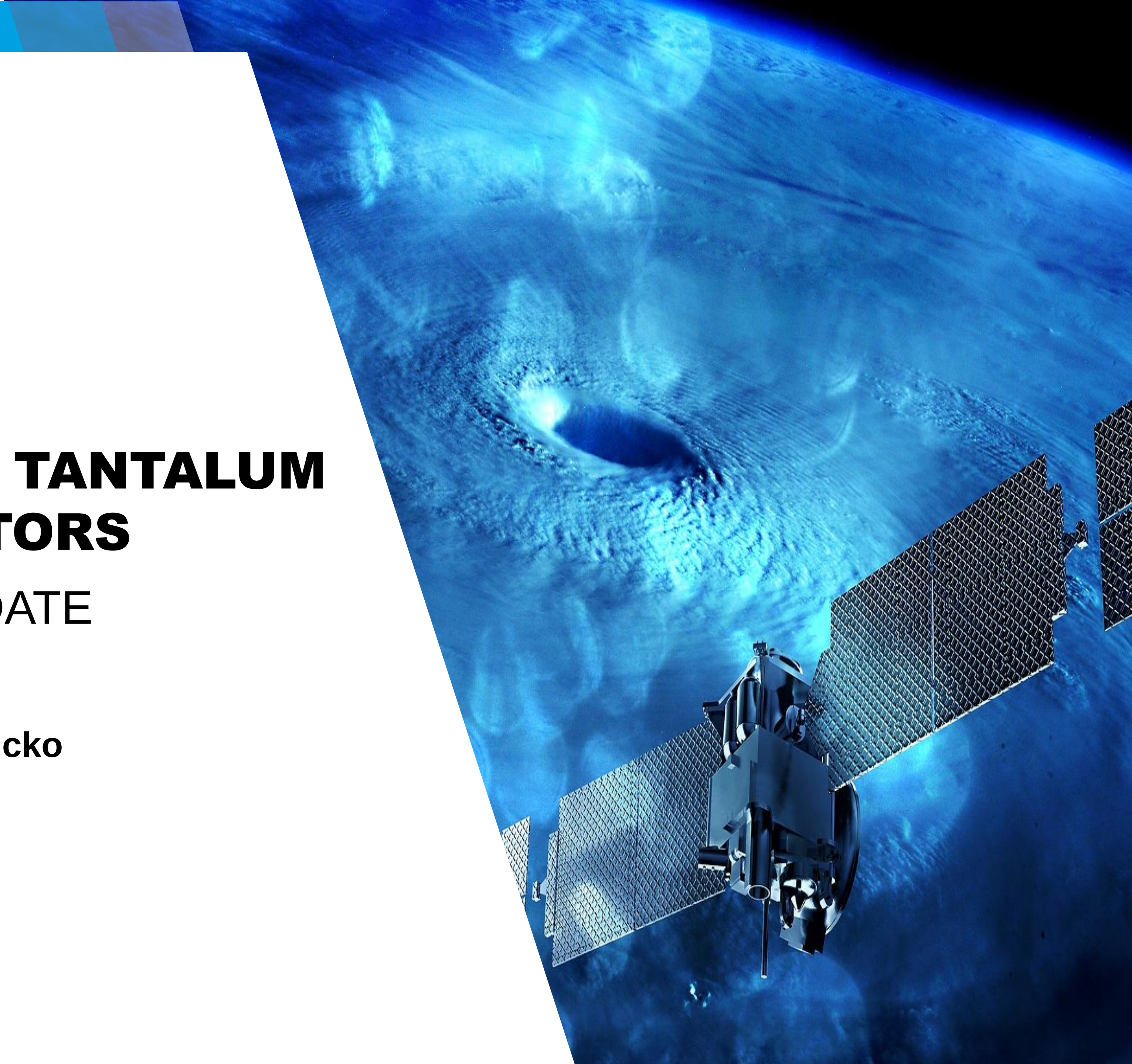
# HERMETIC SPACE GRADE TANTALUM POLYMER CAPACITORS

PERFORMANCE UPDATE

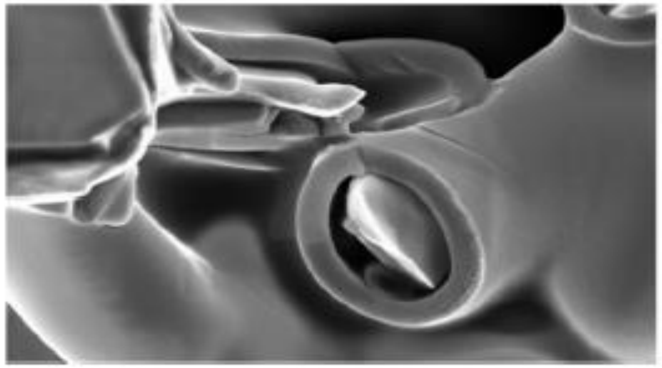
**Slavomir Pala | Ron Demcko**



# OUTLINE

- Introduction to Tantalum Capacitor Technologies
- Bulk Capacitor Applications
- Recap: Role & Progression of Bulk Capacitors - Tantalum, Tantalum Polymer, Hermetic
- Advantages and Limitations of Tantalum Polymer Capacitors
- Hermetic Tantalum Polymer Capacitor Discussions
- Impact Upon Systems & Further Direction
- Summary

# CAPACITOR TECHNOLOGIES

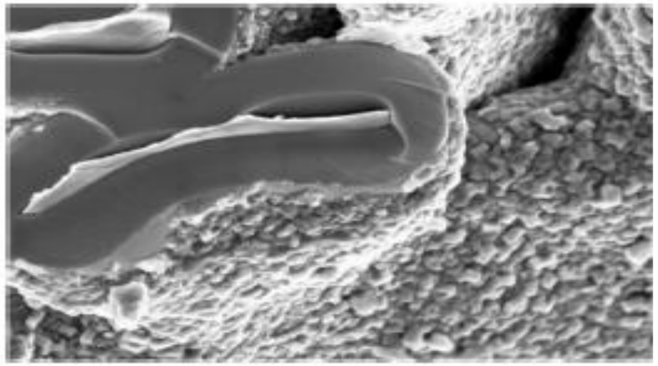


## Liquid Electrolyte

**WET Tantalums**
Ionic Conduction
Hermetically Sealed

+ Surge Robust
+ High Voltage
+ High Temperature

- Temperature Dependent
- Frequency Dependent
- Electrolyte Leak Possible

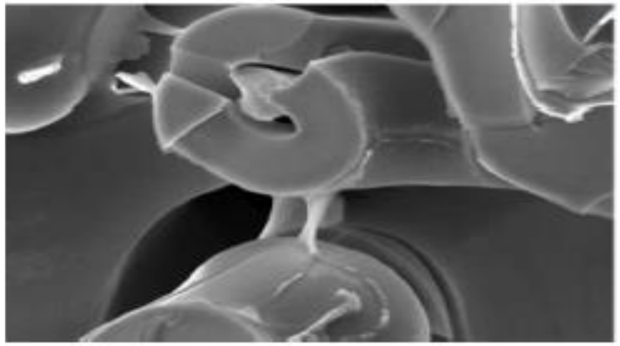


## $MnO_2$

**Solid – $MnO_2$**
Electronic Conduction

+ High Temperature
+ Well Established Reliability

- Failure Mode
- Voltage Limited
- ESR Higher



## Polymer

**Solid – Polymer**
Electronic Conduction

+ Low ESR
+ Safe Failure Mode
+ High Voltage

- Temperature Limited
- Humidity & Oxygen Sensitive

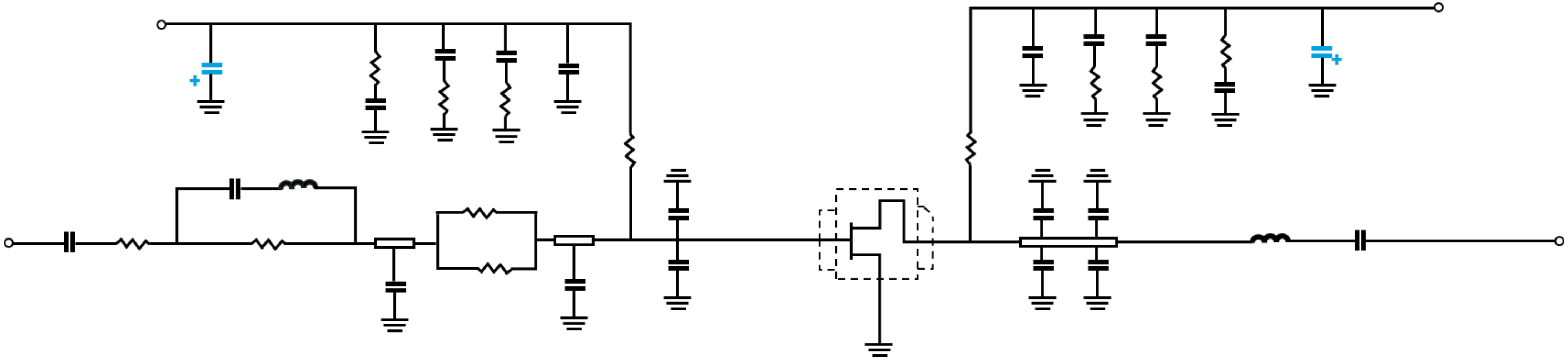
# BULK CAPACITOR DESIGN

As Flight Semiconductors Evolve and Enable Faster Processing the Demand for Low Parasitic Loss Bulk Capacitors will Naturally Grow

## Applications

- Semiconductor Mixed Logic Power Rails
- High Power GaN HEMTs
- FPGA's

**Power Amplifier Example**



# BULK CAPACITORS: $MnO_2$, TANTALUM POLYMER & HERMETIC

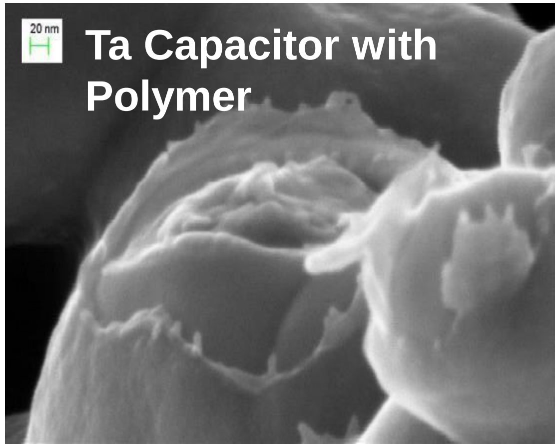
- Purpose:
  - Low Frequency Filter Capacitor
  - Hold up Capacitor

- Problem/Need:
  - Power Trees are Quickly Evolving and Becoming More Complex Due to Complex FPGA & Multi-Core ICs

Solutions From Known & Emerging Devices:

| Non-Hermetic Polymer | Hermetic Polymer | Traditional $MnO_2$ Tantalum |
|---|---|---|
| Solid – Polymer Electronic Conduction | Solid – Polymer Electronic Conduction | Solid- $MnO_2$ Electronic Conduction |
| Non-Hermetic | Hermetic | Non-Hermetic |
| Low ESR ≥ 6mΩ | Low ESR 40mΩ to 150mΩ | ESR ≥10 mΩ |
| Voltage Range: 2.5V to 125V | Voltage Range: 10V to 100V | Voltage Range: 2.5V to 50V |
| Temperature Range: -40°C to + 150°C | Temp. Range: -40°C to + 125°C | Temperature Range: -40°C to +200°C |
| Capacitance Range: 0.47uF to 1500uF | Capacitance Range: 22uF to 330uF | Capacitance Range: 0.1uF to 3300uF |
| DCL: 0.1CV to 0.001CV | DCL: 0.1CV | DCL: 0.01CV to 0.001CV |
| MSL: 3, 4, 5 | MSL: 1 | MSL: 1 to MSL 3 |

# $MnO_2$ and TANTALUM POLYMER CAPACITORS

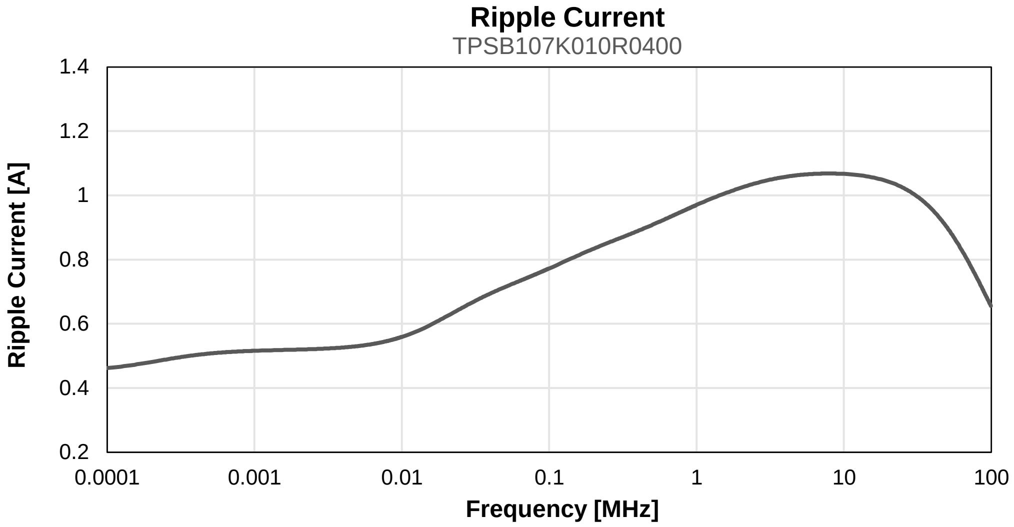



## Why Tantalum Polymer?

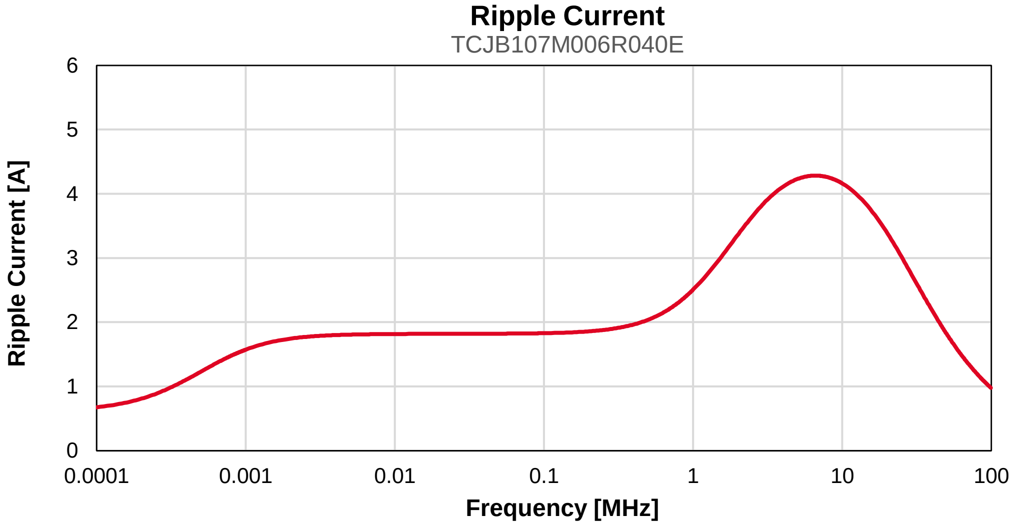
Lowered ESR that Contributes to Reduced Ripple at the IC Load

**Additional Advantages:**
Allowable Ripple Current - Increased

### $MnO_2$ Capacitor Electrical Characteristics




### TaPoly Capacitor Electrical Characteristics



# $MnO_2$ and TANTALUM POLYMER CAPACITORS

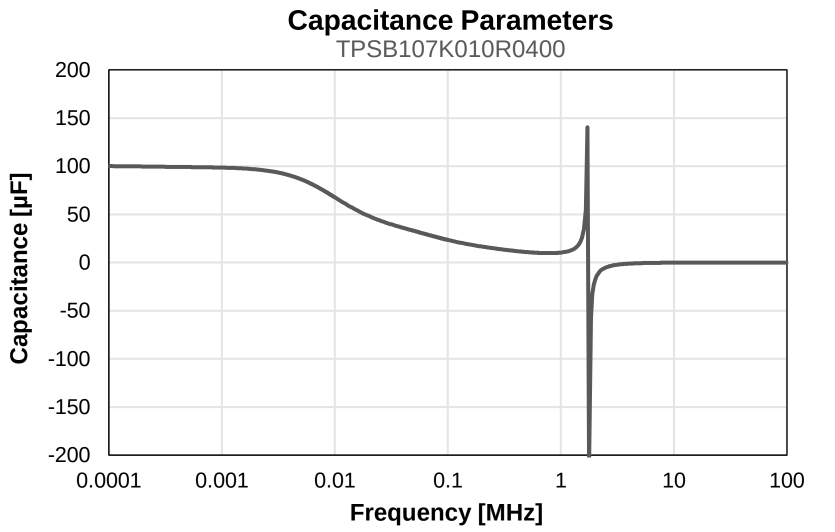
## Typical Inductance by Case Code

| | | | | |
|---|---|---|---|---|
| A(EIA:1206) = 1.8 nH | G(EIA: 1206)= 1.8 nH | P(EIA: 0805)= 1.4 nH | V(EIA: 2924)= 2.4 nH | 4(EIA:2924)= 2.2 nH |
| B(EIA:1210)= 1.8 nH | H(EIA: 1210)= 1.8 nH | R(EIA: 0805)= 1.4 nH | W(EIA: 2312)= 2.2 nH | 5(EIA: 2917)= 2.4 nH |
| C(EIA: 2312)= 2.2 nH | K(EIA: 1206)= 1.8 nH | S(EIA: 1206)= 1.0 nH | X(EIA: 2917)= 1.8 nH | 8(EIA: 2924)= 2.2 nH |
| D(EIA: 2917)= 2.4 nH | L(EIA: 0603)= 1.0 nH | T(EIA: 1210)= 1.0 nH | Y(EIA: 2917)= 2.4 nH | |
| E(EIA: 2917)= 2.5 nH | N(EIA: 2917)= 1.4 nH | U(EIA: 2924)= 2.4 nH | Z(EIA: 2917)= 1.8 nH | |

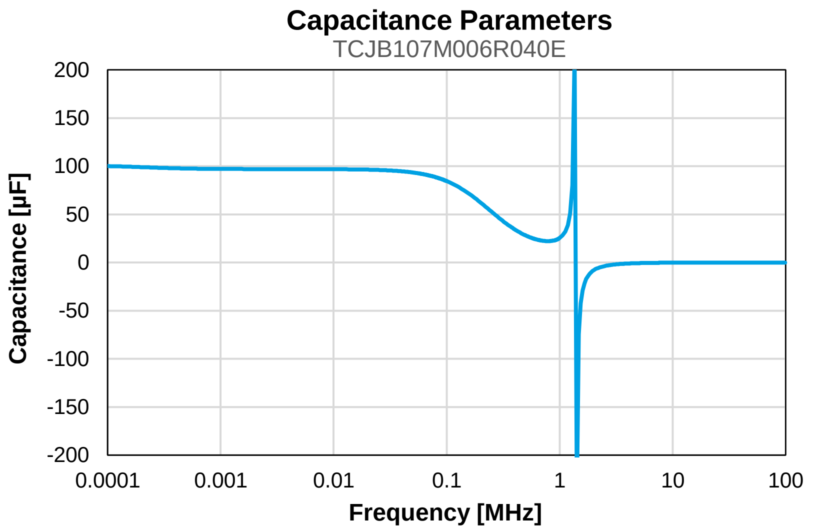
## Why Tantalum Polymer?

Reduces Capacitance Drop Over Frequency

### $MnO_2$ Capacitor Electrical Characteristics



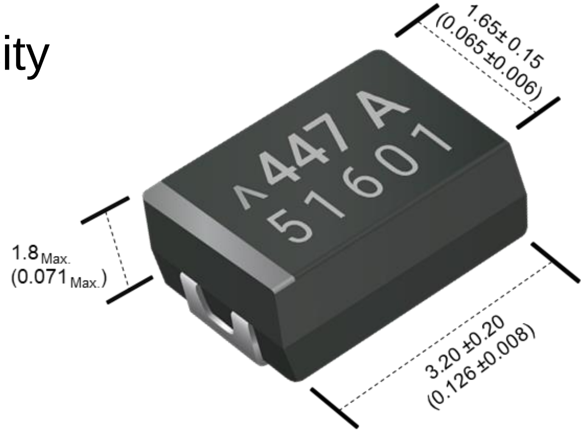

### TaPoly Capacitor Electrical Characteristics



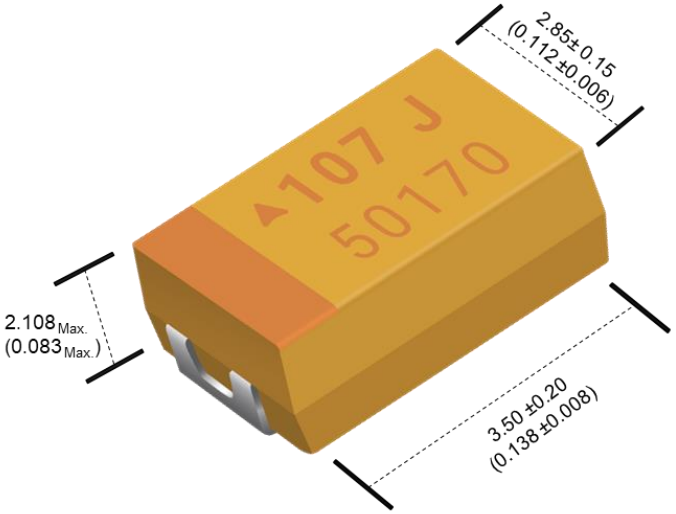
# $MnO_2$ and TANTALUM POLYMER CAPACITORS

## Why Tantalum Polymer?

Improved Energy Density




TCJ Polymer
Case A (28mg / 8.192mm$^3$): 1.15mJ




TPS $MnO_2$
Case B (68mg / 18.62mm$^3$): 1.20mJ

### Additional Advantages:

- **Broader Voltage Range:** 2.5V to 125V
- **Lower De-Rating:** 10% or 20% Voltage De-Rating
- **Size:** 0402 to 2924
- **Weight:** 5.7mg 2200mg
- **Benign Failure Mode**

## Concerns:

### Non-Hermetic Moisture Sensitivity

- **Moisture is Present in Molding Resin and Polymer Cathode During Reflow**
  - Creating Internal Pressure
  - Lower Performance and Reliability
- **Polymer Cathode Degrades from Long Term Exposure**
  - Degradation Accelerates with Increased Temperature / Voltage
  - Conductive Polymer Conductivity Drop: Increased ESR
  - Non-Recoverable shift in Capacitance

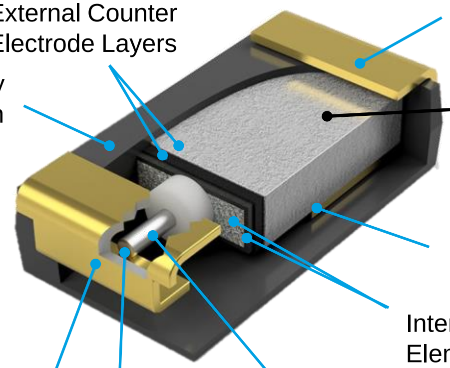
## Addressing the Concern:

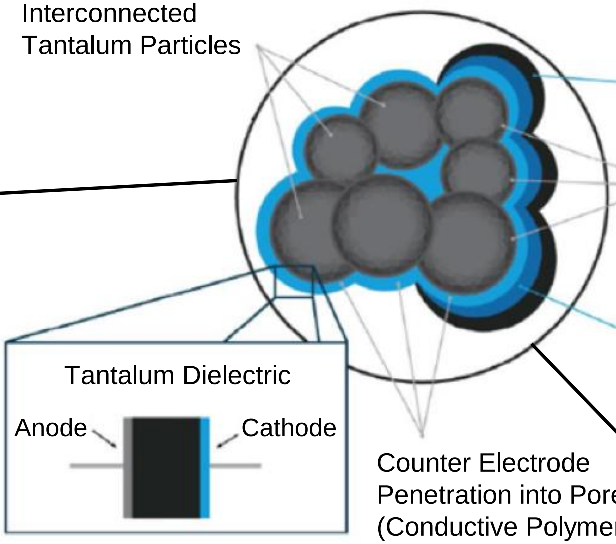
### High Reliability Polymers Have Additional Protection To Help With Moisture & Ageing

- **Slower Degradation**
  - Lifetime: 15+ years

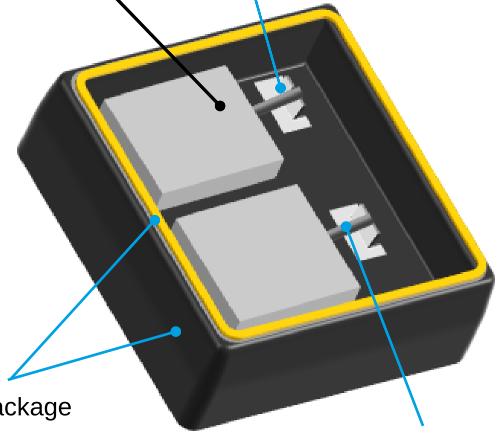
# TANTALUM POLYMER CONSTRUCTION

## Non- Hermetic Polymer




## Hermetically Sealed

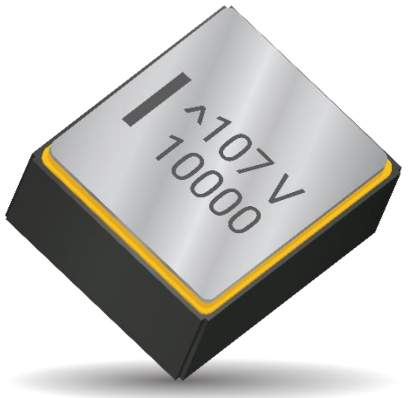



- Conductive Polymer in the Cathode
- Porous pellet of Tantalum Powder is Pressed onto the Tantalum Anode Wire
- Structure is Sintered into a Monolithic Block and a $Ta_2O_5$ Dielectric is Formed
- Conductive Polymer Layer is Deposited
- Welded / Conductive Epoxied onto a Lead Frame and Then Over-Molded

# TCH LOW ESR HERMETIC SERIES

SMD Low ESR Conductive Polymer Capacitors in Hermetic Packaging






## FEATURES

- Aerospace & Hi-Rel Applications
- Low ESR Conductive Polymer Electrode
- Endurance up to 10,000 hrs. on Selected Codes
- Ceramic Case Hermetic Packaging
- Stability Under Humidity and Ambient Atmosphere Exposure
- Large Case Sizes Including CTC-21D: Providing High Capacitance Values
- Specific Code Meets NASA EEE-INST-002, Level 2 Requirements

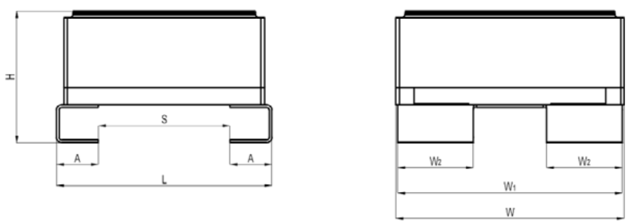
## CAPACITANCE AND VOLTAGE RANGE: CASE CODE (ESR mΩ)

| Capacitance | | Rated Voltage DC (VR) @ 85°C | | | | | | |
|---|---|---|---|---|---|---|---|---|
| μF | Code | 10V | 16V | 25V | 35V | 50V | 75V | 100V |
| 22 | 226 | | | | | | | 9 (150) |
| 33 | 336 | | | | | | 9 (120) | |
| 47 | 476 | | | | | 9 (70) | | |
| 100 | 107 | | | | 9 (55) | | | |
| 150 | 157 | | | 9 (50) | 9 (55) | | | |
| 220 | 227 | | 9 (40) | | | | | |
| 330 | 337 | 9 (40) | | | | | | |

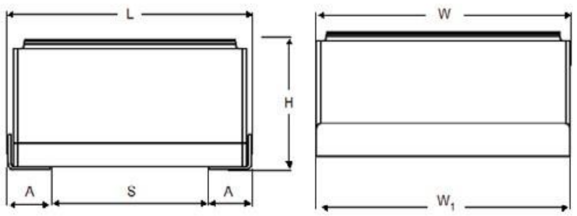
## CASE DIMENSIONS: millimeters (inches)

| Code | Type | L | W | H Max. | $W_1$ | $W_2$ | A | S Min. |
|---|---|---|---|---|---|---|---|---|
| 9 (CTC-21D) | J-Lead (C-Shape) | 12.00 ± 0.50 (0.472 ± 0.020) | 12.50 ± 0.50 (0.492 ± 0.020) | 8.45 (0.333) | 12.30 ± 0.50 (0.484 ± 0.020) | 4.15 ± 0.10 (0.163 ± 0.004) | 2.30 ± 0.50 (0.091 ± 0.020) | 6.50 (0.256) |
| 9 (CTC-21D) | J-Lead (C-Shape) | 11.50 ± 0.50 (0.453 ± 0.020) | 12.50 ± 0.50 (0.492 ± 0.020) | 6.15 (0.242) | 12.50 ± 0.50 (0.492 ± 0.020) | - | 1.90 ± 0.50 (0.075 ± 0.020) | 7.00 (0.276) |
| 9 (CTC-21D) | Undertab | 11.00 ± 0.20 (0.433 ± 0.008) | 12.50± 0.20 (0.492 ± 0.008) | 5.95 (0.234) | 10.50± 0.20 (0.413 ± 0.008) | - | 1.50± 0.20 (0.059 ± 0.008) | 7.80 (0.307) |

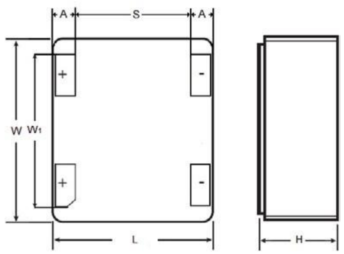
**'J' Lead Termination (C-shape)**




**'J' Lead Termination (L-shape)**




**Undertab Termination**



# HERMETIC POLYMER SPECIFICATION FOCUS

<table>
<tr><th>Test</th><th>Condition</th><th>Characteristics</th></tr>
<tr><td>Endurance</td><td>Apply Voltage$_{Rating}$ for 2000 (10,000) +48/0 hrs. at 85±2ºC. Let sit for 2 hrs.$_{min.}$ at room temperature. Apply Category Voltage$_{125°C\ Rating}$ for 2000 +48/-0 hrs. Let sit for 2 hrs.$_{min.}$ at room temperature. Power supply impedance to be < 3Ω.</td><td>Visual: No Visual Damage<br>DCL: 1.25 x Initial Limit<br>ΔC/C: ±20% Of Initial<br>DF: 1.25 x Initial Limit<br>ESR: 1.25 x Initial Limit</td></tr>
<tr><td>Storage Life</td><td>Store at 125ºC, no voltage applied, for 2000 hrs. Stabilize at room temperature for 1-2 hrs before measuring.</td><td>Visual: No Visual Damage<br>DCL: 2 x Initial Limit<br>ΔC/C: ±20% Of Initial<br>DF: 1.5 x Initial Limit<br>ESR: 2 x Initial Limit</td></tr>
<tr><td>Temperature Stability</td><td>
<table>
<tr><th>Step</th><th>Temperature</th><th>Duration</th></tr>
<tr><td>1</td><td>+20°C</td><td>15 min</td></tr>
<tr><td>2</td><td>-55°C</td><td>15 min</td></tr>
<tr><td>3</td><td>+20°C</td><td>15 min</td></tr>
<tr><td>4</td><td>+85°C</td><td>15 min</td></tr>
<tr><td>5</td><td>+125°C</td><td>15 min</td></tr>
<tr><td>6</td><td>+20°C</td><td>15 min</td></tr>
</table>
</td><td>
<table>
<tr><th>Step</th><th>DCL</th><th>ΔC/C</th><th>DF</th><th>ESR</th></tr>
<tr><td>1</td><td>IL*</td><td>n/A</td><td>IL*</td><td>1.25 x IL*</td></tr>
<tr><td>2</td><td>n/a</td><td>+0/-20%</td><td>1.5 x IL*</td><td>1.25 x IL*</td></tr>
<tr><td>3</td><td>IL*</td><td>±5%</td><td>IL*</td><td>1.25 x IL*</td></tr>
<tr><td>4</td><td>10 x IL*</td><td>+20/-0%</td><td>1.5 x IL*</td><td>1.5 x IL*</td></tr>
<tr><td>5</td><td>12.5 x IL*</td><td>+30/-0%</td><td>2 x IL*</td><td>1.5 x IL*</td></tr>
<tr><td>6</td><td>IL*</td><td>±5%</td><td>IL*</td><td>1.25 x IL*</td></tr>
</table>
</td></tr>
<tr><td>Humidity</td><td>Store at 40ºC and 90% relative humidity for 56 days, with no applied voltage. Stabilize at room temperature and humidity for 2 hrs.$_{min.}$ before measuring.</td><td>Visual: No Visual Damage<br>DCL: 1.25 x Initial Limit<br>ΔC/C: ±10% Of Initial<br>DF: Initial Limit<br>ESR: 1.25 x Initial Limit</td></tr>
<tr><td>Surge Voltage</td><td>Test temperature: 85ºC+3/0ºC<br>Surge voltage: 1.3 x Voltage$_{Rated}$ (Ur ≤ 50V)<br>1.15 x Voltage$_{Rated}$ (Ur > 50V)<br>Series protection resistance: 33Ω (Ur ≤ 50V)<br>1000Ω (for Ur > 50V)<br>Discharge resistance: 33Ω<br>Number of cycles: 1000x-Cycle duration: 6 min; 30 sec charge, 5 min 30 sec discharge</td><td>Visual: No Visual Damage<br>DCL: Initial Limit<br>ΔC/C: ±20% Of Initial<br>DF: Initial Limit<br>ESR: 1.25 x Initial Limit</td></tr>
<tr><td>Mechanical Shock / Vibration</td><td>MIL-STD-202, Method 213, Condition C, 100 G peak<br>MIL-STD-202, Method 204, Condition D, 10 Hz to 2,000 Hz, 20 G peak</td><td>Visual: No Visual Damage<br>DCL: Initial Limit<br>ΔC/C: ±10% Of Initial<br>DF: Initial Limit<br>ESR: 1.25 x Initial Limit</td></tr>
</table>

## COTS+
### HI-REL

1. RA Semiproduct
2. Pulse Age
3. Hand Surge Measurement
4. 100% Electrical Test
5. Ageing Loose Units
6. 100% Electrical Test
7. Leak Test
8. AQL – Solderability Test
9. AQL – Final Inspection

## NASA
### EEE-INST-002:

1. RA Semiproduct
2. Pulse Age
3. Internal Visual Inspection
4. Internal Visual Inspection II
5. Temperature Cycling
6. Hand Surge Measurement
7. 100% Electrical Test
8. Ageing Loose Units
9. 100% Electrical Test
10. High & Low Temperature Electrical Measurements
11. Check For Lot Failure
12. External Visual Inspection
13. AQL – Solderability Test
14. AQL – Final Inspection

NASA/TP—2003–212242

**EEE-INST-002:** Instructions for EEE Parts Selection, Screening, Qualification, and Derating

**Procedures Follow EEE-INST-002:**

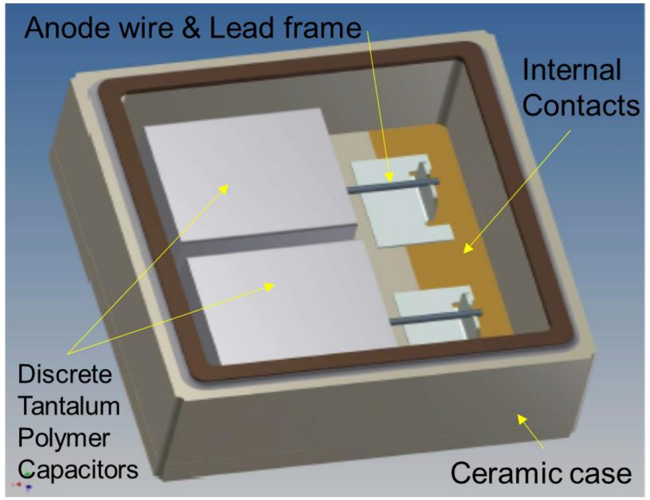
Capacitor Screening Requirements Tantalum, Level 2

**SPACE FLOW CHART**

1. RA Semiproduct
2. Pulse Age
3. Internal Visual Inspection
4. Internal Visual Inspection II
5. Temperature Cycling
6. Hand Surge Measurement
7. 100% Electrical Test
8. Ageing Loose Units
9. 100% Electrical Test
10. High & Low Temperature Electrical Measurements
11. Check For Lot Failure
12. External Visual Inspection
13. Leak Test
14. AQL – Solderability Test
15. AQL – Final Inspection

**STANDARD FLOW CHART**

1. RA Semiproduct
2. Pulse Age
3. Hand Surge Measurement
4. 100% Electrical Test
5. Ageing Loose Units
6. 100% Electrical Test
7. Leak Test
8. AQL – Solderability Test
9. AQL – Final Inspection



# SUMMARY

- Complex Loads are Increasing the Need for High Performance Bulk Caps
- $MnO_2$ Parts Have Proven Performance
- Tantalum Polymer Parts Build Upon Proven Performance with Certain Electrical Parameter Optimizations
- Hermetic Tantalum Polymer Holds Promise in the Advancement of TaPoly Devices
- Hermetic Tantalum Polymer Creates an Electrically Optimized and Highly Reliable Capacitor