

## INTRODUCTION

Advantages of tantalum capacitors are:

- High volumetric efficiency.
- Stable electrical performance over temperature (T.C. 12%).
- Operating temperature range -55°C to +125°C, 2/3 Vr (linear derating) above +85°C, CGT series is derated above +40°C.
- Better frequency characteristics than aluminum electrolytics.
- Self-Healing, no wear out mechanism. No degradation in performance or reliability.
- No limitation on shelf life.

In this application note, we provide tips for design and use

**Substitutions:** Substitutions of higher voltage ratings, lower ESR values, tighter capacitance tolerances and higher temperature rated devices will increase performance and reliability.

It is common practice for engineers to select a voltage rating 2 to 3 times that of the rated voltage for circuits that expected to see swings in voltages. See "Voltage derating"

**Surge voltages:** Surge voltages may be applied up to ten times in an hour for periods up to 30 seconds at a time. They are not intended for continuous operation and should not be used as a parameter for design. See table below.

Rated Working Voltage +85°C	Surge Voltage +85°C	Derated DC Voltage +125°C	Surge Voltage +125°C
2	2.7	1.3	1.7
3	3.9	2.0	2.6
4	5.2	2.7	3.2
5	6.5	3.3	4.0
6	8	4	5
10	13	7	8
16	20	10	12
20	26	13	16
25	32	17	20
35	46	23	28
50	65	33	40

**Voltage derating:** Voltage derating is the practice of select a higher voltage rated part (30% to 70%) than the maximum line voltage. This improves the operating reliability of a tantalum capacitor. In the case of low impedance circuits, the tantalum capacitor is likely to be stressed by current surges. In circuits which undergo rapid charge/discharge, a protective resistor of 1.0 ohm per applied volt is recommended. If this is impossible, a voltage-derating factor of up to 70% is recommended. A combination of tantalum capacitors can be connected in series to increase working voltage of the equivalent capacitor. In many power supply topologies where the di/dt through the capacitor is limited, such as most implementations of buck (current mode), forward converter and flyback, the requirement for series resistance is decreased to 0.1 ohm per applied volt. This level of resistance is used as a basis for the series resistance variable in a 1%/1000 hours 60% confidence level reference. This is what steady state life tests are based on. Certain test circuits such as ICT are likely to subject the capacitor to large voltage and current transients, which will not be seen in normal use. This should be taken into account when considering the capacitors rated voltage.

A small amount of reverse voltage is permissible for short periods. It is not intended to cover continuous operation.

**Polarity:** Tantalum capacitors are polar devices. A non-polar effect can be created by connecting two devices, arranged back-to-back (-to -). The capacitance value of each part should be twice the required capacitance value, equal tolerance and rated voltage. For example, two PCT10/35DK devices connected in a back-to-back configuration would result in a non-polar 5µfd, 35V device.

**Maximum reverse voltages:** Tantalum capacitors are polar devices. They should never be used in a circuitry where a reverse voltage – voltage applied opposite to the polarity – is applied constantly. However – as guideline, the maximum reverse voltages are:

- +25°C 10% of rated voltage not exceeding 1.0 volt
- +85°C 3% of rated voltage not exceeding 0.5 volt
- +125°C 1% of rated voltage not exceeding 0.1 volt

**In DC-DC converters:** The input side is typically fed from voltage sources, which are not regulated and are of nominally low impedance. This type of application severely stresses the capacitor. A higher than normal failure rate level may be experienced. Maximum voltage derating and use of low ESR devices is recommended.

**Higher capacitances and even lower ESR:**

Values can be achieved by connecting tantalum capacitors in parallel.

**Electrostatic Discharge:**

Tantalum capacitors demonstrate no sensitivity to ESD.

**Flammability:** UL Rating UL94 VO, Oxygen Index 35%. Epoxy, Hysol MG 33.

**Ripple current ratings:** Ripple current ratings for all devices can be calculated. For 25°C ripple current ratings, take the square root of the part's free air maximum power dissipation in watts (from the table below) divided by the maximum ESR rating of the component listed in the catalog in ohms (where applicable, convert milliohm values to ohms). Apply the temperature correction factor for temperature above 25°C.

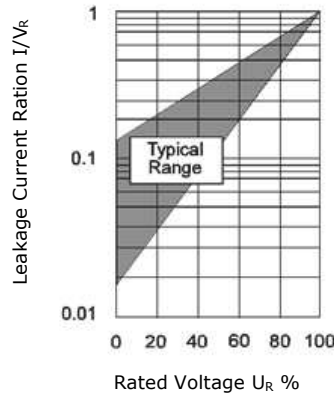
$$I_{RMS} = \sqrt{\frac{\text{Power Rating (MAX Watts)}}{\text{ESR (MAX Ohms)}} \cdot \text{Temperature Correction Factor}}$$

85°C = 0.90  
125°C = 0.40

Surface Mount Tantalums				Dipped Radial			
Case Size	Free Air Max Power Dissipation (W)	Temperature Derating Factors for power dissipation by case size		Case Size	Free Air Max Power Dissipation (W)	Temperature Derating Factors for power dissipation by case size	
A	0.075	Do not use these derating factors when calculating ripple current ratings. Use temperature correction factors.		A	0.045	Do not use these derating factors when calculating ripple current ratings. Use temperature correction factors.	
B	0.085			B	0.050		
C	0.110			C	0.055		
D	0.150			D	0.060		
H	0.185			E	0.065		
Z	0.250			F	0.075		
		Temp °C	Factor	G	0.080	Temp °C	Factor
		+25	1.00	H	0.085	+25	1.00
XL	0.055	+85	0.80	J	0.090	+85	0.40
AL	0.065	+125	0.16	K	0.100	+125	0.09
BL	0.080			L	0.110		
CL	0.090			M	0.120		
DL	0.125			N	0.130		
N	0.015			O	0.140		
P	0.025						

NOTE: For more details, refer to Performance Application Note.

**DC Leakage Current:** DC leakage current is dependent on the voltage applied, elapsed time of voltage applied and temperature. Leakage current is measured after 3-5 minutes application of the rated voltage at +20°C. Leakage current increases with higher temperatures and can be mitigated by increasing the voltage rating of the part. Leakage current drops rapidly below the parts initial value when reduced voltages are applied. Voltage derating of the component has the effect of decreasing leakage as shown in the graph below. This will also give a significant increase in the reliability of the part for any application.



**Self Inductance Value (ESL) for surface mount devices:** The self inductance value can be important for resonance frequency evaluation. This table shows typical ESL values per case size.

Self Inductance Value (ESL)	
Case Size	Typical Self Inductance Value (nH)
A	1.8
B	1.8
C	2.2
D	2.4
H	2.5
Z	2.4
XL	1.4
AL	1.8
BL	1.8
CL	2.2
DL	2.4
P	1.1
R	1.2

**Soldering Considerations:** There are several important general soldering considerations for tantalum capacitors.

- Soldering temperature and time should be the minimum for a good connection.
- Recommended soldering profiles are designed to insure that the temperature of the internal construction of the capacitors does not exceed +220°C.
- Positioning capacitors near components radiating heat such as power transistors should be avoided.
- Allow for an increase to ESR ratings of 1.25 x catalog limit post PCB assembly.

**Lead-free RoHS compliant, 100% Sn termination finish:**

Legislation is being developed worldwide to reduce the lead content and other hazardous substances in electronic products. This will reduce the environmental impact when such products are discarded. Nemco products are lead-free devices which meet RoHS requirements. Optional suffix codes have been added to our part numbering system so either 90/10 Sn/Pb or 100% Sn (lead-free) can be specified. The following general information applies to lead-free surface mount devices.

**IR and Convection reflow:**

Pre-heating: 150°C +/- 15°C / 60-90s  
 Maximum peak temperature: 240°C – 260°C, 250°C max recommended, 10 seconds maximum time at peak, 3 reflow cycles. Ramp rate: 2-3°C/sec.  
 Maximum time (cumulative) above 230°C 40 seconds.  
 Cool down should not be forced. 6°C/sec. is recommended.

**Wave soldering:**

PCT, LSR, MCT, CGT, SPT and MPT: Maximum peak temperature: 250°C – 260°C for 3-5 seconds max (250°C max recommended)  
 TB: Maximum peak temperature: 230°C – 250°C for 3-5 seconds max (240°C max recommended)  
 All other parameters remain the same as for IR reflow.

**Hand soldering:**

Soldering iron tip diameter: select to fit application  
 Maximum tip temperature: +370°C  
 Maximum exposure time: 3 seconds  
 Apply heat to pad, not the terminations.

**Recommended solder alloy for reflow:** SnAgCu

lead-free (100% Sn) termination finish is compatible with all common lead-free solder pastes including SnCu, SnCuAgBi, etc.

**Recommended solder alloy for wave soldering:** SnCu

**Recommended solder alloy for hand soldering:** SnAgCu

**Soldering conditions:**

Fluxes containing acids must not be used.

**Cooling:**

After soldering, the assembly should preferably be allowed to cool naturally to room temperature. In the event that assisted cooling is used, the rate of change in temperature should not exceed that used in reflow.

**Forward compatibility:**

Parts with Sn/Pb can be used in a lead-free process depending on the solder and solder temperature.  
 Solders with Bi are not compatible.

**Backward compatibility:**

Lead-free parts (100% Sn termination finish) can be used in a Sn/Pb process. The 100% Sn (Tin) termination finish is compatible with existing Sn/Pb solder pastes / systems in use today.

**RoHS**

Nemco lead-free product complies with EU Directive 2002/95/EC on the Restriction of Hazardous Substances requirements.

**JEDIC:** JEDEC Standard JESD97

Nemco lead-free surface mount devices are in accordance with category e3 terminations.

**Moisture Sensitivity Level (MSL):**

PCT, LSR, MCT and TB series moisture sensitivity level per IPC/Jedec J-STD-020B is level 1.  
CGT, SPT and MPT series moisture sensitivity level per IPC/Jedec J-STD-020B is level 3.

**Visual standard:**

Lead-free solder joints are not as bright as tin-lead pastes and the fillet may not be as large.

**Resin color:**

The encapsulant resin color may darken due to the increase in temperature required for the paste.

**Self alignment:**

Lead-free solder pastes do not allow the same self alignment as lead containing systems, Standard mounting pads are acceptable, but machine set up may need to be modified.

**Reliability:**

PCT, LSR, MCT, SPT and MCT, and TB series are 1% per 1,000 hours at 85°C, Vr with 0.1Ω / V series impedance, 60% confidence level. CGT series is 0.2% per 1,000 hours at 85°C, 0.5xVr with 0.1Ω / V series impedance, 60% confidence level.