Electrolytic Capacitors That Withstand the Heat

Industry Session APEC 2019
Presented by Scott Franco, Cornell Dubilier Electronics
Bio for Scott Franco

- Director of Market Development: Cornell Dubilier Electronics

- 30 years experience: engineering and marketing of capacitors for power electronics

- BS Physics: University of Massachusetts

- MBA: Bryant College
Applications for High Temperature Capacitors (150 °C to 260 °C)

- **Avionics**
  - Engine Control Systems: -55 °C to 200 °C

- **Automotive**
  - Engine, Transmission and braking: Up to 250°C

- **Down-Hole**
  - Logging Tools: Up to 220 °C
  - Measurement While Drilling: Up to 200 °C
  - Completion Tools: Up to 175 °C
# Capacitors for High Temperature Application
*(150 °C to 260 °C)*

<table>
<thead>
<tr>
<th>Capacitor Type</th>
<th>Temp Range</th>
<th>Cap Range</th>
<th>Voltage Range</th>
<th>Limiting Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLCC - X7R</td>
<td>-55 to +260 °C</td>
<td>100 pF to 4 µF</td>
<td>50-100 Vdc</td>
<td>Cracking, piezo effects</td>
</tr>
<tr>
<td>MLCC - COG</td>
<td>-55 to +260 °C</td>
<td>0.5 pF to 470 µF</td>
<td>10 - 4000 Vdc</td>
<td>Cracking in larger chip sizes</td>
</tr>
<tr>
<td>Clad Mica</td>
<td>-55 to +200 °C</td>
<td>1 pF to 1500 pF</td>
<td>300-1000 Vdc</td>
<td>Small capacitance values</td>
</tr>
<tr>
<td>PPS</td>
<td>-55 to +150 °C</td>
<td>4.7 nF to 10 µF</td>
<td>50 - 400 Vdc</td>
<td>Large Size</td>
</tr>
<tr>
<td>Reconstituted Mica paper</td>
<td>-65 to +260 °C</td>
<td>10 pF to 10 µF</td>
<td>1000-100,000 Vdc</td>
<td>Large size</td>
</tr>
<tr>
<td>PTFE</td>
<td>-55 to +200 °C</td>
<td>1 µF to 100 µF</td>
<td>100- 600 Vdc</td>
<td>Large Size</td>
</tr>
<tr>
<td>Solid Tantalum</td>
<td>-55 to +200 °C</td>
<td>10 µF to 220 µF</td>
<td>4- 35 Vdc</td>
<td>Low voltage</td>
</tr>
<tr>
<td>Wet Tantalum</td>
<td>-55 to +230 °C</td>
<td>10 µF to 3000 µF</td>
<td>4 - 95 Vdc</td>
<td>Cap roll off at -55 °C, voltage derating</td>
</tr>
<tr>
<td>Prismatic Aluminum Electrolytic</td>
<td>-55 to +200 °C</td>
<td>50 µF to 4700 µF</td>
<td>20- 300 Vdc</td>
<td>conventionally sealed parts dry out</td>
</tr>
</tbody>
</table>
The Prismatic Aluminum Electrolytic

Packaging Prevents Dry-Out

Patented Glass-to-Metal Terminations

All welded construction
Mass-Loss of Electrolyte for Aluminum Electrolytic Package Types

Mass Loss of Electrolyte for Aluminum Electrolytic Package Types
11mF, 40V (Life Test at 105 °C)

Test Time (hours)

Mass Loss (grams)

-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02

0 500 1000 1500 2000 2500 3000 3500 4000 4500

- Glass-to-Metal Seal & Welded Seams
- Prismatic, Welded Seams
- Conventional Seals
Advantages of Prismatic Aluminum Electrolytics

- Prismatic packages use laser welded seams
  - Greatly reduce or eliminate loss of electrolyte
  - Some types are available with a patented glass-to-metal terminations.
- Prismatic form factor results in higher energy density
- Flat package is conducive to efficient end-user packaging
- A flat capacitor is easy to heat sink
- High vibration withstand – Up to 80 g’s
Applications for High Temperature Prismatic Aluminum Electrolytic Capacitors

- Used where there’s a need for space and or weight reduction
  - High capacitance and high voltage power holdup
    - Example: Aircraft Power Supplies

- Used as an alternative to banks of wet tantalum Capacitors
  - Smaller
  - Lower Cost
  - Improved system reliability
## Prismatic Aluminum versus T4 Wet Tantalum

### Max. C,V ratings @ 150 °C

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<th>Max Voltage @ 150°C</th>
<th>Max Capacitance @ Max Voltage and 150°C</th>
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<tr>
<td>Wet Ta (T4) Case</td>
<td>85 Vdc</td>
<td>350 μF</td>
</tr>
<tr>
<td>Prismatic Aluminum</td>
<td>300 Vdc</td>
<td>130 μF</td>
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<td>Electrolytic, Hermetic</td>
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- **Wet Ta (T4) Case**
  - Dimensions: 1.0” x 0.5” x 3.0”
  - O.D: 0.375” x 1.0”

- **Prismatic Aluminum Electrolytic, Hermetic**
  - Dimensions: 1.0” x 0.5” x 3.0”

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Prismatic Aluminum versus T4 Wet Tantalum

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- **Wet Ta (T4) Case**
  - Dimensions: 1.0” x 0.5” x 3.0”
  - O.D: 0.375” x 1.0”

- **Prismatic Aluminum Electrolytic, Hermetic**
  - Dimensions: 1.0” x 0.5” x 3.0”
Prismatic Aluminum versus T4 Wet Tantalum

To achieve high capacitance at high voltage at high temperature it is often necessary to bank capacitors in series and parallel.

That’s when it starts to get interesting!
**Application Example: Prismatic Aluminum versus Wet Tantalum**

- Customer using 21 (T4) Wet Tantalums in bank of 7(series) x 3(parallel)
- Each cap is rated at 220 µF, 100 Vdc @ 85 °C , *(65 Vdc @ 150 °C)*
- Application requires operation at 150°C
- Application requires 20g vibration withstand

Resulting capacitance of bank is 
220 µF/7(s) x 3(p) = **94 µF**

*Due to derating requirements for wet Ta, voltage of each cap at 150 °C is 65 Vdc

Resulting voltage of bank is 65 Vdc x 7(s) = **455 Vdc**
Application Example: Prismatic Aluminum versus Wet Tantalum

- CDE offered prismatic capacitors, 2 in series
- Each capacitor is rated for 190µF, 250 Vdc @ 150 °C
- Resulting capacitor bank of the CDE solution is rated for 95 µF @ 500 Vdc @ 150 °C

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Wet Tantalum Bank
94µF @ 455 Vdc, 150 °C

Prismatic Aluminum Electrolytic Bank
95µF @ 500 Vdc, 150 °C
Example: Prismatic Aluminum versus Wet Tantalum
Example: Prismatic Aluminum versus Wet Tantalum

Red: 21 Wet Tantalum in bank of 7(series) x 3(parallel)
Blue: 2 prismatic aluminum electrolytic capacitors in series
Example: Prismatic Aluminum versus Wet Tantalum

- For both banks, the voltage drop across each capacitor was monitored during the vibration test.
- The Max Vdc difference is the difference between the highest and lowest measured voltage drops within each bank.
## Application Summary

<table>
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<tr>
<th></th>
<th>Capacitance (µF)</th>
<th>Voltage Rating (Vdc) @ 150 ºC</th>
<th>Case Volume (in³)</th>
<th>Leakage Current (mA)</th>
<th>Weight (g)</th>
<th>Cost of components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Ta Bank 7(s) x 3(p)</td>
<td>94</td>
<td>455</td>
<td>3.6</td>
<td>.08</td>
<td>318</td>
<td>$(3-4)X$</td>
</tr>
<tr>
<td>Aluminum Bank 2(s)</td>
<td>95</td>
<td>500</td>
<td>2.0</td>
<td>.025</td>
<td>80</td>
<td>$X$</td>
</tr>
</tbody>
</table>
High Temperature Capacitors need Low Temperature Performance

- Almost all mil/aero applications require “cold start” performance at -55 °C
- Wet tantalum caps have lower capacitance retention at low temperatures
- Replace multiple T4 wet tantalum caps with one prismatic aluminum electrolytic
- Prismatic aluminum electrolytic capacitors save weight, size and cost compared to banks of wet tantalum capacitors

<table>
<thead>
<tr>
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<th>MLSH, Prismatic AL Electrolytic</th>
<th>Wet Ta 4 x T4 1000μF, 40 Vdc @ 125 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance @ 125 °C, 120 Hz</td>
<td>2100μF</td>
<td>4910μF</td>
</tr>
<tr>
<td>Cap Change at -55 °C, 120 Hz</td>
<td>-20%</td>
<td>-68%</td>
</tr>
<tr>
<td>Capacitance @ -55 °C, 120 Hz</td>
<td>1675μF</td>
<td>1580μF</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>32</td>
<td>59</td>
</tr>
<tr>
<td>Cost</td>
<td>1X</td>
<td>2X</td>
</tr>
</tbody>
</table>
High Temperature Capacitors need Low Temperature Performance

- Aluminum electrolytics have much higher capacitance retention at low temperature.

Hermetic Aluminum Electrolytic Cap Change @ -55°C
MLSH222M040JK0C (2200µF, 40Vdc)

Wet Tanatalum Cap Change @ -55°C
4 X (1000µF, 60Vdc*) D-Size Wet Tantalum Caps in Parallel
* Derated to 40 Vdc for -55°C to 125°C Operating Temp Range
High Temperature Capacitors need Low Temperature Performance

- Aluminum electrolytics have much higher capacitance retention at low temperature.
Summary

- Prismatic aluminum capacitors offers advantages over banks of wet Tantalum capacitors in high temperature applications:
  - Achieve smaller size, less weight, lower cost
  - Simplify board layout and assembly
  - Improve system reliability by using fewer components
QUESTIONS?

THANK YOU!