ADVANCES IN WET TANTALUM CAPACITOR TECHNOLOGY

ESA SPCD

OCTOBER 2018

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Sr. Director, Product Marketing
Tantalum Capacitors
INTRODUCTION

- Tantalum Capacitor Definition
  - tantalum anode with tantalum pentoxide dielectric
  - solid or non-solid cathode or electrolyte

- Tantalum advantages
  - highest capacitance per unit volume

- Tantalum applications
  - automotive, consumer, industrial, telecom
  - avionics, medical, military, space

- Tantalum Capacitor Technology Advances
  - Solid – size, CV, ESR, performance, polymer cathode
  - Wet – CV, case configuration/ form factor, performance
What is a Wet Tantalum Capacitor?
Tantalum capacitor with a liquid electrolyte.

Higher quality dielectric with a self healing effect resulting in:
- Low leakage current (>10 times less than solids)
- Higher CV and Higher Voltage (up to 150V)
- High reliability (>10 times better than solids)
DESCRIPTION

- Wet electrolyte, sintered anode tantalum capacitors
  - Pressed tantalum powder anode
  - Sintered tantalum anode
  - Tantalum pentoxide dielectric
  - Tantalum or silver case
  - Liquid or “wet” electrolyte (sulfuric acid solution)
  - Seal – elastomer or hermetic
ADVANTAGES

VISHAY CAP MAP

Capacitance

Voltage

100 kV

10 kV

1 kV

100 V

10 V

1 V

0.1 pF 1 pF 10 pF 100 pF 1 nF 10 nF 100 nF 1 μF 10 μF 100 μF 1 mF 10 mF

0.1 F 1 F 10 F 100 F

Ceramic Single-Layer

Heavy-Current Power Film (ESTA)

Wet Tantalum

Aluminum Electrolytic Energy Storage

Polymer and Solid Tantalum

Ceramic Multilayer

Thin Film
SILVER CASE, AXIAL LEAD

Elastomer Seal, Silver Case
Commercial Series: 109D
MIL Approved: MIL-DTL-3965/4 Style CL64/65
Operating Temperature: -55°C to +125°C
Capacitance Range: 1.7µF to 2200µF
Voltage Range: 6 to 125Vdc
Case Sizes: T1, T2, T3, T4
Failure Rate: Non-ER

Hermetic Seal, Silver Case
Commercial Series: 138D
CECC Approved: 30 202 004 Styles CT9, 738D
MIL Approved: CLR65 (M39006/09) – Standard Values
CLR69 (M39006/21) – Extended Range Values
Operating Temperature: -55°C to +125°C
Capacitance Range: 1.7µF to 2200µF
Voltage Range: 6 to 125Vdc
Case Sizes: T1, T2, T3, T4
Failure Rates: L (2%), M (1%)
# Axial, Four Industry Standard Case Sizes

## Dimensions

<table>
<thead>
<tr>
<th>CASE CODE</th>
<th>DCLR 79 / 81 EQUIV.</th>
<th>D</th>
<th>L₁ (min) / -0.016</th>
<th>L₁ (max) / -0.016</th>
<th>L₂ (max.)</th>
<th>E</th>
<th>WEIGHT (g) (Max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>T1</td>
<td>0.186 ± 0.016 [4.78 ± 0.41]</td>
<td>0.453 ± 0.031 / -0.016 [11.51 ± 0.79 / -0.41]</td>
<td>0.734 [18.64]</td>
<td>1.500 ± 0.250 [38.10 ± 6.35]</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>T2</td>
<td>0.281 ± 0.016 [7.14 ± 0.41]</td>
<td>0.641 ± 0.031 / -0.016 [16.28 ± 0.79 / -0.41]</td>
<td>0.922 [23.42]</td>
<td>2.250 ± 0.250 [57.15 ± 6.35]</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>T3</td>
<td>0.375 ± 0.016 [9.53 ± 0.41]</td>
<td>0.766 ± 0.031 / -0.016 [19.46 ± 0.79 / -0.41]</td>
<td>1.047 [26.59]</td>
<td>2.250 ± 0.250 [57.15 ± 6.35]</td>
<td>11.6</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>T4</td>
<td>0.375 ± 0.016 [9.53 ± 0.41]</td>
<td>1.062 ± 0.031 / -0.016 [26.97 ± 0.79 / -0.41]</td>
<td>1.343 [34.11]</td>
<td>2.250 ± 0.250 [57.15 ± 6.35]</td>
<td>17.7</td>
<td></td>
</tr>
</tbody>
</table>
In 1973, Sprague Electric Company was contacted by NASA for the Design, Development, Manufacture, and Qualification of Wet Slug All-Tantalum Capacitors. The purpose of the program was to develop a hermetically sealed all-tantalum capacitor capable of meeting the performance requirements of MIL-C-39006, but with the ability to withstand nominal reverse voltages and ripple currents.

Hermetic Seal, Tantalum/Glass Cover

**Commercial Series:** 135D

- 136D (low ESR)

**CECC Approved:**

- 30 202 001 Style 735D
- 30 202 801 Style 735DE
- 30 202 005 Style CT79

**MIL Approved:**

- CLR79 (M39006/22) – Standard Values
- CLR81 (M39006/25) – Extended Range Values
- CLR90 (M39006/30) – Low ESR, Standard Values
- CLR91 (M39006/31) – Low ESR, Extended Range Values

**Operating Temperature:** -55°C to +200°C

**Capacitance Range:** 1.7µF to 2200µF

**Voltage Range:** 6 to 125Vdc

**Case Sizes:** T1, T2, T3, T4

**Failure Rates:** M (1%), P (0.1%), R (0.01%)

**Characteristic H:** 54g random, 80g sine, 500g shock
LONG TERM STORAGE, CLR79 TYPE

Table 2: CLR79 Long Term Storage Data

<table>
<thead>
<tr>
<th>UNIT</th>
<th>RATINGS</th>
<th>Measured December 1979</th>
<th>Measured July 1996</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CAP</td>
<td>ESR</td>
</tr>
<tr>
<td>1</td>
<td>47μF, 10 vdc</td>
<td>46.7</td>
<td>1.37</td>
</tr>
<tr>
<td>2</td>
<td>120μF, 15 vdc</td>
<td>120.3</td>
<td>0.72</td>
</tr>
<tr>
<td>3</td>
<td>170μF, 15 vdc</td>
<td>164.1</td>
<td>0.48</td>
</tr>
<tr>
<td>4</td>
<td>2.5μF, 100 vdc</td>
<td>2.6</td>
<td>3.64</td>
</tr>
<tr>
<td>5</td>
<td>22μF, 100vdc</td>
<td>22.9</td>
<td>0.85</td>
</tr>
<tr>
<td>6</td>
<td>43 μF, 100 vdc</td>
<td>44.4</td>
<td>0.55</td>
</tr>
</tbody>
</table>

NOTES: 1) Capacitors were manufactured to MIL-PRF-39006/22, style CLR79
2) All parts were subjected to 300 thermal shock cycles prior to the initial measurements
3) Data was derived from 3 to 5 samples of each rating
Space Grade DLA Drawings (original dated 2006)

**DLA Styles:**
- **06013** [CLR79 (M39006/22) Values]
- **06014** [CLR81 (M39006/25) Values]
- **06015** [CLR90 (M39006/30) Values]
- **06016** [CLR91 (M39006/31) Values]

**Failure Rate:** R (0.01%/1000 Hours)

**Characteristic H:** 80g Sine Vibration, 54g Random Vibration, 500g Mechanical Shock

<table>
<thead>
<tr>
<th>Group A Inspection</th>
<th>Sample</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Shock</td>
<td>100%</td>
<td>10 Cycles, -55°C to +125°C</td>
</tr>
<tr>
<td>Voltage Conditioning</td>
<td>100%</td>
<td>168 Hours at +85°C</td>
</tr>
<tr>
<td>DC leakage at 25°C &amp; +85°C</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Capacitance</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Dissipation Factor</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Seal (Fine Leak)</td>
<td>100%</td>
<td>MIL-STD-202, Method 112, Condition C</td>
</tr>
<tr>
<td>Seal (Gross Leak)</td>
<td>100%</td>
<td>MIL-STD-202, Method 112, Condition A or D</td>
</tr>
<tr>
<td>Solderability</td>
<td>5/0</td>
<td>MIL-STD-202, Method 108</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group B Inspection</th>
<th>Sample</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Stability</td>
<td>13/0</td>
<td>-55°C to +125°C</td>
</tr>
<tr>
<td>Thermal Shock</td>
<td>10/0</td>
<td>30 Cycles, -55°C to +125°C</td>
</tr>
<tr>
<td>Life</td>
<td>10/0</td>
<td>1000 Hours at +85°C</td>
</tr>
</tbody>
</table>

**DLA 06013-06016 specifications meet or exceed NASA/TP-2003-212242, Level 1 requirements.**
SuperTan® Era
135D vs. ST Construction

135D
- Tantalum Cathode Sintered to Case Wall
- Crimped “O” Ring (Primary Seal)
- Tinned Nickel lead

ST
- Proprietary Cathode Preparation
- High temperature Non Woven Cloth (Reduces Positional Sensitivity)
- Crimped “O” Ring (Primary Seal)

Electrolyte H₂SO₄ & Water (30-40%)
- Plasm Ball Weld, Tantalu tinned nickel interface
- Secondary Seal Formed By Glass to Tantalum Interface
- Imbedded and Sintered Tantalum Riser Wire

Tantalam Anode
- Tantalam Case
- Tantalam Tube
- Glass
- Teflon® Bushing
- Teflon® Vibration Spacer

Tinnned Nickel lead

135D ST

OCTOBER 2018
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CAPACITANCE EXTENSION, SUPERTan® AXIAL CASE

Table 4: Examples of 100 V Capacitance Extension with the ST

<table>
<thead>
<tr>
<th>Case Size</th>
<th>CLR79</th>
<th>CLR81</th>
<th>ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.7 μF</td>
<td>10 μF</td>
<td>15 μF</td>
</tr>
<tr>
<td>2</td>
<td>22 μF</td>
<td>39 μF</td>
<td>68 μF</td>
</tr>
<tr>
<td>3</td>
<td>43 μF</td>
<td>68 μF</td>
<td>150 μF</td>
</tr>
<tr>
<td>4</td>
<td>86 μF</td>
<td>120 μF</td>
<td>220 μF</td>
</tr>
</tbody>
</table>
Wet Tantalum Axial Case Product Overview

Robustness

500g Shock
80g Vibration
54g Random
3V reverse

Tantalum Cathode (Sleeve) Deposit

Proprietary Cathode

Proprietary Cathode

Tantalum Cathode

500g Shock
80g Vibration
54g Random
1.5 to 3V reverse

100g Shock
20g Vibration
No reverse

100g Shock
20g Vibration
No reverse

M39006
M39006/33
M39006/33
M39006/33
M39006/33

135D
T16
T18
T34
134D

200°C
125°C
200°C
125°C
230°C
200°C

MIL
MIL
MIL
MIL
MIL

T11
ST
STE

CAP: Standard ➔ Extended

Capacitance
Hermetic Seal, Tantalum/Glass Cover

Commercial Series: T16 – standard range (equal to ST)
Military: DLA 13017
Military: MIL-PRF-39006/33
Operating Temperature: -55° C to +125° C
Capacitance Range: 10µF to 1800µF
Voltage Range: 25V – 125V
Case Sizes: T1, T2, T3, T4

Commercial Series: T18 – extended range (equal or greater than STE)
Military: DLA 15005
Operating Temperature: -55° C to +125° C
Capacitance Range: 18uF – 1500uF
Voltage Range: 50V – 125V
Case Sizes: T1, T2, T3, T4
Ratings available: 1000uF 75V
470uF 100V
Under development: 1500uF/50V - 2nd QTR 2019
1200uF/75V - 1st QTR 2019
560uF/100V - 1st QTR 2019
240uF/125V - 1st QTR 2019
340uF/125V - 1st QTR 2019

Enhanced performance for Avionics and Space
300 thermal shocks
500g mechanical shock
80g sine vibration
54g random vibration
1.5 to 3.0 V reverse voltage
### Capacitance Extension, T18 Axial Case

#### Table 5: Examples of 100 V Capacitance Extension with the T18

<table>
<thead>
<tr>
<th>Case Size</th>
<th>CLR79 (μF)</th>
<th>CLR81 (μF)</th>
<th>T16 (μF)</th>
<th>T18 (μF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.7</td>
<td>10</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>39</td>
<td>68</td>
<td>86</td>
</tr>
<tr>
<td>3</td>
<td>43</td>
<td>68</td>
<td>150</td>
<td>220</td>
</tr>
<tr>
<td>4</td>
<td>86</td>
<td>120</td>
<td>220</td>
<td>470</td>
</tr>
</tbody>
</table>
Oil Exploration Capacitors

- T34
- Tantalum case, axial leaded, high capacitance, “high performance”, HI-TMP®, +200°C
- Target Market/Applications: Oil Exploration
- Provides high capacitance with high performance
  - 3V reverse
  - 500g mechanical shock
  - 57g random vibration
  - 80g sine vibration
  - 1000 hour life minimum @ +200°C
  - stable ESR over life

- Example of Ratings available: 350uF/125v T4
  470uF/ 50v T3
  220uF/ 50v T2
  33uF/ 75v T1

- Ratings under development
  - 560uF/100v T4
  - 100uF/125v T3
  - 220uF/ 75v T2
  - 150uF/100v T2
  - 10uF/125V T1
SURFACE MOUNT “SMD” WET TANTALUM CAPACITORS

- First Generation

- Second Generation

<table>
<thead>
<tr>
<th>CASE CODE</th>
<th>L (MAX.)</th>
<th>W</th>
<th>H</th>
<th>P (MIN.)</th>
<th>T_W</th>
<th>T_H (MIN.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.835</td>
<td>0.315 ± 0.012</td>
<td>0.295 ± 0.012</td>
<td>0.118</td>
<td>0.236 ± 0.012</td>
<td>0.075</td>
</tr>
<tr>
<td>[21.2]</td>
<td>[3.0]</td>
<td>[1.9]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Surface Mount

- Third Generation

Small size SMD, Hermetic Seal, Tantalum Case Capacitors

**Commercial Series:** T22

Capacitance Range: 10µF to 120µF
Voltage Range: 6 to 125Vdc
Operating Temperature: -55°C to +125°C
Case Size: R
Ratings: any T1 axial rating
Rating available:
- 10µF 125V
- 15µF 100V
- 33µF 75V
- 68µF 50V

High Energy Assemblies and Arrays
Standard and Custom

Vishay has over 40 years experience with AMS (Avionics, Military, Space) energy storage and pulsed power applications and petroleum data logging applications.

Vishay continues to provide solutions for these applications with the assembly of arrays or modules built from our extensive line of tantalum capacitors. Assemblies and arrays can be industry standard packages, or a customer driven custom design. Internal elements can be Commercial or Military Grade (Established Reliability) Wet or Solid Tantalum Capacitors.
High energy or hybrid capacitor designs

**Hermetic Seal, Tantalum/Glass Cover**

**Commercial Series:** HE3

**Military:** DLA 10011

- Operating Temperature: -55°C to +125°C
- Capacitance Range: 1100µF to 72,000µF
- Voltage Range: 25 to 125Vdc
- Case Sizes: A, B, C
- Failure Rate: Non-ER

**Hermetic Seal, Tantalum/Glass Cover**

**Commercial Series:** HE5 w/ mounting studs

- Operating Temperature: -55°C to +125°C
- Capacitance Range: 1100µF to 72,000µF
- Voltage Range: 25 to 125Vdc
- Case Sizes: A, B, C
- Failure Rate: Non-ER

**Hermetic Seal, Tantalum/Glass Cover**

**Commercial Series:** EP1 Energy-Pack

- Operating Temperature: -55°C to +125°C
- Capacitance Range: 1100µF to 72,000µF
- Voltage Range: 25 to 125Vdc
- Case Sizes: A (available), B (under development – 4th QTR 2018), C (under development – 1st QTR 2019)
- Failure Rate: Non-ER
Scope of rating qualification plan going forward

<table>
<thead>
<tr>
<th>Case (# anodes)</th>
<th>A (1)</th>
<th>B (2)</th>
<th>C (3)</th>
<th>D (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EP1</td>
<td>Comp</td>
<td>EP1</td>
<td>Comp</td>
</tr>
<tr>
<td>Voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125V</td>
<td>2.0</td>
<td>1.5</td>
<td>3.6</td>
<td>3.0</td>
</tr>
<tr>
<td>100V</td>
<td>3.0</td>
<td>2.2</td>
<td>5.8</td>
<td>4.4</td>
</tr>
<tr>
<td>80V</td>
<td>4.0</td>
<td>3.0</td>
<td>8.5</td>
<td>6.0</td>
</tr>
<tr>
<td>63V</td>
<td>6.0</td>
<td>4.7</td>
<td>12.0</td>
<td>9.4</td>
</tr>
<tr>
<td>50V</td>
<td>13.0</td>
<td>11.0</td>
<td>24.0</td>
<td>22.0</td>
</tr>
<tr>
<td>35V</td>
<td>22.0</td>
<td>16.0</td>
<td>40.0</td>
<td>32.0</td>
</tr>
<tr>
<td>25V</td>
<td>30.0</td>
<td>24.0</td>
<td>55.0</td>
<td>48.0</td>
</tr>
</tbody>
</table>

Available
Under Development 2018
Future Potential Development
CONCLUSION

- Wet tantalum capacitors provide:
  - High capacitance
  - High voltage
  - Low DC leakage
  - Long Life
  - Mechanical Robustness

- Developments Continue
  - Higher capacitance
  - New form factors such as High energy and surface mount
  - High shock and vibration

- Wet tantalum capacitors will continue to be an important segment of the tantalum capacitor market
WET TANTALUM CAPACITORS
THE ULTIMATE RELIABILITY AND PERFORMANCE CHOICE
FOR EXTREME APPLICATIONS

KEY FACTORS

Capacitance
High Performance
Energy
Temperature

QUALIFICATIONS

• M39006/09/21/22/25/30/31/33
• DLA 06013/06014/06015/06016
• DLA 04003/10004/10011/13017/15008/93026
• CECC 30202/001/002/004/005/801

LEAD CONFIGURATIONS

Axial
Radial
SMD

TERMINATION OPTIONS

Tin / Lead

Lead-free (100% tin)
RoHS compliant

VISHAY CAPABILITY

T1
T2
L2
T3
T4

HE5

FOOTPRINT + PROFILE

EP1

T22

For Technical Questions: tantalum@vishay.com
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Thank You