MnO2 and polymer tantalum capacitors with significant differences in their derating guidelines.