

COMPONENT PERFORMANCE CHARACTERISTICS

Introduction

KEMET has developed a new type of tantalum capacitor that replaces the solid manganese dioxide electrode with a solid conductive polymer. This product is named the KO-CAP for **KEMET Organic Capacitor**. The basic families are the T520, T525 and T530 series. A separate detail of performance characteristics is presented here as there are some differences between the polymer tantalums and the standard MnO₂ types. Like all KEMET tantalum chips, these series are 100% screened for all electrical parameters: Capacitance @ 120 Hz, Dissipation Factor (DF) @ 120 Hz, ESR @ 100 kHz and DC Leakage. It is also 100% surge current tested at full rated voltage through a low impedance circuit. The advantages of the polymer include very low ESR and elimination of the potentially catastrophic failure mode that may occur with standard tantalum capacitors in a high current application. Although the natural KO-CAP series failure mechanism is a short circuit, it does not exhibit an explosive failure mode.

ELECTRICAL

1. Operating Temperature Range

- **-55°C to +105°C for T520; -55°C to +125°C for T525 and T530**

For T525 and T530 Series above 105°C, the voltage rating is reduced linearly from 1.0 x rated voltage to 0.8 x rated voltage at 125°C.

2. Non-Operating Temperature Range

- **-55°C to +105°C for T520**
- **-55°C to +125°C for T525 and T530**

3. Capacitance and Tolerance

- **15µF to 1500µF**
- **±20% Tolerance**

Capacitance is measured at 120 Hz, up to 1.0 volt rms maximum and up to 2.5V DC maximum. 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 for room temperature measurements but is more commonly used when measuring at temperature extremes.

Capacitance does decrease with increasing frequency, but not nearly as much or as quickly as standard tantalums. Figure 1 compares the frequency induced cap roll-off between the KO-CAP and traditional MnO₂ types. Capacitance also increases with increasing temperature. See section 12 for temperature coefficients.

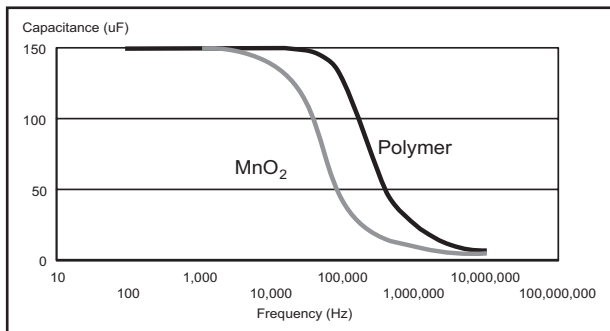
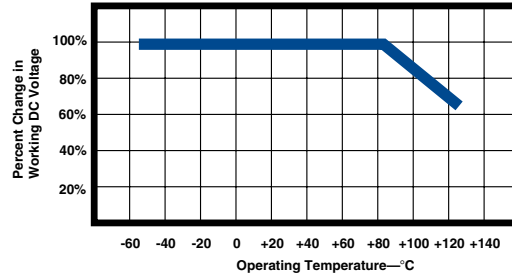


FIGURE 1

4. Voltage Ratings

- **2V-25V DC Rated Voltage**

This is the maximum peak DC operating voltage from -55°C to +105°C for continuous duty. Above 105°C, this voltage is derated linearly to 2/3 the rated voltage for operation at 125°C for T525 and T530 Series.



• Surge Voltage Ratings

Surge voltage capability is demonstrated by application of 1000 cycles of the relevant voltage, at 25°C, 85°C or 105°C. The parts are charged through a 33 ohm resistor for 30 seconds and then discharged through a 33 ohm resistor for 30 seconds for each cycle.

• Voltage Ratings • Table 1

Rated Voltage	Surge Voltage	Derated Voltage	Derated Surge Voltage
-55°C to +105°C		+125°C	
2V	2.6V	1.6V	2.1V
2.5V	3.3V	2.0V	2.6V
3V	3.9V	2.4V	3.1V
4V	5.2V	3.2V	4.2V
6.3V	8.2V	5V	6.5V
8V	10.4V	6.4V	8.3V
10V	13V	8V	10.4V
16V	20.8V	12.8V	16.6V
25V	32.5V	20V	26V

5. Reverse Voltage Rating & Polarity

Polymer capacitors are polar devices and may be permanently damaged or destroyed if connected in the wrong polarity. The positive terminal is identified by a laser-marked stripe and may also include a beveled edge. These capacitors will withstand a small degree of transient voltage reversal for short periods as shown in the following table. Please note that these parts may not be operated continuously in reverse, even within these limits.

Table 2

Temperature	Permissible Transient Reverse Voltage
25°C	15% of Rated Voltage
55°C	10% of Rated Voltage
85°C	5% of Rated Voltage
85°C	5% of Rated Voltage
105°C	3% of Rated Voltage
125°C	1% of Rated Voltage

6. DC Leakage Current

Because of the high conductivity of the polymer, the KO-CAP family has higher leakage currents than traditional MnO₂ type Tantalum caps. The DC Leakage limits at 20°C are calculated as $0.1 \times C \times V$, where C is cap in µF and V is rated voltage in Volts. Limits for all part numbers are listed in the ratings tables.

DC Leakage current is the current that flows through the capacitor dielectric after a five minute charging period at rated voltage. Leakage is measured at 20°C with full rated voltage applied to the capacitor through a 1000 ohm resistor in series with the capacitor.

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DC Leakage current does increase with temperature. The limits for 85°C @ Rated Voltage and 105°C @ 0.8 x Rated Voltage are both 10 times the 25°C limit.

7. Surge Current Capability

Certain applications may induce heavy surge currents when circuit impedance is very low (<0.1 ohm per volt). Driving inductance may also cause voltage ringing. Surge currents may appear as transients during turn-on of equipment.

The KO-CAP has a very high tolerance for surge current. And although the failure mechanism is a short circuit, they do not ignite as may occur with standard tantalums in such applications.

The KO-CAP series receives 100% screening for surge current in our production process. Capacitors are surged 4 times at full rated voltage applied through a total circuit resistance of <0.5 ohms. Failures are removed during subsequent electrical testing.

8. 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 2.5 volts DC maximum at +20°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.

Dissipation factor 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.

$$DF = \frac{R}{X_c} = 2 \pi f CR$$

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 $\tan \delta$ or “loss tangent.” The “Quality Factor,” “Q,” is the reciprocal of DF.

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

The Equivalent Series Resistance (ESR) of the KO-CAP is much lower than standard Tantalum caps because the polymer cathode has much higher conductivity. 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.

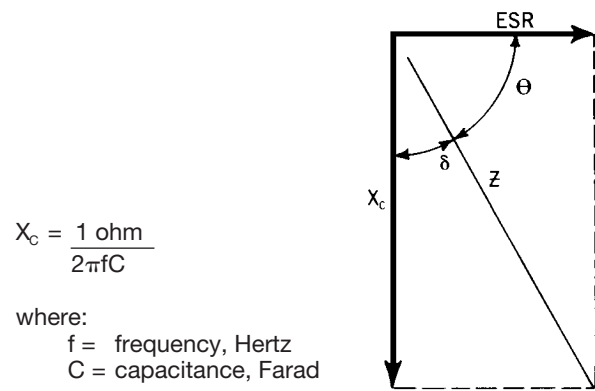


FIGURE 2a Total Impedance of the Capacitor Below Resonance

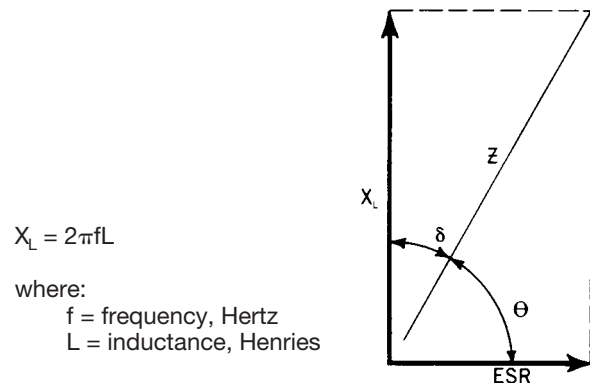


FIGURE 2b Total Impedance of the Capacitor Above Resonance

To understand the many elements of a capacitor, see Figure 3.

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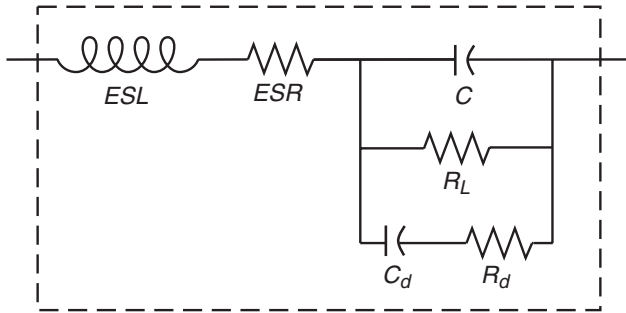


FIGURE 3 The Real Capacitor

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.

Figure 4 compares the frequency response of a KO-CAP to a standard Tantalum chip. Maximum limits for 100 kHz ESR are listed in the part number tables for each series.

The T530 Capacitance, Impedance and ESR vs. Frequency Comparisons are located on page 57. Maximum limits for 100 kHz are listed in the part number table on page 56.

ESR and Impedance

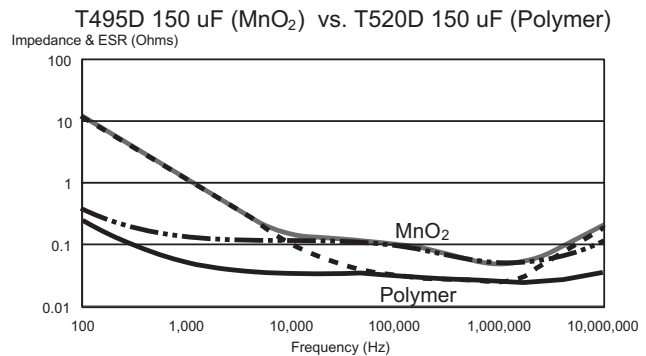


FIGURE 4

10. 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 3 Power Dissipation Ratings

Case Code		Maximum Power Dissipation
KEMET	EIA	mWatts @ +45°C w/+30°C Rise
T520/525T	3528-12	105
T520M	3528-15	120
T520A	3216-18	112
T520/525B	3528-21	127
T520U	6032-15	135
T520L	6032-19	150
T520C	6032-28	165
T520W	7343-15	180
T520V	7343-20	187
T520/525D	7343-31	225
T520Y	7343-40	241
T520X	7343-43	247
T528I	3216-10	95
T528M	3528-15	200
T528Z	7343-17	325
T530D	7343-31	255
T530Y	7343-40	263
T530X	7343-43	270

The maximum power dissipation rating stated in Table 3 must be reduced with increasing environmental operating temperatures. Refer to Table 3a for temperature compensation requirements.

Table 3a Temperature Compensation Multipliers for Maximum Power Dissipation

≤45°C	45°C < T ≤ 85°C	85°C < T ≤ 105°C
1.00	0.70	0.25

*T = Environmental Temperature

11. Ripple Current/ Ripple Voltage

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:

- The positive peak AC voltage plus the DC bias voltage, if any, must not exceed the DC voltage rating of the capacitor.
- The negative peak AC voltage, in combination with bias voltage, if any, must not exceed the permissible reverse voltage ratings presented in Section 5.
- The power dissipated in the ESR of the capacitor must not exceed the appropriate value specified in Section 10.

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Actual power dissipated may be calculated from the following:

$$P = I^2R$$

$$\text{Substituting } I = \frac{E}{Z}, \quad P = \frac{E^2R}{Z^2}$$

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 3, maximum allowable rms ripple current or voltage may be determined as follows:

$$I(\text{max}) = \sqrt{P \text{ max}/R} \quad E(\text{max}) = Z \sqrt{P \text{ max}/R}$$

ENVIRONMENTAL

12. Temperature Stability

Mounted capacitors withstand extreme temperature testing at a succession of continuous steps at +25°C, -55°C, +25°C, +85°C, +105°C, +25°C in that order*. Capacitors are allowed to stabilize at each temperature before measurement. Cap, DF, and DCL are measured at each temperature except DC Leakage is not measured at -55°C.

*Maximum temperature 125°C for T525 and T530 series.

Table 4

Acceptable limits are as follows:

Step	Temp.	ΔCap	DCL	DF
1	+25°C	Specified Tolerance	Catalog Limit	Catalog Limit
2	-55°C	±20% of initial value	N/A	Catalog Limit
3	+25°C	±10% of initial value	Catalog Limit	Catalog Limit
4	+85°C	±20% of initial value	10x Catalog Limit	1.2x Catalog Limit
5	+105°C (125°C for T525, T530)	±30% of initial value	10x Catalog Limit	1.5x Catalog Limit
6	+25°C	±10% of initial value	Catalog Limit	Catalog Limit

13. Standard Life Test

• **85°C, Rated Voltage, 2000 Hours**

Post Test Performance:

- Capacitance: within -20%/+10% of initial value
- DF: within initial limit
- DC Leakage: within initial limit
- ESR: within initial limit

14. High Temperature Life Test - 2000 Hours

• **105°C, T520 - 1.0 x Rated Voltage;**
125°C, T525, T530 - .67 x Rated Voltage

Post Test Performance:

- Capacitance: within -20%/+10% of initial value
- DF: within initial limit
- DC Leakage: within 1.25 initial limits for T520; 2 x initial limit for T525, T530
- ESR: within 2 x initial limit for T520, T530
ESR: within initial limit for T525

15. Storage Life Test

• **105°C, 0VDC, 2000 Hours for T520; 125°C for T525, T530**

Post Test Performance:

- Capacitance: within -20%/+10% of initial value
- DF: within initial limit
- DC Leakage: within 1.25 initial limits for T520; 2 x initial limit for T525, T530
- ESR: within 2 x initial limit for T520, T530
ESR: within initial limit for T525

16. Thermal Shock

• **Mil-Std-202, Method 107, Condition B**

Minimum temperature is -55°C

Maximum temperature is +105°C for T520; 125°C for T525, T530

500 Cycles

Post Test Performance:

- Capacitance: within +10%/-20% of initial value
- DF: within initial limit
- DC Leakage: within initial limit
- ESR: within 2 x initial limit

17. Moisture Resistance Testing

• **J-Std-020**

Steps 7a and 7b excluded, 0V, 21 cycles

Post Test Performance:

- Capacitance: within ±30% of initial value
- DF: within initial limit
- DC Leakage: within initial limit
- ESR: within initial limit
- JEDEC J-STD-020C Meets MSL Level 3

18. Load Humidity

• **60°C, 90% RH, Rated Voltage, 500 Hours**

Post Test Performance:

- Capacitance: within +35%/-5% of initial value
- DF: within initial limit
- DC Leakage: within 5 x initial limit
- ESR: within 2 x initial limit

19. ESD

• **Polymer tantalum capacitors are not sensitive to Electro-Static Discharge (ESD).**

20. Failure Mechanism and Reliability

The normal failure mechanism is dielectric breakdown. Dielectric failure can result in high DC Leakage current and may proceed to the level of a short circuit. With sufficient time to charge, healing may occur by one of two potential mechanisms. The polymer adjacent to the dielectric fault site may overheat and vaporize, disconnecting the fault site from the circuit. The polymer may also

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Conductive Polymer Surface Mount

oxidize into a more resistive material that eliminates the defect site in the dielectric and reduces the flow of current.

Capacitor failure may be induced by exceeding the rated conditions of forward DC voltage, reverse DC voltage, surge current, power dissipation or temperature. Excessive environmental stress, such as prolonged or high temperature reflow processes may also trigger dielectric failure.

Failure rates may be improved in application by derating the voltage applied to the capacitor. KEMET recommends that KO-CAPs be derated to 90% or less of the rated voltage in application for part types $\leq 10V$. Parts $> 10V$ should be derated to 80% or less of the rated voltage.

KO-CAPs exhibit a benign failure mode in that they do not fail catastrophically even under typical fault conditions. If a shorted capacitor is allowed to pass unlimited current, it may overheat and the case may discolor. But this is distinctly different from the "ignition" that may occur with standard MnO₂ cathode tantalums. Replacement of the MnO₂ by the polymer removes the oxygen that fuels ignition during a failure event.

MECHANICAL

21. Resistance to Solvents

- *Mil-Std-202, Method 215*

Post Test Performance:

- Capacitance — within $\pm 10\%$ of initial value
- DC Leakage — within initial limit
- Dissipation Factor — within initial limit
- ESR — within initial limit
- Physical — no degradation of case, terminals or marking

22. Fungus

- *Mil-Std-810, Method 508*

23. Flammability

- *UL94 VO Classification*

Encapsulant materials meet this classification

24. Resistance to Soldering Heat

- *Maximum Reflow*
+240 $\pm 5^\circ\text{C}$, 10 seconds
- *Typical Reflow*
+230 $\pm 5^\circ\text{C}$, 30 seconds

Post Test Performance:

- Capacitance — within $\pm 10\%$ of initial value
- DC Leakage — within initial limit
- Dissipation Factor — within initial limit
- ESR — within initial limit

25. Solderability

- *Mil-Std-202, Method 208*
- *ANSI/J-STD-002, Test B*

Applies to Solder Coated terminations only.

26. Vibration

- *Mil-Std-202, Method 204, Condition D, 10 Hz to 2,000 Hz, 20G Peak*

Post Test Performance:

- Capacitance — within $\pm 10\%$ of initial value
- DC Leakage — within initial limit
- Dissipation Factor — within initial limit
- ESR — within initial limit

27. Shock

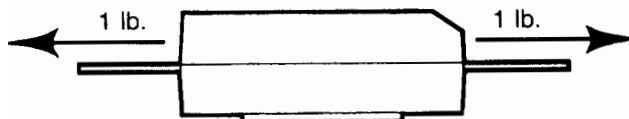
- *Mil-Std-202, Method 213, Condition I, 100 G Peak*

Post Test Performance:

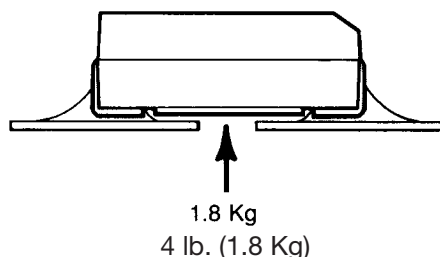
- Capacitance — within $\pm 10\%$ of initial value
- DC Leakage — within initial limit
- Dissipation Factor — within initial limit
- ESR - within initial limit

28. Terminal Strength

- **Pull Force**
• **One Pound (454 grams), 30 Seconds**



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

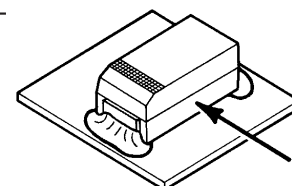


- **Shear Force**
Table 5 Maximum Shear Loads

Case Code		Maximum Shear Loads	
KEMET	EIA	Kilograms	Pounds
A	3216-18	3.2	7.0
T	3528-12	3.6	8.0
B	3528-21	3.6	8.0
C	6032-28	4.5	10.0
V	7343-20	5.0	11.0
W	7343-15	5.0	11.0
D	7343-31	5.0	11.0
Y	7343-40	5.0	11.0
X	7343-43	5.0	11.0

Post Test Performance:

- Capacitance — within $\pm 5\%$ of initial value
- DC Leakage — within initial limit
- Dissipation Factor — within initial limit
- ESR - within initial limit



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APPLICATIONS

29. 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.

30. Termination Coating

KEMET's standard termination finish is 100% Sn. 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.

31. Recommended Mounting Pad Geometries

Proper mounting pad geometries are essential for successful solder connections. These dimensions are highly process sensitive and should be designed

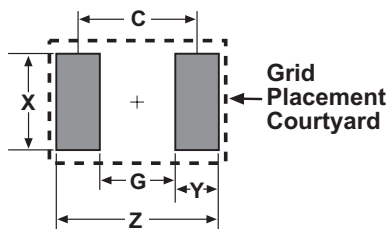


Table 6 - Land Pattern Dimensions for Reflow Solder

KEMET/EIA Size Code	Pad Dimensions				
	Z	G	X	Y (ref)	C (ref)
B/3528-21, T/3528-12	5.00	1.10	2.50	1.95	3.05
C/6032-28	7.60	2.50	2.50	2.55	5.05
D/7343-31, V/7343-20, W/7343-15, X/7343-43, Y/7343-40	8.90	3.80	2.70	2.55	6.35

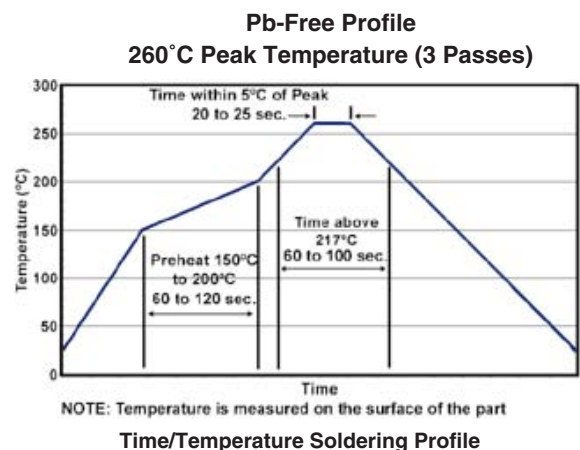
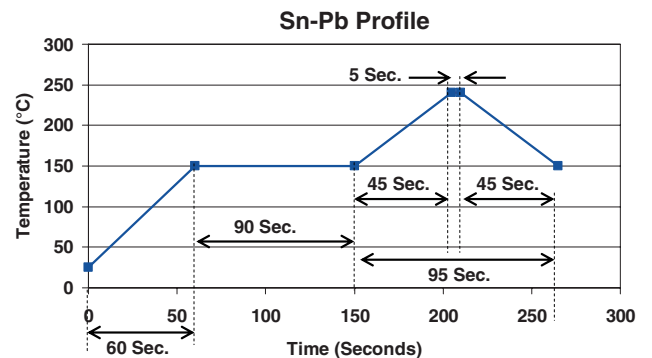
to maximize the integrity of the solder joint, and to minimize component rework due to unacceptable solder joints.

Figure 5 illustrates pad geometry. The table provides recommended pad dimensions for 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.

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

32. Soldering

The T52X KO-CAP family has been designed for reflow solder processes. Solder-coated terminations have excellent wetting characteristics for high integrity solder fillets. Preheating of these components is recommended to avoid extreme thermal stress. Pb (lead) Free peak temperature is 260°C (with up to 3x reflow capabilities).



Hand-soldering should be avoided. If necessary, it should be performed with care due to the difficulty in process control. 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.

The EIA standards for conductive polymer capacitors allows an ESR movement to 1.1 times (or 3 milliohms, whichever is greater) the catalog limit past mounting.

33. 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. Please note that we are not endorsing the use of banned or restricted solvents. We are simply stating that they would not be harmful to the 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.

34. Encapsulations

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

35. Storage Environment

Conductive polymer series (T520, T525, T528, T530) are shipped in moisture barrier bags with a desiccant and moisture indicator card. These series are classified as MSL (Moisture Sensitivity Level 3). Upon opening the moisture barrier bag, parts should be mounted within 7 days to prevent moisture absorption and outgassing. If the 7 day window is exceeded, the parts can be baked per the instructions on the bag (168 hours at 40±5°C).

Polymer 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 the 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 1.5 years of receipt.

COMPONENT WEIGHTS

Series	Case Size	Typical Weight (mg)
T52x	A/3216-18	35
T52x	B/3528-21	65
T52x	C/6032-28	130
T52x	D/7343-31	325
T52x	X/7343-43	500
T52x	T/3528-12	38
T52x	W/7343-15	172
T52x	V/7343-20	210
T530	D/7343-31	342
T530	Y/7343-40	480
T530	X/7343-43	515
T530	E/7360-38	650