Solid Electrolytic SMD – Technology Combinations

Traditional

Cathode

MnO₂

Ta₂O₅

Ta

Polymer

Ta₂O₅

Ta

NbO - OxiCap

MnO₂

Nb₂O₅

NbO

Nb – small reliability advantage over Ta; limited voltage range; adds material availability.

NbO – The only option with a non-short circuit failure mode, greater material availability.

MnO₂ – Promotes self-healing; source of O₂ in failures; long-term stability.

Polymer – Low ESR capability; no O₂ contribution; higher humidity sensitivity.
Technology Comparison – Temperature Characteristics

Tantalum capacitor market remains strong in applications requiring volumetric efficiency, long term reliability and stability over thermal cycling.
Technology Comparison – ESR Characteristics

![Graph showing ESR characteristics at 100 kHz with temperature dependency.](graph)

- **Conventional MnO₂ tantalum**
  - 10/50 MnO₂
  - 22/35 MnO₂

- **Tantalum Polymer**
  - 10uF 50v MnO₂
  - 22uF 35v MnO₂
  - 10uF 50v Polymer
  - 22uF 35v Polymer

ESR@100 kHz - temperature dependency
Molded Solid Electrolytic SMD – Construction Basis

- Leadframe
- Wire
- Anode
- Resin case
- Cathode Connection

- Anode
- Manganese Dioxide
- Graphite
- Outer Silver Layer
- Silver Epoxy
- Cathode Connection
Molded Solid Electrolytic SMD – Technology Basis

Solid Ta / Nb Electrolytic Capacitor Materials

Particle Size
Low Surface Area High

High Purity Ta / Nb or NbO powder

High Purity Ta / Nb or NbO sintered

Ta / Nb or NbO post formation (pentoxide dielectric layer)

Application of Internal counter-electrode
Molded Solid Tantalum Capacitors – Electrolyte Options

Solid - MnO₂ Semiconductor
Electronic conduction
+ Solid crystal – parametric stability vs time
  - Stable Capacitance / DF
  - Stable ESR
+ Self healing
+ High temperature
- Overheating possible
- Voltage limited
- Standard ESR

Solid – Conductive Polymer
Electronic conduction
+ Self healing
+ Low ESR
+ Safe failure mode
+ High voltage
- Lifetime – time dependent properties
  - Temperature limited
  - Humidity & oxygen sensitive
Hermetic Seal Polymer Capacitor

Why Hermetic Packaging?
In molded packages, the thin conductive polymer cathode layer is susceptible to degradation under extreme conditions of high temperature and high humidity.

- Stable, low ESR
- Parametric stability under extreme conditions
- Aerospace & Hi-Rel application compatible

Hermetic seal:
Protects from degradation by humidity
Protects from degradation by oxidation

© AVX Corporation 2017
Hermetic Seal Polymer Capacitor

- -55/+125°C Temperature Range
- **Low ESR** conductive polymer electrode
- High ripple current capability up to 3A
- Ceramic **hermetic** packaging suppresses environmental degradation
- Stability under humidity and ambient atmospheric conditions
- **Large CTC-21D case size enables high capacitance / voltage ratings**
- Developed with ESA for aerospace applications
- ESCC EPPL2 specification approval in process

**TECHNICAL SPECIFICATIONS:**

<table>
<thead>
<tr>
<th>Technical Data</th>
<th>All technical data relate to an ambient temperature of +25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance Range</td>
<td>15μF to 680μF</td>
</tr>
<tr>
<td>Capacitance Tolerance</td>
<td>±20%</td>
</tr>
<tr>
<td>Leakage Current DCL</td>
<td>0.1CV</td>
</tr>
<tr>
<td>Rated Voltage (V_{R}) ≤ +85°C</td>
<td>10   16  20  25  35  50  63  75  100</td>
</tr>
<tr>
<td>Category Voltage (V_{C}) ≤ +125°C</td>
<td>7    11   13.5 17   23.5 33   42   50   66</td>
</tr>
<tr>
<td>Temperature Range</td>
<td>-55°C to +125°C</td>
</tr>
</tbody>
</table>

© AVX Corporation 2017
Hermetic Seal Polymer Capacitor

TCH SERIES

- Hermetic package design removes humidity / oxidation related limitations to conductive polymer.
  - Lifetime capability of polymer capacitor: $125^\circ C / 0.66U_R/10,000hrs$
  - $85^\circ C/85\% \text{ RH}/1,000hrs$

- Low ESR enables higher power rating, more efficient filtering and faster response in power supply applications

**Reliability Testing Results**

- ESCC 3012          PASS
- ESCC 5000          PASS
- Vibration up to $125^\circ C$  PASS
- Vibration up to $40g$   PASS

© AVX Corporation 2017
Hermetic Seal Capacitor Construction

Hermetic Sealing:
- Lid (Kovar)
- Sealing ring
- Ceramic case
- Inert gas
- Anode & contacts

Common Packaging technology for timing devices etc.

CTC21 tantalum case
Hermetic Polymer Capacitor Range

<table>
<thead>
<tr>
<th>Capacitance (µF)</th>
<th>Code</th>
<th>10V (µF)</th>
<th>16V (µF)</th>
<th>20V (µF)</th>
<th>25V (µF)</th>
<th>35V (µF)</th>
<th>50V (µF)</th>
<th>63V (µF)</th>
<th>75V (µF)</th>
<th>100V (µF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>156</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9(150)*</td>
<td></td>
<td>9(150)</td>
</tr>
<tr>
<td>22</td>
<td>226</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9(120)*</td>
<td>9(120)</td>
</tr>
<tr>
<td>33</td>
<td>336</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9(100)*</td>
<td></td>
<td>9(120)</td>
</tr>
<tr>
<td>47</td>
<td>476</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9(70)</td>
<td>9(100)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>686</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9(70)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>107</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9(50)*</td>
<td>9(100)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>157</td>
<td></td>
<td></td>
<td></td>
<td>9(50)</td>
<td>9(55)</td>
<td>9(55)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>220</td>
<td>227</td>
<td>9(40)*</td>
<td>9(40)</td>
<td>9(45)*</td>
<td>9(50)</td>
<td>9(55)</td>
<td>9(55)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>330</td>
<td>337</td>
<td>9(40)*</td>
<td>9(40)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>470</td>
<td>477</td>
<td>9(40)*</td>
<td>9(40)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Approved
Under Development

CASE DIMENSIONS: millimeters

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>L</th>
<th>W</th>
<th>H</th>
<th>W₁</th>
<th>A</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 (CTC-21D)</td>
<td>J-lead</td>
<td>11.8</td>
<td>12.5</td>
<td>5.8</td>
<td>10.5</td>
<td>1.9</td>
<td>8</td>
</tr>
<tr>
<td>9 (CTC-21D)</td>
<td>Undertab</td>
<td>11</td>
<td>12.5</td>
<td>5.45</td>
<td>10.5</td>
<td>1.5</td>
<td>8</td>
</tr>
</tbody>
</table>

CTC21 tantalum case styles:

Undertab Style

J-lead Style

© AVX Corporation 2017
http://www.avx.com
Hermetically Sealed Polymer Capacitors

Testing & Performance
Every capacitor is voltage stressed.
Statistical approach applied to 3 sigma acceptance limit.
Hermetic Capacitor Performance - HAST

HAST Test Conditions:
- Temperature: 120°C
- Relative Humidity: 85%
- Voltage: Rated Voltage
- Duration: 64h

Results:
Demonstration of improved CAP and ESR Stability by Hermetic Sealing

HAST - CAPACITANCE

<table>
<thead>
<tr>
<th></th>
<th>before</th>
<th>HAST</th>
</tr>
</thead>
<tbody>
<tr>
<td>hermetical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hermetic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Initial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HAST - ESR

<table>
<thead>
<tr>
<th></th>
<th>before</th>
<th>HAST</th>
</tr>
</thead>
<tbody>
<tr>
<td>hermetical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hermetic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Initial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

© AVX Corporation 2017
Hermetic Capacitor Performance – Shock / Vibration

1) Mechanical Shock Test: 5x 1500g
2) Vibration Test: 20g at 125C

Results:
- Stable Electrical Performance CAP, DF, ESR, DCL
- Post Test Hermeticity: Pass
Lifetime Stability of Hermetic Seal Capacitors

Stability of capacitance and ESR

- 35V rated voltage capacitor at 125°C and UR
- Stable Performance

10,000 hrs
DCL Stability of Hermetic Seal Capacitors

DCL measurement after 10,000h at 125°C and rated voltage

- Current spec @5min @25°C
- Standard DCL limit (350µA)
- Slow DCL decrease
- Very low steady state DCL

© AVX Corporation 2017
http://www.avx.com
## ESCC 5000 TESTS

### subgroup I
- **initial measurement - loose units**
- **mechanical shock**
  - MIL-STD-750, test method 2016
  - 1500g, 0.5ms duration, 5 shock, planes X, Y, Z
- **vibration**
  - MIL-STD-750, test method 2056
  - 20g, 10-2000Hz, cross over at 50Hz
- **seal**
  - MIL-STD-750, test method 1071
  - seal (fine leak)
  - condition H1, H2
  - seal (gross leak)
  - condition C, K
- **visual control**

### subgroup II
- **initial measurement - loose units**
- **temperature cycling**
  - MIL-STD-750, test method 1051
  - test condition C, 100cycles
- **moisture resistance**
  - MIL-STD-750, test method 1021
- **seal**
  - MIL-STD-750, test method 1071
  - seal (fine leak)
  - condition H1, H2
  - seal (gross leak)
  - condition C, K
- **visual control**

### subgroup III
- **initial measurement - loose units**
- **operating life**
  - 125°C, without voltage, 2000hrs
- **seal**
  - MIL-STD-750, test method 1071
  - seal (fine leak)
  - condition H1, H2
  - seal (gross leak)
  - condition C, K
- **visual control**

### subgroup IV
- **bond strength**
  - anode - ceramic package
  - leadframe - carammic package

### Test Results

<table>
<thead>
<tr>
<th>TEST RESULTS ESCC 5000</th>
<th>size 9</th>
<th>100/35</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mechanical shock (1500g) - vibration – seal test</td>
<td></td>
<td>PASS</td>
</tr>
<tr>
<td>2. Rapid change temperature – moisture resistance – seal test</td>
<td></td>
<td>PASS</td>
</tr>
<tr>
<td>3. Life test - seal test</td>
<td></td>
<td>PASS</td>
</tr>
<tr>
<td>4. Bond strength</td>
<td></td>
<td>PASS</td>
</tr>
</tbody>
</table>
# ESCC 3012 TESTS

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Description</th>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>PCB mounting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adhesion</td>
<td>M0</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Rapid change of temperature</td>
<td>M0</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>High and low temp. stability</td>
<td>M0</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Operating life</td>
<td>M0</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Solderability</td>
<td></td>
<td>PASS</td>
</tr>
<tr>
<td>II</td>
<td>PCB mounting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vibration</td>
<td>M1</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Surge test</td>
<td>M1</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>DHSS</td>
<td>M2</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Damp heat tests</td>
<td>M(final)</td>
<td>PASS</td>
</tr>
<tr>
<td>III</td>
<td>PCB mounting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visual control</td>
<td>M0</td>
<td>PASS</td>
</tr>
<tr>
<td>IV</td>
<td>PCB mounting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visual control</td>
<td>M0</td>
<td>PASS</td>
</tr>
<tr>
<td>V</td>
<td>Visual control</td>
<td>M0</td>
<td>PASS</td>
</tr>
</tbody>
</table>

## TEST RESULTS ESCC 3012

<table>
<thead>
<tr>
<th>Description</th>
<th>PASS</th>
<th>PASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. mounting - adhesion – damp heat test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. mounting - rapid change temperature – vibration, shock – damp heat test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. mounting - high and low temp. stability – surge test – DHSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. mounting - operating life 125°C, UC, 2000hrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. solderability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Stability of Hermetically Sealed Capacitors

Additional Tests:

1. Life Test at 125°C/100V, 5000h  pass
2. Extended Temperature Cycling -55/125°C, 30 min, 1000 cycles  pass
3. Biased Humidity (85°C/85RH/1000h, Ur)  pass
4. Vibration 40g 6h, 10-2000-10Hz at room temperature  pass
MODULAR SOLUTIONS
Hermetic Seal Modular Solutions

- **TCH 9 case**
  - 22µF/ 100V
  - ESR 60 mOhm

- **Customized case**
  - 400µF/ 100V
  - ESR 3 - 15 mOhm

- Multiple capacitors connected in parallel
- High Capacitance
- Ultra-Low ESR (< 5mOhms)
Modular Solution - Capacitance and ESR

- 400µF/ 100V – low ESR model

- Capacitance stable with temperature and frequency
Summary & Conclusion

Hermetically Sealed Conductive Polymer Tantalum Capacitors

- Stable performance and reliability exceeding:
  - 10,000 hours, 85°C at Ur,
  - 10,000 hours, 125°C at 0.66x Ur
- Super-low DCL and low ESR performance achieved
  - Sub 0.0001 CV
  - Lowest DCL ever for any tantalum based capacitor technology!

A New Class of SMD Tantalum Polymer Capacitors:

- Lowest Tantalum DCL specifications (Lower Than Conventional MnO₂)
- Improved Humidity Stability