New Polymer Capacitors for DC to DC Convertors in Automobile Infotainment Systems

APEC 2015: Jayson Young
As more electronic systems continue to be integrated into our automobiles, the need for capacitor technologies that deliver high reliability, long life, stable performance, low ESR and low cost continue to grow. Polymer Capacitors have met these needs in the enterprise, commercial, consumer, medical, military and aerospace segments for more than 15 years. But polymer technology has been challenged when it comes to meeting the AEC Q-200 requirements. Today, these challenges are being overcome as polymer capacitor technology makes it entrance into the automotive segment.
### Advantages of Polymer Capacitors

**Stable Capacitance Behavior**

<table>
<thead>
<tr>
<th>Ta Provides Stable Capacitance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(No Dry out, Bias, AC Ripple or Aging Effect)</td>
</tr>
</tbody>
</table>

- **LYTIC**
- **Ta MnO₂ MLCC**
- **Poly**

- **Time**
- **Temp**
- **Volt**
- **Ripple**
- **Freq**

**Long Life**

![Graph showing long life of capacitor over time]

*Want 100µF? – Get 100µF!*
Advantages of Polymer Capacitors

- **High Capacitance**

- **Low Profile**

- **Safe Failure Mode**

- **Improved Voltage Derating**
  - MnO$_2$ = 50% Derating
  - Poly = 10-20% Derating

- **Low ESR**
  - (High Cap Retention = Reduced Pc Count)

- **Higher Application Voltage Range**
  - 35V, 50V, 63V

- **Replacement for MLCC Piezo Noise**
Meeting the Q-200 Requirements

<table>
<thead>
<tr>
<th>Stress Test Name</th>
<th>Conditions</th>
<th>MnO₂</th>
<th>Poly</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temp Exposure (Storage)</td>
<td>125°C, Unbiased, 1000 Hrs</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Temperature Cycling</td>
<td>-55°C to 125°C, 1000 Cycles</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Biased Humidity</td>
<td>85°C, 85% RH, Biased, 1000 Hrs</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Operational Life</td>
<td>125°C, Biased, 1000 Hrs</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Resistance to Solvents</td>
<td>Mil-Std-202, Meth. 215</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mechanical Shock</td>
<td>Mil-Std-202, Meth. 213, Cond F</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Vibration</td>
<td>Mil-Std-202, Meth. 208, 5G’s-20min</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Resistance to Soldering Heat</td>
<td>Mil-Std-202, Meth. 210, Cond D</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ESD</td>
<td>AEC-Q200- 002 or ISO/DIS 10605</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Solderability</td>
<td>J-STD-002</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Terminal Strength</td>
<td>AEC Q200-006</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Testing that is challenging for Polymer Capacitors:
- **High Temp Exposure**: 125°C, 0Vr, 1000 hrs
- **Operational Life**: 125°C, 0.67Vr, 1000 hrs
- **Biased Humidity**: 85°C/85%RH, 1.0Vr, 1000 hrs
Disadvantages of Polymer Capacitors

High Temperature

Temperature Range

-55°C -40°C 105°C 125°C 150°C 175°C 200°C

LYTIC
MLCC
MnO₂
Poly

= Standard Series  = Special Series  = Not Capable

High Humidity

Sensitivity to Humidity
60°C/90%RH (500-1000Hrs)
85°C/85%RH (1000Hrs)

AEC Q200 Requirement: 85°C/85%RH

AEC Q200 Requirement: 125°C
Issues with Polymer Cathode Systems

High Temperature:
- Polymer Oxidation: Extended exposure of polymer to air (primarily oxygen) at elevated temperature results in oxidation of the polymer. This breakdown of the conductive polymer’s structure results in increasing DF and ESR of the component over time.

High Humidity:
- Polymer De-doping: De-doping of the conductive species within the polymer.
- Metal Migration: Migration of metallic species from the cathode and lead frame materials onto the dielectric surface result in increases in leakage and can lead to shorts.
Distinctive Characteristics
Technology Enhancements for Automotive Polymer

T591 Series

- Robust anode design
- Moisture protection system to minimize risk of humidity penetration and oxidation;
- Packaging System to reduce permeability and migration

Initial Releases for 0.9V to 5V Rails

<table>
<thead>
<tr>
<th>Series</th>
<th>Description</th>
<th>Part Number</th>
<th>Cap</th>
<th>Voltage</th>
<th>ESR (mΩ)</th>
<th>Temp</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>T591</td>
<td>Polymer, Automotive</td>
<td>T591V227M2R5ATE009</td>
<td>220</td>
<td>2.5</td>
<td>9</td>
<td>105</td>
<td>7343-20</td>
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<tr>
<td>T591</td>
<td>Polymer, Automotive</td>
<td>T591B336M006ATE080</td>
<td>33</td>
<td>6</td>
<td>80</td>
<td>125</td>
<td>3528-21</td>
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<tr>
<td>T591</td>
<td>Polymer, Automotive</td>
<td>T591B336M010ATE080</td>
<td>33</td>
<td>10</td>
<td>80</td>
<td>125</td>
<td>3528-21</td>
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<tr>
<td>T591</td>
<td>Polymer, Automotive</td>
<td>T591B476M006ATE070</td>
<td>47</td>
<td>6</td>
<td>70</td>
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<td>T591</td>
<td>Polymer, Automotive</td>
<td>T591B476M010ATE070</td>
<td>47</td>
<td>10</td>
<td>70</td>
<td>125</td>
<td>3528-21</td>
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<tr>
<td>T591</td>
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<td>T591D107M010ATE025</td>
<td>100</td>
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<td>25</td>
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<td>7343-31</td>
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</table>
Technical Improvements – AUTO Grade
Life Test Improvement – 125°C

Control: Standard Process

Test: Improved Process

KEMET Ref: Polymer Tantalum Capacitors for Automotive Applications, CARTS 2014 – Jayson Young and Javaid Qazi
Technical Improvements – AUTO Grade
Humidity Improvement – 85°C/85%RH

Control: Standard Process

Test: Improved Process

1000 Hrs Humidity Testing: 85°C/85%RH @ 1.0Vr
Control: ESR

1000 Hrs Humidity: 85°C/85%RH @ 1.0Vr
Test Group: ESR

1000 Hrs Humidity: 85°C/85%RH @ 1.0Vr
Control Group: Leakage

1000 Hrs Humidity: 85°C/85%RH @ 1.0Vr
Test Group: Leakage
### Product Offerings, T591 Series

**Existing and Under development Waterfall**

<table>
<thead>
<tr>
<th>Vr</th>
<th>Cap (µF)</th>
<th>2.5V</th>
<th>4V</th>
<th>6.3V</th>
<th>10V</th>
<th>16V</th>
<th>20V</th>
<th>25V</th>
<th>35V</th>
<th>50V</th>
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<tbody>
<tr>
<td>6,8</td>
<td>B(200) UD 2QCY2015</td>
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<td>10</td>
<td>V(120) UD 2QCY2015 D(90) UD 2QCY2015</td>
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<tr>
<td>33</td>
<td>B (80) B (80) D(65) UD 2QCY2015 D(65) UD 2QCY2015 X(75) UD 2QCY2015</td>
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<tr>
<td>47</td>
<td>B (70) B (70) X(75) UD 2QCY2015</td>
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<tr>
<td>100</td>
<td>V(45) UD 1QCY2015 D(50) UD 1QCY2015</td>
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<tr>
<td>150</td>
<td>D (80, 40, 25)</td>
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<tr>
<td>220</td>
<td>V (15, 12, 9) D (25) UD 1QCY2015</td>
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<tr>
<td>330</td>
<td>V(25) UD 1QCY2015 D (25) UD 1QCY2015</td>
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</tbody>
</table>

UD under development
Product Roadmap
Short & Long Term Vision – Automotive Polymer

**Vision!**
150°C

**Target 1st to market**
Full AEC-Q200
125°C
1000h
85°C/85%RH Ur

**KEMET’s 1st step!**
500h Ur
85°C/85%RH

**T599**
Material Settings R&D

- **Vision!**
  - T599 - tbd

**T598**

- **T598**
- **T598 Phase 1**
  - Ur <= 16V
- **T598 Phase 2**
  - Ur 20-50V

**T591**

- **T591 Phase 1**
  - Ur <= 10V
- **T591 Phase 2**
  - 16V extensions
- **T591 Phase 3**
  - 20-50V

**T599**

- **Sub A Expansion**
  - T527/T529 *

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2014 | 2015 | 2016…
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* New series name to be define
Replacing Traditional Tantalum with T591 Automotive Polymer

DC/DC Converter → 5V → Active

Polymer:
- Derate 10%

Traditional Tantalum (MnO₂):
- Derate 50%

6.3V 47uF 70mΩ B Case
10V 47uF 80mΩ D Case
Cost Study

The Need: ~47uF for a 5V Input

Part Type and Pc Count

<table>
<thead>
<tr>
<th>Part Type</th>
<th>Price: (Based on Digi-Key Full Reel Quantities)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLCC: 2pcs Auto Grade 1210, 47uF, 6.3V, X7R</td>
<td>$0.6783 x 2 = $1.35</td>
</tr>
<tr>
<td>MLCC: 3pcs General Purpose 1210, 47uF, 6.3V, X5R</td>
<td>$0.1208 x 3 = $0.3624</td>
</tr>
<tr>
<td>Traditional Tantalum: 1pcs Auto Grade 7343, 47uF, 10V</td>
<td>$0.52 x 1 = $0.52</td>
</tr>
<tr>
<td>Polymer: 1pcs <strong>T591 Series</strong>, 3528, 47uF, 6.3V</td>
<td>$0.35 x 1 = $0.35</td>
</tr>
</tbody>
</table>

1210 Imperial = 3528 Metric
• To meet the requirements of the AEC Q-200 Document, improvements to the design of polymer capacitors have been implemented.

• The conductive polymer used in the construction of these devices is sensitive to extreme temperature and humidity.

• By enhancing the design, polymer capacitors can meet and exceed the requirements of these harsh environmental tests.

• Polymer Capacitors offer a series of technical advantages over other dielectric options. While the individual piece price may be higher, the total solution cost is often the lowest cost solution.