Wet Electrolyte Tantalum Capacitors: An Introduction to the Basics

By Mike Mosier

INTRODUCTION

Tantalum electrolytic capacitors are the preferred choice in applications where volumetric efficiency, stable electrical parameters, high reliability, and long service life are the primary considerations. The stability and resistance to elevated temperatures of the tantalum/tantalum oxide system make wet tantalum capacitors an appropriate choice for today's technology. Vishay is a pioneer and leader in this field, producing a large variety of solid and wet tantalum capacitor types for industrial, automotive, medical, military, and aerospace electronic applications.

Tantalum is not found in its pure state. Rather, it is commonly found in a number of oxide minerals, often in combination with Columbium ore. This combination is known as tantalite when its contents are more than one-half tantalum. Important sources of tantalite include Australia, Brazil, Canada, China, and several African countries. Synthetic tantalite concentrates produced from tin slags in Thailand, Malaysia, and Brazil are also a significant raw material for tantalum production.

Electronic applications and particularly capacitors consume the largest share of world tantalum production. Other important applications for tantalum include cutting tools (tantalum carbide), high temperature super alloys, chemical processing equipment, medical implants, and military ordnance. Vishay is one of the major users of tantalum materials in the form of powder and wire for capacitor elements and rod and sheet for high temperature vacuum processing.

THE BASICS OF TANTALUM CAPACITOR TECHNOLOGY

Most metals form crystalline oxides which are electrically conductive, such as rust on iron or black oxide on copper. A few metals form dense, stable, tightly adhering, electrically insulating oxides. These are the so-called valve metals and include titanium, zirconium, niobium, tantalum, hafnium, and aluminum. Only a few of these permit the accurate control of oxide thickness by electrochemical process parameters. Of these, the most valuable for the electronics industry are aluminum and tantalum. Wet tantalum capacitors are basic to all kinds of electrical equipment from satellites, aerospace, airborne, military ground support, oil exploration, and power supplies. Their function is to store an electrical charge for later use.

Capacitors consist of two conducting surfaces and an insulating material, or dielectric that separates them. The dielectric used in all tantalums electrolytic capacitors is tantalum pentoxide. Tantalum pentoxide compound possesses high dielectric strength and a high dielectric constant. As capacitors are being manufactured, a film of tantalum pentoxide is applied to their electrodes by means of an electrochemical process. The film is applied at various voltages resulting in various thicknesses, and although transparent to begin with, it takes on different colors as light refracts through it. Rating for rating, tantalum capacitors tend to have as much as three times better capacitance / volume efficiency than aluminum electrolytic capacitors. An approximation of the capacitance / volume efficiency of other types of capacitors may be inferred from the following table, which shows the dielectric constant ranges of the various materials used in each type. Note that tantalum pentoxide has a dielectric constant of 26, some three times greater than that of aluminum oxide. This, in addition to the fact that extremely thin films can be deposited during the electrochemical process mentioned earlier, makes the tantalum capacitor extremely efficient with respect to the number of microfarads available per unit volume. The capacitance of any capacitor is determined by surface area of two conducting plates, distance between the plates, and the dielectric constant of the insulating material.

COMPARISON OF CAPACITOR DIELECTRIC CONSTANTS

DIELECTRIC	K DIELECTRIC CONSTANT
Air or vacuum	1.0
Paper	2.0 to 6.0
Plastic	2.1 to 6.0
Mineral oil	2.2 to 2.3
Silicone oil	2.7 to 2.8
Quartz	3.8 to 4.4
Glass	4.8 to 8.0
Porcelain	5.1 to 5.9
Mica	5.4 to 8.7
Aluminum oxide	8.4
Tantalum pentoxide	**26**
Ceramic	12 to 400 000

TECHNICAL NOTE

For technical questions, contact: tantalum@vishay.com

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In the tantalum electrolytic capacitor, the distance between the plates is very small since it is only the thickness of the tantalum pentoxide film. As the dielectric constant of the tantalum pentoxide and area of the plates are large, resulting in very high capacitance of a tantalum capacitor:

$C = (eA/t)$,

where

C = capacitance

e = dielectric constant

A = surface area of the dielectric

t = thickness of the dielectric

The tantalum pellet along with the attached tantalum wire form the anode (positive) plate. The external anode lead wire is welded to the tantalum wire. The liquid electrolyte in wet slug capacitor, along with the case, forms the cathode (negative) plate. The external cathode lead wire is attached to metal case (can). The pellet is inserted into a tantalum or silver can, which contains an electrolyte solution. A suitable end seal arrangement prevents the loss of the electrolyte.

The cross section drawings clearly show the construction details of the various wet tantalum capacitor types.

Wet slug tantalum capacitors are manufactured in a voltage range up to 150 V_{DC}.

TANTALUM CAPACITORS FOR ALL DESIGN CONSIDERATIONS

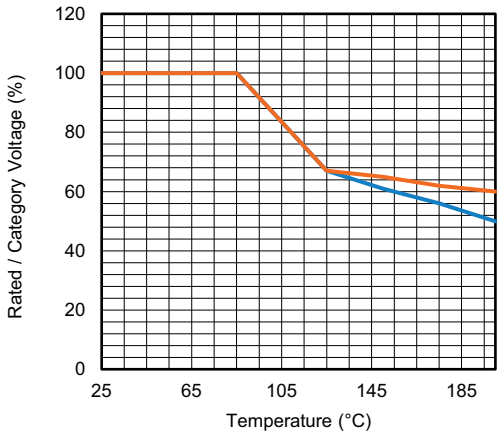
In choosing between the solid or wet style of tantalum capacitor, the circuit designer customarily uses wet tantalum capacitors, where the lowest DC leakage is required. The conventional silver can design will not tolerate any reverse voltages. In military or aerospace applications, tantalum cases units are used in place of silver cases where the utmost reliability is desired. The tantalum cased styles, CLR79 and CLR81, will withstand reverse voltages up to 3 V. They will operate under higher ripple currents and can be used at temperatures up to +392 °F (+200 °C). Some series can be operated even up to +446 °F (+230 °C). Vishay has the broadest line of tantalum capacitors and has continued its position of leadership in this field. Datasheets covering the various types and styles of Vishay capacitors for various applications are available on the Vishay website: www.vishay.com.

Refer also to following guides:

- www.vishay.com/doc?42088
- www.vishay.com/doc?49054
- www.vishay.com/doc?49079

WET TANTALUM CAPACITORS DERATING RECOMMENDATIONS

In working conditions, the voltage on the capacitor is the sum of the DC bias, AC ripple voltage, plus any possible transient peaks. The sum of these voltages (working voltage) should not exceed the rated voltage (RV). This means that the DC voltage applied to the capacitor has to be lower than the RV to leave “room” for the AC ripple voltage and any possible transients, spikes, etc. The maximum working voltage is equal to the RV in the temperature range of -55 °C to +85 °C; then it decreases linearly to 2/3 x RV at the maximum working temperature of +125 °C. For series with higher maximum operating temperatures, like the 134D, 135D, T11, T24, and some others, it will go to (0.6 to 0.5) x RV at extreme temperatures, depending on specific part number. Above +85 °C, it is common to refer to the maximum working voltage as the category voltage. For the ratio between the RV and category voltage, refer to the graph below.



Most of tantalum wet capacitors series do not require voltage derating when used below +85 °C. But DC working voltage (bias) should be chosen so that the sum of the DC bias and AC (ripple) voltages not to exceed the RV. For increased reliability it is recommended to have 10 % to 20 % guard band, meaning not to exceed 80 % to 90 % of RV below +85 °C; at higher temperatures same ratio should be kept with respect to the category voltage.

See also Vishay White Paper “Derating Tantalum Capacitors Depends On The Cathode System”:
www.vishay.com/doc?40292

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RIPPLE CURRENT

AC ripple current: subjecting a capacitor to an AC voltage causes an AC current to flow through it. The amplitude of the current is dependent on the impedance of the capacitor at the frequency of the applied signal:

$I = (V/Z)$,

where

I = ripple current

V = applied AC voltage

Z = impedance of capacitor (frequency dependent)

This current causes heating in the capacitor because of I^2R losses (R is the equivalent series resistance at the applied frequency). Ability to dissipate this heating, or power dissipation, is one of the limiting factors of the capacitor's ripple current rating.

CASE CODE	MAXIMUM PERMISSIBLE POWER DISSIPATION (W) AT 25 °C IN FREE AIR
A (C, T1)	1.00
B (F, T2)	1.55
C (T, T3)	1.75
D (K, T4)	1.95

The maximum allowable ripple currents are usually given in the Standard and Extended Ratings tables and are based on these ratings case sizes and the maximum equivalent series resistance at specified frequency.

The relationship is written as follows:

$P = I^2R$,

therefore:

$I = \sqrt{P/R}$.

Where

P = maximum permissible power dissipation in Watts

I = maximum ripple current in Amperes

R = equivalent series resistance (ESR) in Ohms

109D COMMERCIAL STYLE

SILVER CASE ELASTOMER SEAL

Voltage Range:

6 V_{DC} to 150 V_{DC}

Capacitance Range:

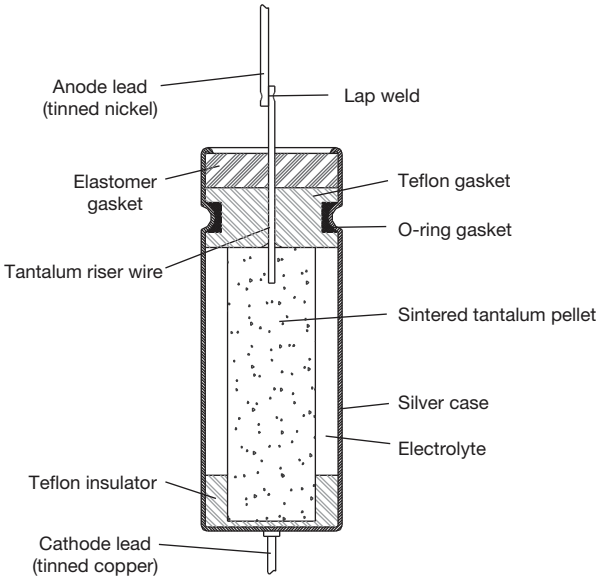
1.7 µF to 2200 µF

Size Range:

0.188" [4.78 mm] diameter x 0.453" [11.51 mm] long to
0.375" [9.52 mm] diameter x 1.062" [26.97 mm] long

Primary Applications:

Industrial, automotive, and telecommunication applications where a superior quality, reliable design is desired.



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135D AND MIL-STYLES M39006/22 (CLR79); M39006/25 (CLR81); DLA 06013; DLA 06014; 136D AND MIL-STYLES M39006/30 (CLR90); M39006/31 (CLR91); DLA 06015; DLA 06016

ALL TANTALUM HERMETIC SEAL (MILITARY SPECIFICATION MIL-PRF-39006)

Voltage Range:

6 V_{DC} to 125 V_{DC}

Capacitance Range:

1.7 µF to 2200 µF

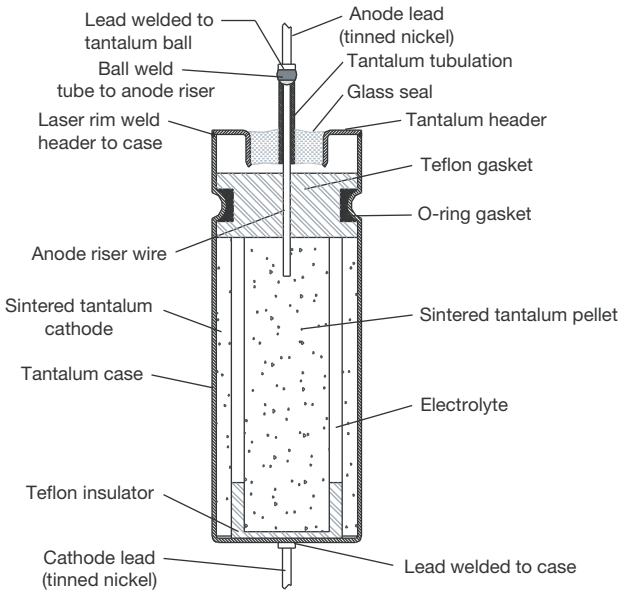
Size Range:

0.188" [4.78 mm] diameter x 0.453" [11.51 mm] long to
0.375" [9.52 mm] diameter x 1.062" [26.97 mm] long

Primary Applications:

Industrial and military applications requiring energy storage, voltage hold-up, and filtering. Designed for aerospace, oil exploration, and power supplies.

The capacitors have a high resistance to damage from shock and vibration.



138D AND MIL-STYLES M39006/09 (CLR65); M39006/21 (CLR69)

SILVER CASE HERMETIC SEAL (MILITARY SPECIFICATION MIL-PRF-39006)

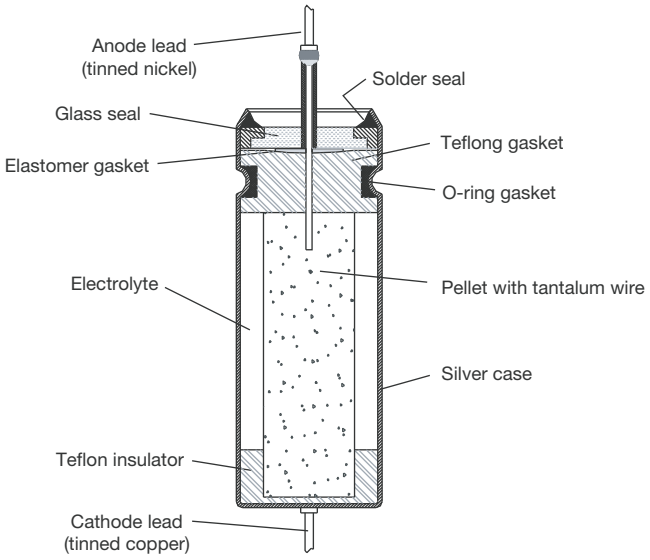
	Voltage Range	Capacitance Range
138D	6 V_{DC} to 150 V_{DC}	1.7 µF to 2200 µF
M39006/09	6 V_{DC} to 125 V_{DC}	1.7 µF to 1200 µF
M39006/21	6 V_{DC} to 125 V_{DC}	6.8 µF to 2200 µF

Size Range:

0.188" [4.78 mm] diameter x 0.453" [11.51 mm] long to
0.375" [9.52 mm] diameter x 1.062" [26.97 mm] long

Primary Applications:

Industrial and military equipment where reliability and premium performance with respect to low DC leakage current, high inrush current capability, and high volumetric efficiency are vital.



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Wet Electrolyte Tantalum Capacitors: An Introduction to the Basics

The Vishay SuperTan® capacitor represents a breakthrough in tantalum electrolyte capacitor design. The SuperTan design dramatically increased the available capacitance in each of the four standard case sizes. It provides two to three times more capacitance per unit volume while substantially increasing ripple current capability as well as reduced ESR. In airborne, aerospace, satellite, and smart munitions applications where size and weight are the primary considerations, SuperTan is the preferred capacitor style for the energy storage, voltage hold-up, timing and filtering circuit design. With these circuit functions in mind, along with long-term shelf life, operation life and reliability, SuperTan provides the circuit designer a solution to many of the problems that previously were resolved with marginally reliable and ineffective size options. SuperTan is available in four commercial product series (ST, STA, STE, STH) and in two DLA approved drawings (93026 and 10004). SuperTan and several more wet product series are available with surface-mounted configuration, please check the datasheets.

SuperTan® AND MIL-STYLES DLA 93026; DLA 10004

ALL TANTALUM HERMETIC SEAL

Voltage Range:

ST	25 V_{DC} to 125 V_{DC}
STA	6 V_{DC} to 15 V_{DC}
STE	10 V_{DC} to 125 V_{DC}
STH	60 V_{DC} to 125 V_{DC}
DLA 93026	25 V_{DC} to 125 V_{DC}
DLA 10004	10 V_{DC} to 125 V_{DC}

Capacitance Range:

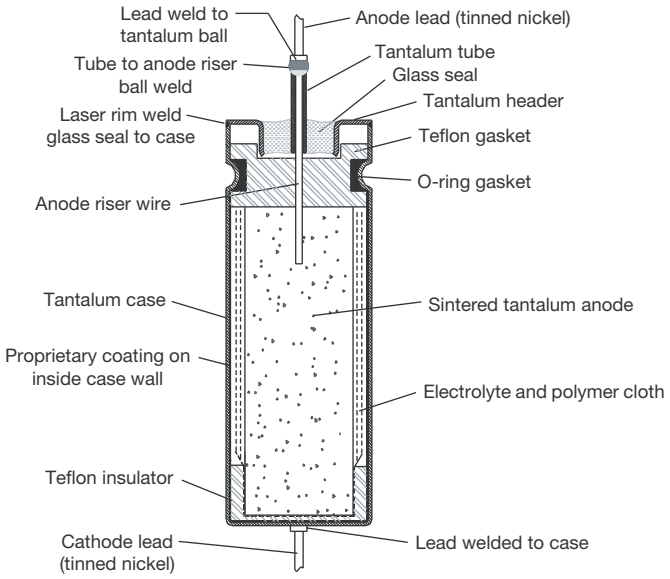
ST	10 µF to 2200 µF
STA	150 µF to 4700 µF
STE	22 µF to 10 000 µF
STH	47 µF to 1500 µF
DLA 93026	10 µF to 2200 µF
DLA 10004	22 µF to 10 000 µF

Size Range:

0.188" [4.78 mm] diameter x 0.453" [11.51 mm] long to
0.375" [9.52 mm] diameter x 1.062" [26.97 mm] long

Primary Applications:

Industrial and military applications where high capacitance, size, and weight are the primary considerations. SuperTan® is preferred capacitor style for the voltage hold-up timing and filtering circuit design.



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T16 / T18 COMMERCIAL STYLES AND MIL-STYLES M39006/33 (CLR93); DLA 13017; DLA 20001; DLA 15005

TANTALUM HERMETIC SEAL

Voltage Range:

T16	25 V_{DC} to 125 V_{DC}
T18	50 V_{DC} to 125 V_{DC}
M39006/33	50 V_{DC} to 100 V_{DC}
DLA 13017	25 V_{DC} to 125 V_{DC}
DLA 20001	50 V_{DC} to 100 V_{DC}
DLA 15005	75 V_{DC} to 100 V_{DC}

Capacitance Range:

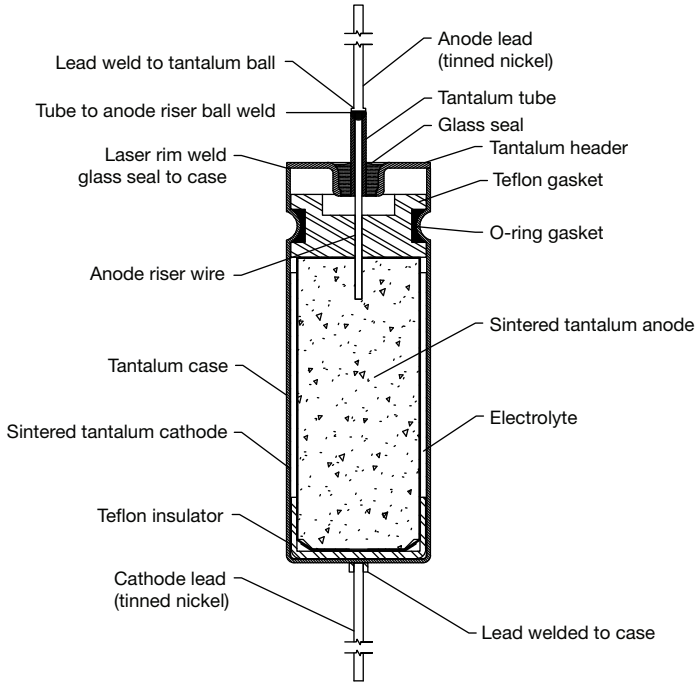
T16	10 µF to 1800 µF
T18	22 µF to 1200 µF
M39006/33	15 µF to 680 µF
DLA 13017	10 µF to 1800 µF
DLA 20001	15 µF to 1800 µF
DLA 15005	470 µF to 1000 µF

Size Range:

0.188" [4.78 mm] diameter x 0.453" [11.51 mm] long to
0.375" [9.52 mm] diameter x 1.062" [26.97 mm] long

Primary Applications:

Industrial and military avionics and aerospace applications



134D COMMERCIAL STYLE

TANTALUM HERMETIC SEAL

Voltage Range:

50 V_{DC} to 125 V_{DC}

Capacitance Range:

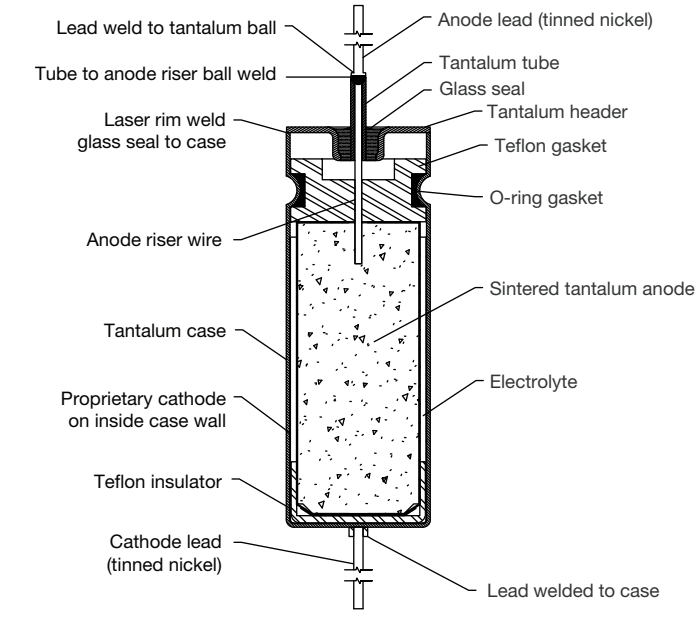
10 µF to 1000 µF

Size Range:

0.188" [4.78 mm] diameter x 0.453" [11.51 mm] long to
0.375" [9.52 mm] diameter x 1.062" [26.97 mm] long

Primary Applications:

Industrial in high temperature / high stress environment.
Petroleum exploration



TECHNICAL NOTE

Wet Electrolyte Tantalum Capacitors: An Introduction to the Basics

T34 COMMERCIAL STYLE

TANTALUM HERMETIC SEAL

Voltage Range:

50 V_{DC} to 125 V_{DC}

Capacitance Range:

10 µF to 1500 µF

Size Range:

0.188" [4.78 mm] diameter x 0.453" [11.51 mm] long to
0.375" [9.52 mm] diameter x 1.062" [26.97 mm] long

Primary Applications:

Industrial in high temperature / high stress environment.
Petroleum exploration