SOLID TANTALUM CHIP CAPACITORS

TANTALUM MnO$_2$ COMPONENT PERFORMANCE CHARACTERISTICS

Introduction

KEMET solid tantalum capacitors are identified by the initial "T." followed by a unique "Series" number: for example, T491, T492, etc. Each Series denotes a general physical form and type of encapsulation, as well as limits on dimensions and certain electrical characteristics under standard conditions of 25°C, 50% relative humidity, and one atmosphere pressure. Specific requirements are set forth in the respective Product Series in this catalog. All series are 100% screened for leakage, capacitance, dissipation factor, and ESR. All Series are inspected to electrical limits using a minimum .1% AQL sampling plan, according to the Military Standard MIL-STD-105, even after 100% testing. This sampling plan, to the best of KEMET Electronics' knowledge, meets or exceeds the generally accepted industry standard for similar products. KEMET capacitors may also be supplied, with prior agreement, to meet specifications with requirements differing from those of KEMET catalogs.

ELECTRICAL

1. General Application Class

Solid tantalum capacitors are usually applied in circuits where the AC component is small compared to the DC component. Typical uses known to KEMET Electronics include blocking, by-passing, decoupling, and filtering. They are also used in timing circuits. General purpose devices are recommended to have an external series resistance of 0.1Ω/volt to reduce the failure due to surge current. Newer devices designed for power applications (T495, T5XX), are built to eliminate this series resistance requirement. Because tantalum capacitors can experience scintillation (self-healing) in their life, the circuit impedance should not exceed 100KΩ or this will circumvent the scintillation and degrade leakage.

2. Operating Temperature Range
• −55 °C to +125 °C

Voltage derating is specified in Section 5. Performance characteristics over this temperature range are presented within the following sections.

3. Non-Operating Temperature Range
• −55 °C to +125 °C

Tantalum capacitors do not lose capacitance from the "de-forming" effect as do liquid-electrolytic capacitors. Storage at high temperature may cause a small, temporary increase in leakage current (measured under standard conditions), but the original value is usually restored within a few minutes after application of rated voltage.

Tantalum chips are not hermetically sealed, therefore they do exhibit reversible changes in parameters with respect to relative humidity (RH). Capacitance increases with increasing humidity. The limiting change, reached upon establishment

of equilibrium with the environment, is approximately -5% to +12% over the range from 25% to 95% RH, referred to the standard 50% RH. The amount of change is dependent upon size (capacitance and voltage rating, ie: CV product); small sizes might change no more than ±5%. Equilibrium at such extremes is seldom attained by plastic-cased capacitors, and the change in capacitance is consequently less. The rate of response to humidity changes increases with increasing temperature. Dissipation factor and ESR also increase with increasing RH.

DC leakage current may rise upon exposure to a combination of high temperature and high humidity, but is normally restored by voltage conditioning under standard conditions. The increase will be greater than that experienced under temperature influence alone because of conduction through absorbed water.

Tantalum chips may be affected by absorption of water on external insulating surfaces. The water film may also attract a layer of dust from the air, increasing the effect. The most sensitive parameter is leakage current.

4. Capacitance
• 0.1 µF to 1000 µF

Refer to part number tables for available capacitance ratings and tolerances by series.

Capacitance is measured at 120 Hz, up to 1.0 volt rms maximum and up to 2.5 volts DC maximum, at +25°C. DC bias causes only a small reduction in capacitance, up to about 2% when full rated voltage is applied. DC bias is not commonly used at room temperature, but is more commonly used at elevated temperatures. Capacitance decreases with increasing frequency.
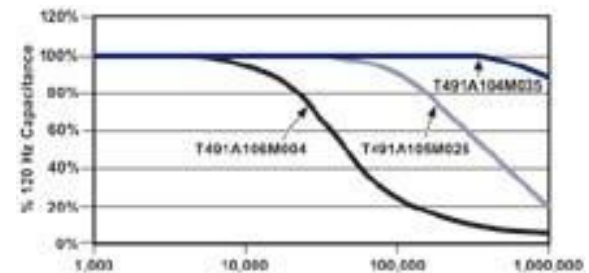

FIGURE 1   Typical Effect of Frequency upon Capacitance

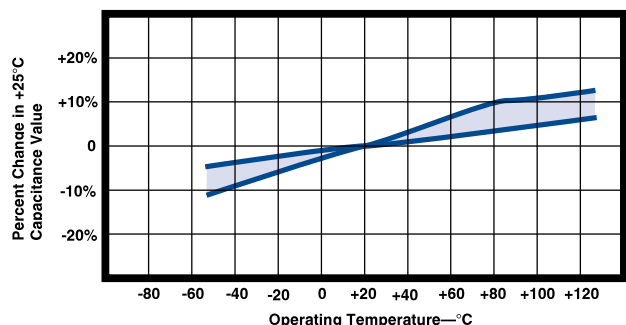Capacitance increases with increasing temperature.

FIGURE 2   Typical Effect of Temperature upon Capacitance

TANTALUM MnO$_2$ COMPONENT PERFORMANCE CHARACTERISTICS (con't.)

TABLE 1 Maximum Capacitance Change with Temperature (ref: 25°C)

Ambient Temperature		
−55°C	+85°C	+125°C
−10%	+10%	*+12% or +15% to 20%

*+12% is standard. +15% and 20% apply to certain extended CV values as noted in part number tables.

5. Working DC Voltage (WVDC)

• 3 to 50 volts

Refer to part number tables for available voltage ratings by series.

These voltages are the maximum recommended peak DC operating voltages from −55°C to +85°C for continuous duty. These voltages are derated linearly above +85°C to 2/3 rated voltage for operation at +125°C (See Figure 3). For added reliability it is recommended to operate at a 50% derating of the working voltage for tantalum capacitors with MnO$_2$ as a cathode. See page 39 for working DC Voltage of high temperature T498 product.
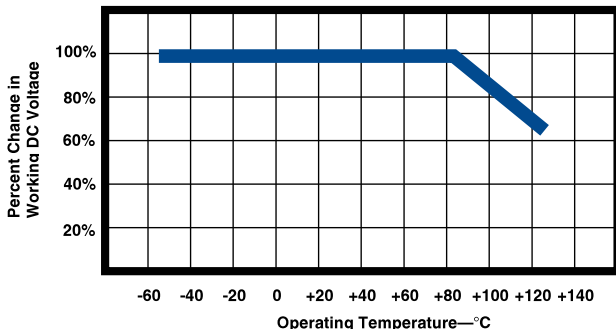

FIGURE 3 Working DC Voltage Change with Temperature

6. Surge Voltage

TABLE 2 Surge Voltage Ratings at +25°C, +85°C & +125°C

Rated Working Volts @ +25°C & +85°C	Surge Voltage @ +25°C & +85°C	Derated DC Volts @ +125°C	Surge Voltage @ +125°C
3	4	2	2.4
4	5.2	2.7	3.2
6	8	4	5
10	13	7	8
16	20	10	12
20	26	13	16
25	33	17	20
35	46	23	28
50	65	33	40

Surge voltage tests are performed at +25°C, +85°C and +125°C with the applicable surge voltage. The surge voltage is applied for 1000 cycles of 30 seconds at voltage through a 33 ohm series resistor and 30 seconds off voltage with the capacitor discharged through a 33 ohm resistor. Upon completing the test, the capacitors are allowed to stabilize at room temperature. Capacitance, DCL and DF are then tested:

a. Capacitance — within ± 5% of initial value
b. DC Leakage — within initial limit
c. Dissipation Factor — within initial limit
d. ESR — within initial limit

7. Reverse Voltage and Polarity

TABLE 3 Reverse Voltage Ratings

Temperature	Permissible Reverse Voltage
+25°C	**15% of Rated Voltage**
+85°C	**5% of Rated Voltage**
+125°C	**1% of Rated Voltage**

Solid tantalum capacitors are polarized devices and may be permanently damaged or destroyed if connected with the wrong polarity. The positive terminal is identified on the capacitor body by a stripe and a beveled edge. A small degree of transient reverse voltage is permissible for short periods per Table 3. The capacitors should not be operated continuously in reverse mode, even within these limits.

8. DC Leakage Current (DCL)

Refer to part number tables for maximum leakage current limits.

DC leakage current is the current that, after a one- to five-minute charging period, flows through a capacitor when voltage is applied. Leakage is measured at +25°C with full rated DC voltage applied to the capacitor through a 1000 ohm resistor in series with the capacitor.

DC leakage current increases with increasing temperature.

TABLE 4 Leakage Limit Multipliers at Specified Temperatures (ref: 25°C limits)

Ambient Temperature		
−55°C	+85°C	+125°C
N/A	10X	12X

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Multiplier of DC Leakage Current
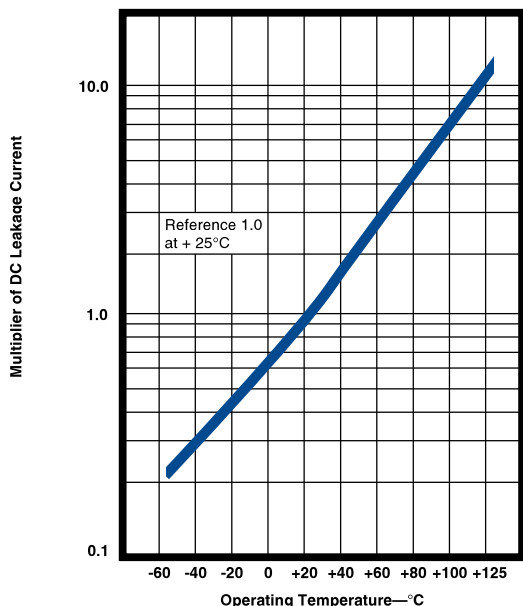
Reference 1.0
at + 25°C

Operating Temperature—°C

FIGURE 4   Typical Effect of Temperature upon
DC Leakage Current

DC leakage current decreases with decreasing applied voltage.

Multiplier of DC Leakage Current
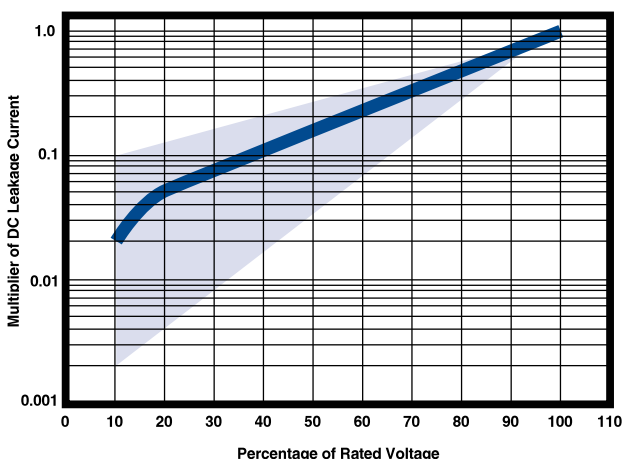
Percentage of Rated Voltage

FIGURE 5   Typical Effect of Applied Voltage on DC
Leakage Current.

9. Dissipation Factor (DF)

Refer to part number tables for maximum DF limits.

Dissipation factor is measured at 120 Hz, up to 1.0 volt rms maximum, and up to 2.0 volts DC maximum at +25°C. The application of DC bias causes a small reduction in DF, about 0.2% when full rated voltage is applied. DF increases with increasing frequency.

Multiplier of 120 Hz D.F.

Reference
1.0 at 120 Hz
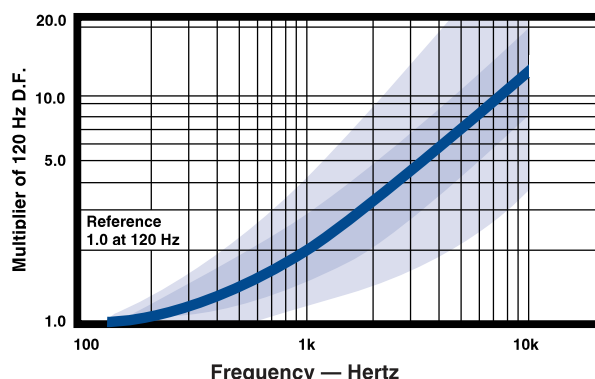
Frequency — Hertz

FIGURE 6   Typical Effect of Frequency upon Dissipation
Factor

Dissipation factor is a very useful low frequency (120 Hz) measurement of the resistive component of a capacitor. It is the ratio of the equivalent series resistance (ESR) to the capacitive reactance. (X$_c$) and is usually expressed as a percentage. It is directly proportional to both capacitance and frequency. Dissipation factor loses its importance at higher frequencies, (above about 1 kHz), where impedance (Z) and equivalent series resistance (ESR) are the normal parameters of concern.

$$DF = \frac{R}{X_c} = 2\pi fCR$$

DF = Dissipation Factor
R = Equivalent Series
Resistance (Ohms)
X$_c$ = Capacitive Reactance
(Ohms)
f = Frequency (Hertz)
C = Series Capacitance
(Farads)

DF is also referred to as tan δ or "loss tangent." The "Quality Factor," "Q," is the reciprocal of DF.

DF decreases with temperature above +25°C and may also increase at lower temperatures. Unfortunately, one general limit for DF cannot be specified for all capacitance/voltage combinations, nor can response to temperature be simply stated. DC bias is not commonly used at room temperature, but is more commonly used at elevated temperatures.

10. Equivalent Series Resistance (ESR) and Impedance (Z)

Equivalent Series Resistance (ESR) is the preferred high-frequency statement of the resistance unavoidably appearing in these capacitors. ESR is not a pure resistance, and it decreases with increasing frequency.

Total impedance of the capacitor is the vector sum of capacitive reactance (X$_c$) and ESR, below resonance; above resonance total impedance is the vector sum of inductive reactance (X$_L$) and ESR.
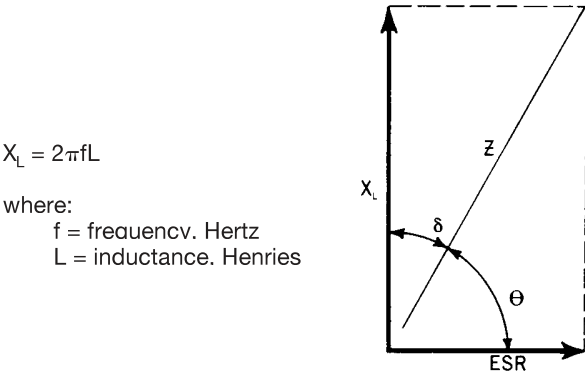
TANTALUM MnO$_2$ COMPONENT PERFORMANCE CHARACTERISTICS (con't.)

ESR

Θ

δ

Z

X_c
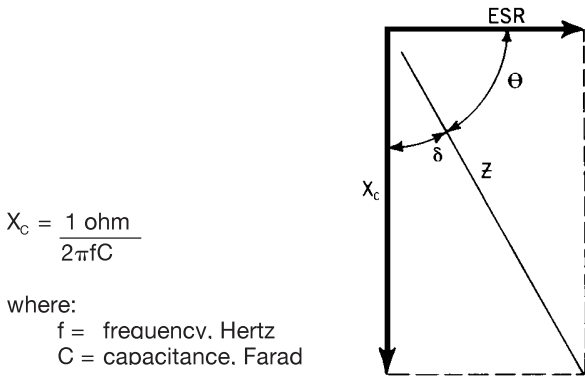
$$X_C = \frac{1 \text{ ohm}}{2\pi fC}$$

where:
    f = frequency, Hertz
    C = capacitance, Farad

FIGURE 7a   Total Impedance of the Capacitor Below Resonance

Z

X_L

δ

Θ

ESR

$$X_L = 2\pi fL$$

where:
    f = frequency, Hertz
    L = inductance, Henries

FIGURE 7b   Total Impedance of the Capacitor Above Resonance

To understand the many elements of a capacitor, see Figure 8.

ESL   ESR   C
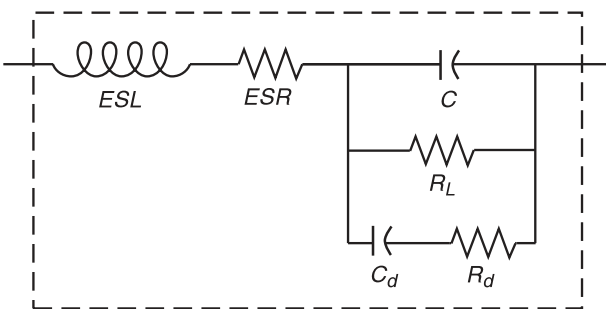
R_L

C_d R_d

FIGURE 8   The Real Capacitor

A capacitor is a complex impedance consisting of many series and parallel elements, each adding to the complexity of the measurement system.

ESL — Represents lead wire and construction inductance. In most instances (especially in solid tantalum and monolithic ceramic capacitors) it is insignificant at the basic measurement frequencies of 120 and 1000 Hz.

ESR — Represents the actual ohmic series resistance in series with the capacitance. Lead wires and capacitor electrodes are contributing sources.

R$_L$ — Capacitor Leakage Resistance. Typically it can reach 50,000 megohms in a tantalum capacitor. It can exceed 10^{12} ohms in monolithic ceramics and in film capacitors.

R$_d$ — The dielectric loss contributed by dielectric absorption and molecular polarization. It becomes very significant in high frequency measurements and applications. Its value varies with frequency.

C$_d$ — The inherent dielectric absorption of the solid tantalum capacitor which typically equates to 1-2% of the applied voltage.

As frequency increases, X$_c$ continues to decrease according to its equation above. There is unavoidable inductance as well as resistance in all capacitors, and at some point in frequency, the reactance ceases to be capacitive and becomes inductive. This frequency is called the self-resonant point. In solid tantalum capacitors, the resonance is damped by the ESR, and a smooth, rather than abrupt, transition from capacitive to inductive reactance follows.

Typical ESR/Z frequency response curves are shown in Figures 9a and 9b. These curves are for selected ratings and represent typical T491 Series performance. Maximum limits for 100 kHz ESR are listed in the part number tables for each series. Note that the T494 Series offers low ESR and the T495 Series is specially designed for very low ESR performance. Refer to page 31 for more information. See also KEMET's T510 Series low ESR ratings on page 40.
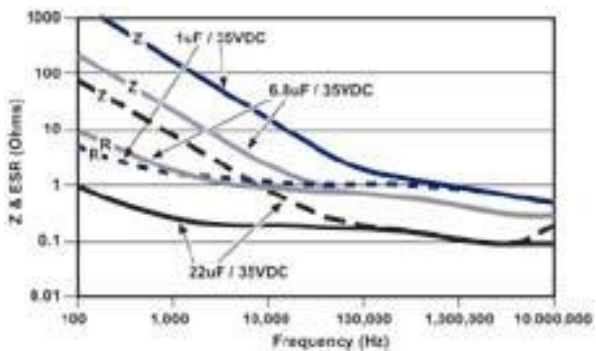
FIGURE 9a   ESR & Impedance (Z) vs Frequency

SOLID TANTALUM CHIP CAPACITORS KEMET

CHARGED.

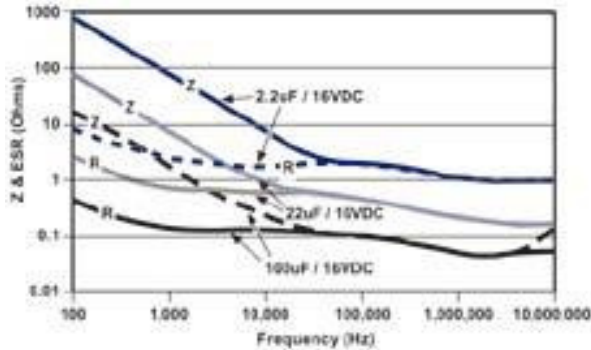## TANTALUM MnO$_2$ COMPONENT PERFORMANCE CHARACTERISTICS (con't.)

FIGURE 9b   ESR & Impedance (z) vs Frequency

ESR and Z are also affected by temperature. At 100 kHz, ESR decreases with increasing temperature. The amount of change is influenced by the size of the capacitor and is generally more pronounced on smaller ratings.
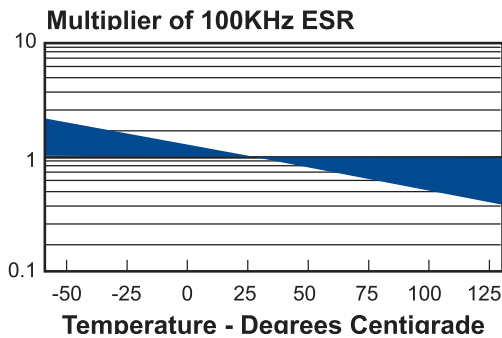

Multiplier of 100KHz ESR

FIGURE 10   Typical Effect of Temperature on 100 kHz ESR

11. AC Power Dissipation

Power dissipation is a function of capacitor size and materials. Maximum power ratings have been established for all case sizes to prevent overheating. In actual use, the capacitor's ability to dissipate the heat generated at any given power level may be affected by a variety of circuit factors. These include board density, pad size, heat sinks and air circulation.

TABLE 5 Tantalum Chip Power Dissipation Ratings

Case Code		Maximum Power Dissipation
KEMET	EIA	mW @ +25°C w/+20°C Rise
R	2012-12	25
S	3216-12	60
T	3528-12	70
U	6032-15	90
V	7343-20	125
A	3216-18	75
B	3528-21	85
C	3062-28	110
D	7343-31	150
X	7343-43	165
E	7260-38	200
T530D	7343-31	255
T510X, T530X	7343-43	270
T510E, T530E	7260-38	285

12. AC Operation

Permissible AC ripple voltage and current are related to equivalent series resistance (ESR) and power dissipation capability.

Permissible AC ripple voltage which may be applied is limited by three criteria:

a. The positive peak AC voltage plus the DC bias voltage, if any, must not exceed the DC voltage rating of the capacitor.

b. The negative peak AC voltage, in combination with the bias voltage, if any, must not exceed the permissible reverse voltage ratings presented in Table 3.

c. The power dissipated in the ESR of the capacitor must not exceed the appropriate value specified in Table 5.

Actual power dissipated may be calculated from the following:

$$P = I^2 R$$

Substituting $I = \dfrac{E}{Z}$, $P = \dfrac{E^2 R}{Z^2}$

where:

I = rms ripple current (amperes)
E = rms ripple voltage (volts)
P = power (watts)
Z = impedance at specified frequency (ohms)
R = equivalent series resistance at specified frequency (ohms)

Using P max from Table 5, maximum allowable rms ripple current or voltage may be determined as follows:

$$I\ (max) = \sqrt{\frac{P\ max}{R}} \qquad E\ (max) = Z\sqrt{\frac{P\ max}{R}}$$

These values should be derated at elevated temperatures as follows:

Temperature	Derating Factor
85°C	.9
125°C	.4

ENVIRONMENTAL

13. Temperature Stability

TABLE 6 Temperature Stability Limits

Step No.	Temp.	Δ Capacitance	Leakage Current	Dissipation Factor
1	+25°C	within specified tolerance	within original limit	within original limit
2	-55°C	within ± 10% of initial value	N/A	within original limit**
3	+25°C	within ± 5% of initial value	within original limit	within original limit**
4	+ 85°C	within ± 10% of initial value	within 10X original limit	within original limit***
5	+125°C	*within ± 12%or 20% of initial value	within 12X original limit	within original limit***
6	+25°C	within ± 5% of initial value	within original limit	within original limit

*+12% is standard. +15% or +20% applies to certain CV values as noted in part number table.
**within 1.5x initial limit for extended CV values.
***within 1.15x initial limit for extended CV values.

TANTALUM MnO$_2$ COMPONENT PERFORMANCE CHARACTERISTICS (con't.)

Mounted capacitors withstand extreme temperature testing at a succession of continuous steps at +25°C, -55°C, +25°C, +85°C, +125°C, +25°C, in the order stated. Capacitors shall be brought to thermal stability at each test temperature. Capacitance, DF and DCL are measured at each test temperature except that DCL is not measured at -55°C. DC bias of 2.0± 0.5 is recommended for the capacitance and D F requirements.

14. Thermal Shock
• *Mil-Std-202, Method 107, Condition B*

Minimum temperature -55°C, mounted

Post Test Performance:

    a. Capacitance — within ±5% of initial value

    b. DC Leakage — within initial limit

    c. Dissipation Factor — within initial limit

    d. ESR — within initial limit

15. Moisture Resistance
• *Mil-Std-202, Method 106*

Steps 7a and 7b excluded, rated voltage, 42 cycles, mounted

Post Test Performance:

    a. Capacitance — within ±10% of initial value

    b. DC Leakage — within initial limit

    c. Dissipation Factor — within initial limit

    d. ESR — within initial limit

• *JEDEC J-STD-20C — meets MSL1 for Pb-free assembly*

16. Electrostatic Discharge (ESD)
  • *Human Body Model*
    2,000 ±50 volts, 1,500 ±5% ohms, 40 nanosecond pulse each polarity, 1 pulse each polarity, 5 seconds between pulses, +25°C.
  • *Charged Device Model*
    200 ± 5 volts, 0 ohms, 40 nanosecond pulse, each polarity, 9 pulses each polarity, 5 seconds between pulses, +25°C.

Product subjected to above test condition demonstrate *no sensitivity* to electrostatic discharge.

17. Long Term Stability

Within the general class of electrolytic capacitors, solid tantalum capacitors offer unusual stability of the three important parameters: capacitance, dissipation factor and leakage current. These solid-state devices are not subject to the effects of electrolysis, deforming or drying-out associated with liquid-electrolyte capacitors.

When stabilized for measurement at standard conditions, capacitance will typically change less than ±3% during a 10,000 hour life test +85°C.

The same comparative change has been observed in shelf tests at +25°C extending for 50,000 hours. (Some of this change may stem from instrument or fixture error.)

Dissipation factor exhibits no typical trend. Data from 10,000 hour life test at +85°C show that initial limits (at standard conditions) are not exceeded at the conclusion of these tests.

Leakage current is more variable than capacitance or DF: in fact, leakage current typically exhibits a logarithmic dependence in several respects. Military Specifications permit leakage current (measured at standard conditions) to rise by a factor of four over 10,000 hour life tests. Typical behavior shows a lower rate of change, which may be negative or positive. Initial leakage currents are frequently so low (less than 0.1 nanoampere in the smallest CV capacitors) that changes of several orders of magnitude have no discernable effect on the usual circuit designs.

18. Failure Mode
Capacitor failure may be induced by exceeding 50% of rated voltage of the capacitor with forward DC voltage, reverse DC voltage, power dissipation, or temperature. As with any practical device, these capacitors also possess an inherent, although low, failure rate when operated at less than 50% of the rated voltage of the capacitor.

The dominant failure mode is by short-circuit. Minor parametric drifts are of no consequence in circuits suitable for solid tantalum capacitors. Catastrophic failure occurs as an avalanche in DC leakage current over a short (millisecond) time span. The failed capacitor, while called "short-circuited", may exhibit a DC resistance of 10 to 10^4 ohm.

If a failed capacitor is in an unprotected low-impedance circuit, continued flow of current through the capacitor may obviously produce severe overheating. The over-heated capacitor may damage the circuit board or nearby components. Protection against such occurrence is obtained by current-limiting devices or fuses provided by the circuit design. KEMET's T496 series offers a built-in fuse to convert the normal short circuit failure mode to an open circuit.

Fortunately, the inherent failure rate of KEMET solid tantalum capacitors is low, and this failure rate may be further improved by circuit design. Statistical failure rates are provided for military capacitors. Relating circuit conditions to failure rate is aided by the guides in the section following.

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RELIABILITY

19. Reliability Prediction

Solid tantalum capacitors exhibit no degradation failure mode during shelf storage and show a constantly decreasing failure rate (i.e., absence of any wear out mechanism) during life tests. This failure rate is dependent upon three important application conditions: DC Voltage, ambient temperature, and circuit impedance. Additional effects are attributable to the capacitance of the device and atmospheric and mechanical exposure of the assembled circuit. The 1000 multiplier at the end converts the failure rate to parts-per-billion piece-hours. A prediction of the failure rate can be made using these application conditions and the formulas and tables listed in MIL-HDBK-217F (Notice 2).

Base Multiplier: The first multiplier is the base multiplier (2) established for the capacitor type. For "CWR-Chips" or surface mount components the base multiplier is 0.00005, and for "CSR-Leaded" devices, the base multiplier is 0.00040.

Temperature: The temperature factor is given as (3). From this formula, it can be seen that the unity factor, or 1, is derived at an ambient temperature of +25°C (+298°K), and that at temperatures below this the multiplier is decreasing and at temperatures above this the multiplier is increasing.

Voltage: The multiplier for application voltage (4) is a two step process: first, the application voltage is compared to 60% of rated voltage, and then this ratio is raised to an exponential power of 17 and added to unity. Consider applications of 50%, 60%, 70%, 80% and 90% of rated voltage. The multipliers for these applications would be 1.045, 2.00, 14.7, 134, and 986, respectively. From these results it is evident why manufacturers recommend application voltages not to exceed 50% rated voltages.

Capacitance: There is a factor (5) applied to the capacitance (in µF) which effectively increases the failure rate for increasing capacitance (increases in effective area resulting in increases in possible faults).

Series Resistance: The series resistance is only concerned with the resistance per application bias (ohms per volt) external to the capacitor, and does not include the ESR as a factor.

Environmental: The environmental factor is determined by the harshness of the ambient conditions beyond temperature. An explanation of these ratings is included in the MIL specification and are too extensive to be covered here. In most cases, this factor is set to around benign or G$_B$, with the resulting factor equal to "1".

(1) $\quad \lambda_V = \lambda_b \pi_T \pi_C \pi_V \pi_{SR} \pi_Q \pi_E$ x 1000

(2) $\quad \lambda_b = 0.00005_{CWR}$ or 0.0004_{CSR}

(3) $\quad \pi_T = \exp\left[\dfrac{-0.15}{8.617 \cdot 10^{-5}} \left(\dfrac{1}{T_{Amb}} - \dfrac{1}{298} \right) \right]$

(4) $\quad S = \dfrac{\text{Application-Voltage}}{\text{Rated-Voltage}} \qquad \pi_V = \left(\dfrac{S}{0.6} \right)^{17} + 1$

(5) $\quad \pi_C = 1.0 \cdot C^{.023}$

(6) $\quad \pi_{SR} =$ Lookup Table $\qquad \pi_E =$ Lookup Table

(7) $\quad \pi_Q = \sqrt{\left(\dfrac{\text{Pcs. Fail}}{\text{Pcs. Tested x Hrs. Tested}} \text{ x } 100,000 \right)}$

FIGURE 11a. MIL-HDBK-217F Notice 2 formulas.

CR (ΩV)	π_{SR}
>0.8	0.66
0.6-0.8	1.0
0.4-0.6	1.3
0.2-0.4	2.0
0.1-0.2	2.7
<0.1	3.3

FIGURE 11b. Table for circuit resistance multipiers.

Quality Factor: All of these multipliers are applied to the established or base failure rate of the part. The T492 Series is qualified under U.S. military specification MIL-PRF-55365. Failure rates as low as 0.001% kHr are available under this test program.

For series not covered by military specifications, an internal sampling program is operated by KEMET Quality Assurance whereby parts are put on life test at rated voltage for 2000 hours. The confidence level chosen for the reporting data is 60%. (The cost of sampling each batch would be prohibitive, and no claim is made to guarantee the failure rate of each batch.) With this testing and each new qualification test for new parts, the average failure rate for all commercial Series lies between 0.1% and 1.0% per thousand-piece-hours.

FIT Calculator

All of these factors are gathered into a Windows based software, available free from the KEMET web site (www.kemet.com). The "FIT Calculator" software does all the calculations and look-ups based on information entered or selected by the operator. A manual may also be downloaded from the same web page to explain the controls and displays The manual as well as a help screen also detail the environmental conditions.

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20. Surge Current

All conventional reliability testing is conducted under steady-state DC voltage. Experience indicates that AC ripple, within the limits prescribed, has little effect on failure rate. Heavy surge currents are possible in some applications, however. Circuit impedance may be very low (below the recommended 0.1 ohm/volt) or there may be driving inductance to cause voltage "ringing." Surge current may appear during turn-on of equipment, for example. Failure rate under current-surge conditions may not be predictable from conventional life test data.

Capacitors are capable of withstanding a 4 ±1 second charge of rated voltage (±2%) through a total circuit resistance (excluding the capacitor) of 1 ±0.2 ohms at +25°C, followed by a 4 ±1 second discharge to a voltage below 1% of the rated voltage. This cycle is repeated consecutively three (3) times. Post test performance:

a. Capacitance — within ±5% of initial value
b. DC Leakage — within initial limit
c. Dissipation Factor — within initial limit

100% production surge current testing is performed on all Tantalum Chip series for case sizes C, D, E, X, U, V. The total test circuit resistance is ≤ 0.5 ohms. The applied voltage is 75% of rated voltage for all series except the T495 and T510 which are surged at 100% of rated voltage. Four surge cycles are applied. Parts not capable of surviving this test are removed at subsequent electrical screening. See T493 Series on page 22 for specific surge options.

21. Storage Life Test
• *2,000 hours, +125°C, Unbiased, Mounted*
Post Test Performance:
a. Capacitance — within ±10% of initial value
b. DC Leakage — within initial limit
c. Dissipation Factor — within initial limit
d. ESR — within initial limit
e. Physical — no degradation of function

22. Standard Life Test
• *2,000 hours, +85°C, Rated Voltage, Mounted*
Post Test Performance:
a. Capacitance — within ±10% of initial value
b. DC Leakage — within 125% of initial limit
c. Dissipation Factor — within initial limit
d. ESR — within initial limit
e. Physical — no degradation of function

23. High Temperature Life Test
• *2,000 hours, +125°C, 2/3 Rated Voltage, Mounted*
Post Test Performance:
a. Capacitance — within ±10% of initial value
b. DC Leakage — within 125% of initial limit
c. Dissipation Factor — within initial limit
d. ESR — within initial limit
e. Physical — no degradation of function

MECHANICAL

24. Resistance to Solvents
• *Mil-Std-202, Method 215*
Post Test Performance:
a. Capacitance — within ±10% of initial value
b. DC Leakage — within initial limit
c. Dissipation Factor -— within initial limit
d. Physical — no degradation of case, terminals or marking.

25. Fungus
• *Mil-Std-810, Method 508*

26. Flammability
• *UL94 VO Classification*
Encapsulant materials meet this classification.

27. Resistance to Soldering Heat
• *Wave Solder +260 ±5°C, 10 Seconds*
• *Infrared Reflow +230 ±5°C, 30 Seconds*
• *Vapor Phase Reflow +215 ±5°C, 2 minutes*
Post Test Performance:
a. Capacitance — within ±10% of Initial Value
b. DC Leakage — within Initial Limit
c. Dissipation Factor — within Initial Limit

28. Solderability
• *Mil-Std-202, Method 208*
• *ANSI/J-STD-002, Test B*
Applies to Solder and Tin Coated terminations only. Does not apply to optional gold-plated terminations.

29. Vibration
• *Mil-Std-202, Method 204, Condition D. 10 Hz to 2,000 Hz, 20G Peak*
Post Test Performance:
a. Capacitance — within ± 10% of initial value
b. DC Leakage — within initial limit
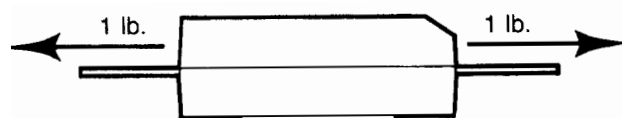c. Dissipation Factor — within initial limit

30. Shock
• *Mil-Std-202, Method 213, Condition I. 100 G Peak*
Post Test Performance:
a. Capacitance — within ±10% of initial value
b. DC Leakage — within initial limit
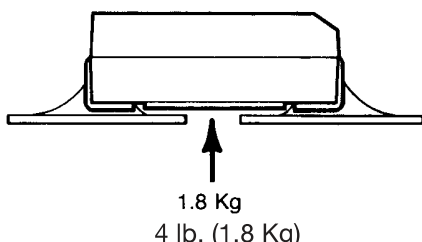c. Dissipation Factor — within initial limit

31. Terminal Strength
• **Pull Force**
• *One Pound (454 grams), 30 Seconds*

SOLID TANTALUM CHIP CAPACITORS

KEMET
CHARGED.

TANTALUM MnO$_2$ COMPONENT PERFORMANCE CHARACTERISTICS (con't.)

- **Tensile Force**
  - *Four Pounds (1.8 kilograms), 60 Seconds*

1.8 Kg
4 lb. (1.8 Kg)

- **Shear Force**

Table 8 Maximum Shear Loads

Case Code		Maximum Shear Loads	
KEMET	EIA	Kilograms	Pounds
R	2012-12	2.4	5.3
S	3216-12	3.2	7.0
T	3528-12	3.6	8.0
U	6032-15	4.5	10.0
V	7343-20	5.0	11.0
A	3216-18	3.2	7.0
B	3528-21	3.6	8.0
C	6032-28	4.5	10.0
D	7343-31	5.0	11.0
X	7343-43	5.0	11.0
E	7260-38	5.0	11.0
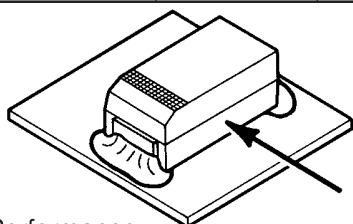
Post Test Performance:
  a. Capacitance — within ±5% of initial value
  b. DC Leakage — within initial limit
  c. Dissipation Factor — within initial limit

APPLICATIONS

32. Handling

Automatic handling of encapsulated components is enhanced by the molded case which provides compatibility with all types of high speed pick and place equipment. Manual handling of these devices presents no unique problems. Care should be taken with your fingers, however, to avoid touching the solder-coated terminations as body oils, acids and salts will degrade the solderability of these terminations. Finger cots should be used whenever manually handling all solderable surfaces.

33. Termination Coating

KEMET's standard termination finish is 100% Sn (Excluding the T492/3 series. Refer to specific lead frame options available on T493 Series). Standard terminations can be ordered with a "T" suffix in the lead material designator of the KEMET part number. Components ordered with the "T" suffix are Pb-Free/RoHS compliant and are backward and forward compatible with SnPb and Pb-Free soldering processes.

90Sn/10Pb terminations are also available and can be ordered with an "H" suffix.

KEMET's "S" suffix remains an active termination designator for current designs but is not recommended for new designs. Parts ordered with an "S" suffix are not guaranteed to be Pb-Free or RoHS compliant. Refer to www.kemet.com for information on Pb-Free transition.

For conductive adhesive attachment processes, a gold termination finish is available for most series and case sizes. Refer to the specific series for details.

34. Recommended Mounting Pad Geometries

Proper mounting pad geometries are essential for successful solder connections. These dimensions are highly process sensitive and should be designed to maximize the integrity of the solder joint, and to minimize component rework due to unacceptable solder joints.

Figure 12 illustrates pad geometry. Tables 9 & 10 provide recommended pad dimensions for both wave and reflow soldering techniques. These dimensions are intended to be a starting point for circuit board designers, to be fine tuned, if necessary, based upon the peculiarities of the soldering process and/or circuit board design.

Contact KEMET for Engineering Bulletin Number F-2100 entitled "Surface Mount Mounting Pad Dimensions and Considerations" for further details on this subject.
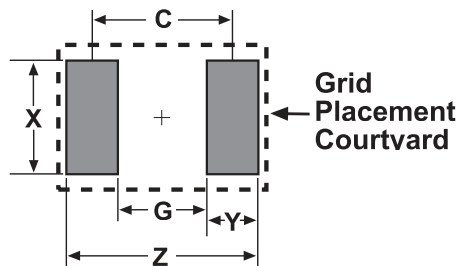
Figure 12

Table 9 – Land Pattern Dimensions for Reflow Solder

KEMET/EIA Size Code	Pad Dimensions - mm				
	Z	G	X	Y (ref)	C (ref)
R/2012-12	3.90	0.80	1.80	1.55	2.35
A/3216-18, S/3216-12	4.70	0.80	1.50	1.95	2.75
B/3528-21, T/3528-12	5.00	1.10	2.50	1.95	3.05
C/6032-28, U/6032-15	7.60	2.50	2.50	2.55	5.05
D/7343-31, V/7343-20, X/7343-43	8.90	3.80	2.70	2.55	6.35
E/7260-38	8.90	3.80	4.40	2.55	6.35

Table 10 – Land Pattern Dimensions for Wave Solder

KEMET/EIA Size Code	Pad Dimensions - mm				
	Z	G	X	Y (ref)	C (ref)
R/2012-12	4.30	0.80	1.26	1.75	2.55
A/3216-18, S/3216-12	5.10	0.80	1.10	2.15	2.95
B/3528-21, T/3528-12	5.40	1.10	1.80	2.15	3.25
C/6032-28, U/6032-15	8.00	2.50	1.80	2.75	5.25
D/7343-31, V/7343-20, X/7343-43	9.70	3.80	2.70	2.95	6.75
E/7260-38	9.70	3.80	4.40	2.95	6.75

TANTALUM MnO$_2$ COMPONENT PERFORMANCE CHARACTERISTICS (con't.)

35. Soldering

KEMET's families of surface mount tantalum capacitors are compatible with wave (single or dual) soldering and IR or vapor phase reflow techniques. Solder-coated terminations have excellent wetting characteristics for high integrity solder fillets. Preheating of these components is recommended to avoid extreme thermal stress. Figure 13 represents recommended maximum solder temperature / time combinations for these devices.

Note that although the X/7343-43 case size can withstand wave soldering, the tall profile (4.3mm maximum) dictates care in wave process development.

Sn-Pb Profile

Pb-Free Profile
260°C Peak Temperature (3 passes)
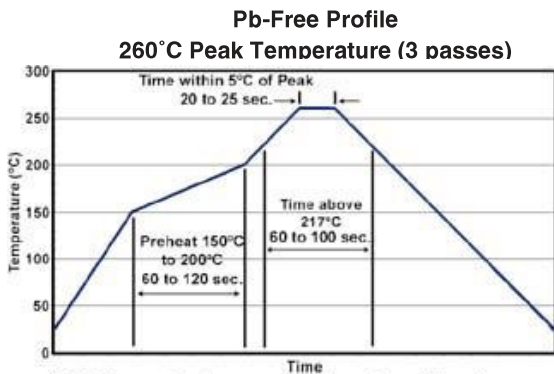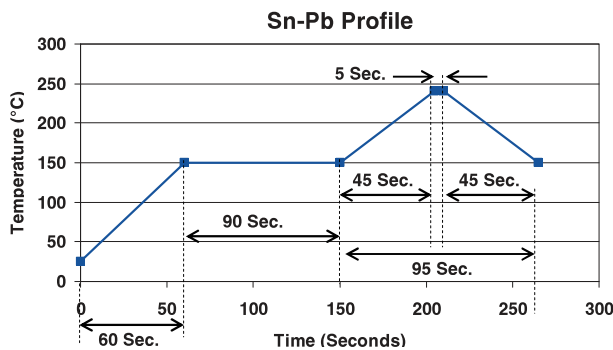
NOTE: Temperature is measured on the surface of the part

FIGURE 13   Time/Temperature Soldering Profile

Hand-soldering should be performed with care due to the difficulty in process control. If performed, care should be taken to avoid contact of the soldering iron to the molded case. The iron should be used to heat the solder pad, applying solder between the pad and the termination, until reflow occurs. The iron should be removed. "Wiping" the edges of a chip and heating the top surface is not recommended.

During typical reflow operations a slight darkening of the gold-colored epoxy may be observed. This slight darkening is normal and is not harmful to the product. Marking permanency is not affected by this change.

36. Washing

Standard washing techniques and solvents are compatible with all KEMET surface mount tantalum capacitors. Solvents such as Freon TMC and TMS, Trichlorethane, methylene chloride, prelete, and isopropyl alcohol are not harmful to these components.

If ultrasonic agitation is utilized in the cleaning process, care should be taken to minimize energy levels and exposure times to avoid damage to the terminations.

KEMET tantalum chips are also compatible with newer aqueous and semi-aqueous processes. Please follow the recommendations for cleaning as defined by the solder vendor.

37. Encapsulations

Under normal circumstances, potting or encapsulation of KEMET tantalum chips is not required.

38. Storage Environment

Tantalum chip capacitors should be stored in normal working environments. While the chips themselves are quite robust in other environments, solderability will be degraded by exposure to high temperatures, high humidity, corrosive atmospheres, and long term storage. In addition, packaging materials will be degraded by high temperature – reels may soften or warp, and tape peel force may increase. KEMET recommends that maximum storage temperature not exceed 40 degrees C, and maximum storage humidity not exceed 60% relative humidity. In addition, temperature fluctuations should be minimized to avoid condensation on the parts, and atmospheres should be free of chlorine and sulfur bearing compounds. For optimized solderability, chip stock should be used promptly, preferably within 3 years of receipt.

39. Component Weights
• *T49x, T510 Series*

Series	Case Size	Typical Weight (mg)
T49x	A/3216-18	32
T49x	B/3528-21	60
T49x	C/6032-28	130
T49x	D/7343-31	320
T49x	X/7343-43	500
T49x	E/7360-38	600
T49x	R/2012-12	10
T49x	S/3216-12	21
T49x	T/3528-12	34
T49x	U/6032-15	70
T49x	V/7343-20	206
T510	D/7343-31	338
T510	X/7343-43	510
T510	E/7360-38	645