POLYCHARGE

PolyCharge

Energizing Personal Mobility

Company Focus: Capacitors for Power Electronics

Polycharge VaporFilm DC-Link capacitors for automotive inverter applications

Reduce size and cost

Improve high temperature performance

Today’s DC-Link Capacitor in an Automotive Inverter..

One of the **largest** most **expensive**, and arquably the **least reliable**, components

Produced using metallized polypropylene (PP) films

THE CHALLENGE

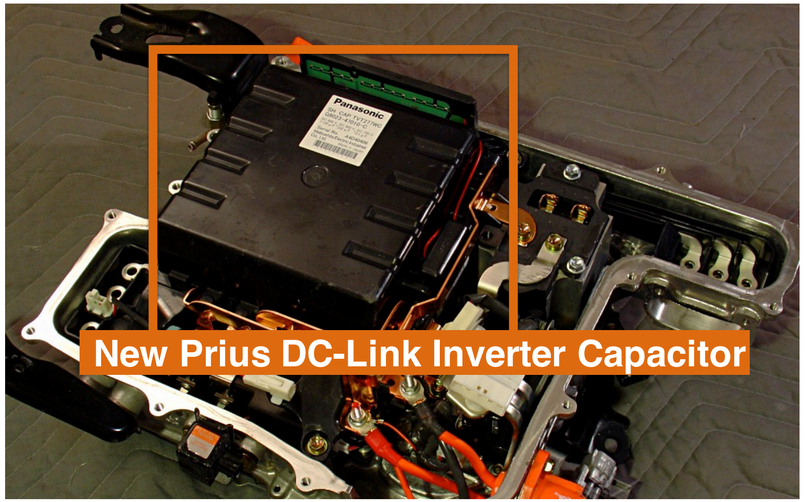
Increase Operating Temperature

Reduce size

Reduce Cost

Benign Failure Mode

Higher Reliability



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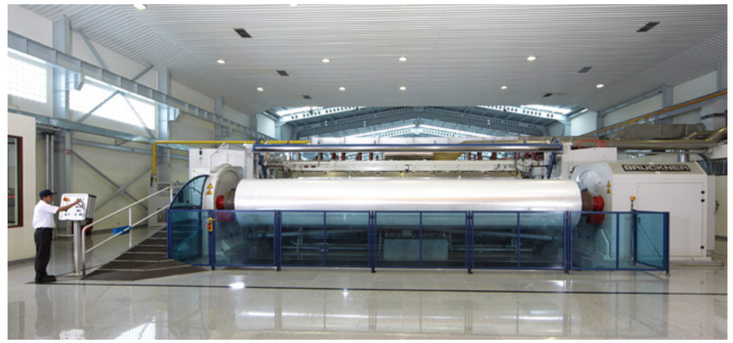
Current Capacitor Technology Supply Chain

PP Film Extrusion

A Handful of OEMs Worldwide



Electrode Metallization

A Handful of OEMs Worldwide
5-6 Capacitor OEMs also Metallize

Winding

Plus Other Operations
Testing, Lead Attach, Packaging

100s of Capacitor OEMs Worldwide Use the Same PP Films
Limiting the Ability to Differentiate and Innovate

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The Solution: Polycharge VaporFilm Capacitors

Polycharge VaporFilm capacitors represent a disruptive change in the way in which polymer capacitors are produced

The film extrusion plant, metallizing converter and winding machines are replaced with a single apparatus that is fed with only metal wire and liquid monomer

Bulk capacitor material (mother capacitor), is produced in a single step process, which is segmented and processed into individual capacitors

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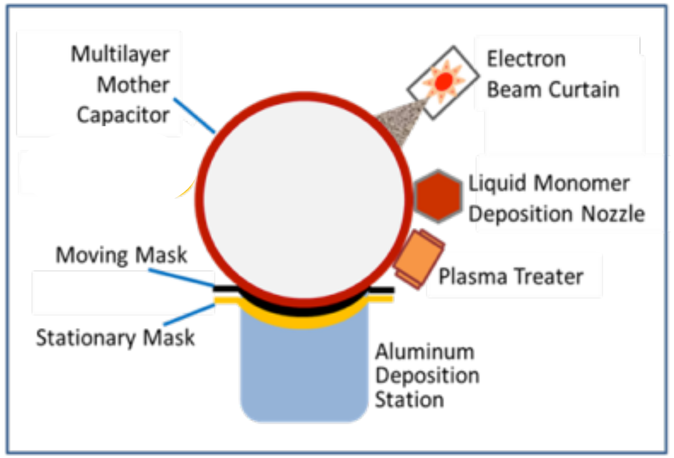
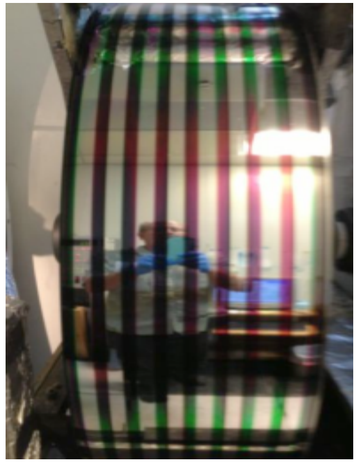
VaporFilm Capacitor Manufacturing Process

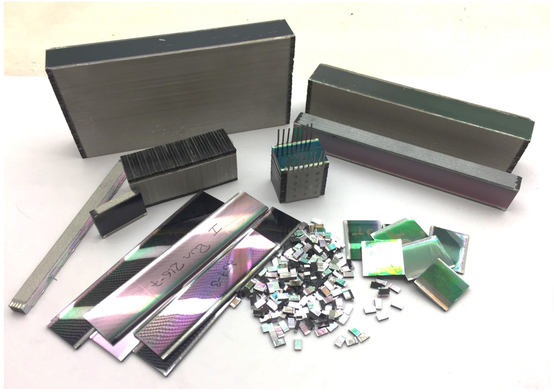


PML Capacitor Process Schematic

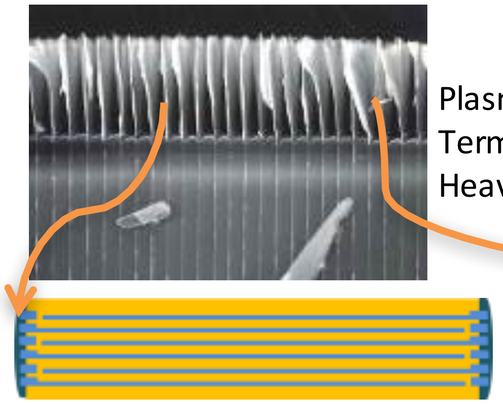


10ft long Mother Capacitor Material On Process Drum

12” x 12” Card Segmented from the Mother Capacitor

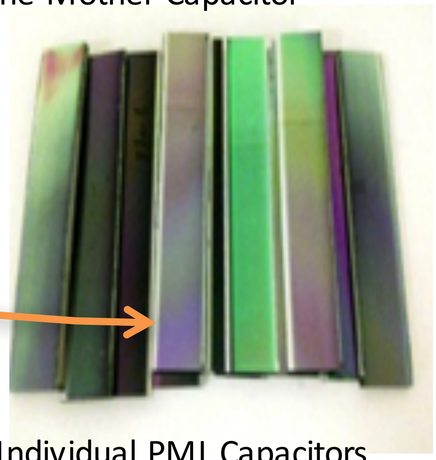


Capacitor Chips and Chip Stacks to Form Larger Capacitors



Plasma Ashed Termination Heavy Edge

Arc Sprayed Termination



Individual PML Capacitors

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Polycharge VaporFilm Polymer Dielectric

- The polymer is formed using acrylate monomers
- $H_2C=CHC(O)O\ \ R(X)\ \ OC(O)CH=CH_2$
- R = aliphatic, aromatic, heterocyclic
- X = functional group, amino, cyano, fluoroalkyl, nitrile, halogen, glycolyl, e.t.c.
- Polymer formulated to have a Dissipation factor DF<0.01
- Polymer dielectric formulated with a glass transition temperature (Tg) >200^{o}C (key for automotive applications)
- Polymer dielectric formulated to maximize the capacitor self-healing process: have maximized H:C and O:C ratio to efficiently convert Al to Al_2O_3 and C to CO, CO_2, CH_4, $C2H_6$, etc

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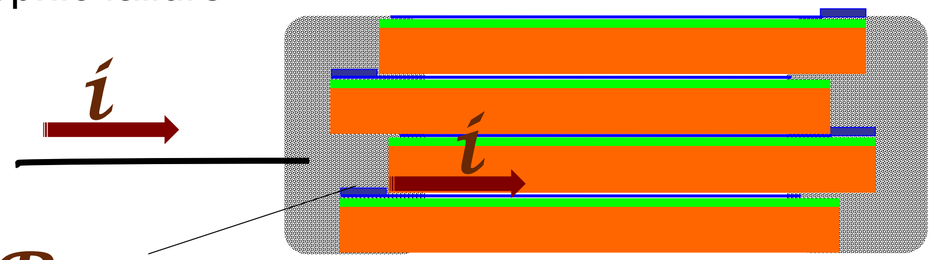
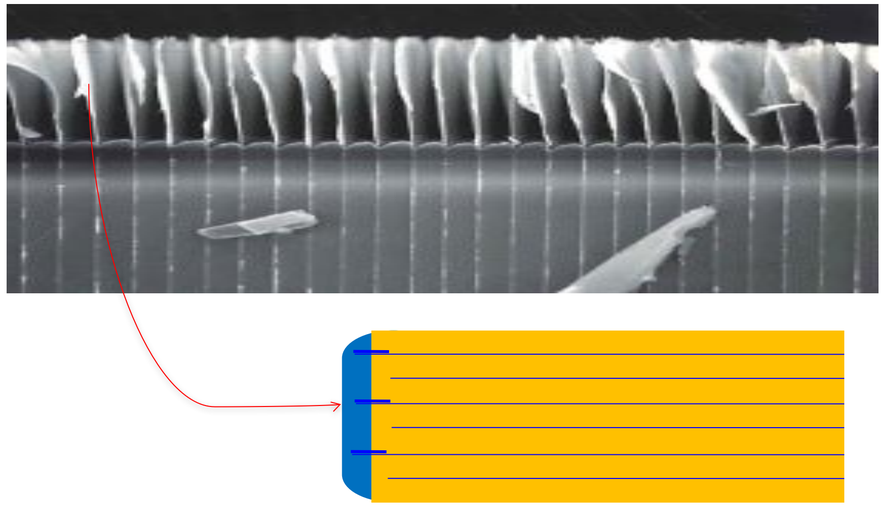
Handling of High Ripple Currents and High dV/dt Transients At High Ambient Temperatures, is a Key Requirement For a DC-Link Capacitor

At high ambient temperature >85°C , heat generated from high ripple current in metallized PP capacitors can lead to loss of contact and higher ESR values, which increases I^2R losses and eventually leads to a catastrophic failure



i^2R (R=ESR)

Failure Mode



VaporFilm capacitor dielectric can handle temperatures >260°C

The arc spray makes direct contact with the aluminum electrodes without the presence of polymer that expands and contracts

These factors result in a thermomechanically superior termination that can handle high ripple and dV/dt currents

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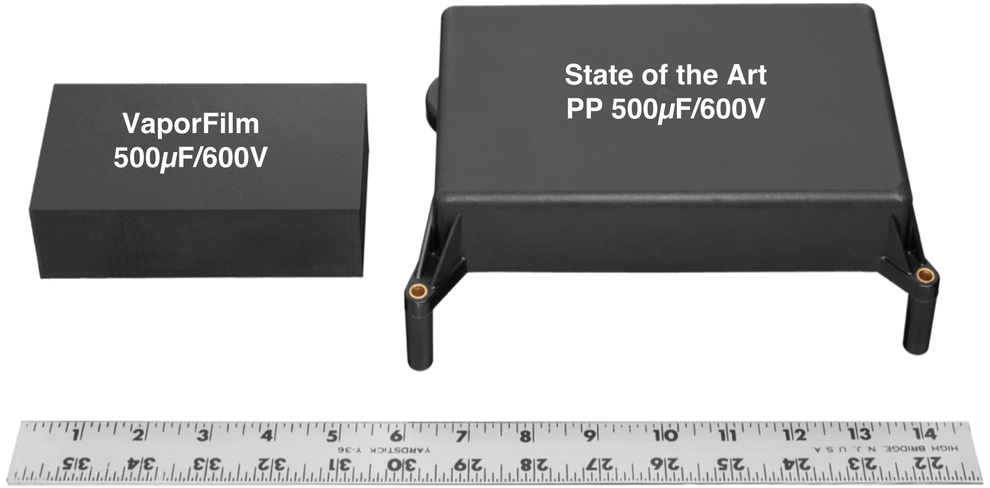
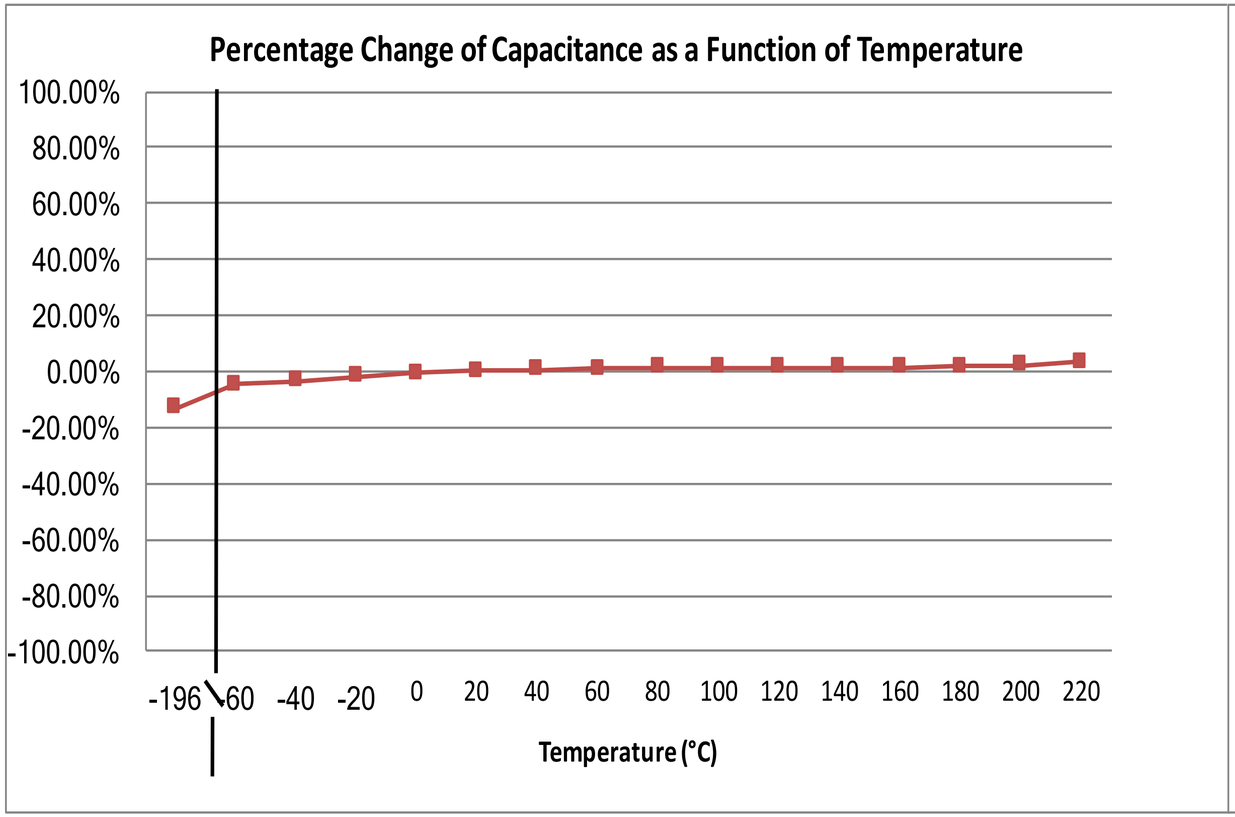
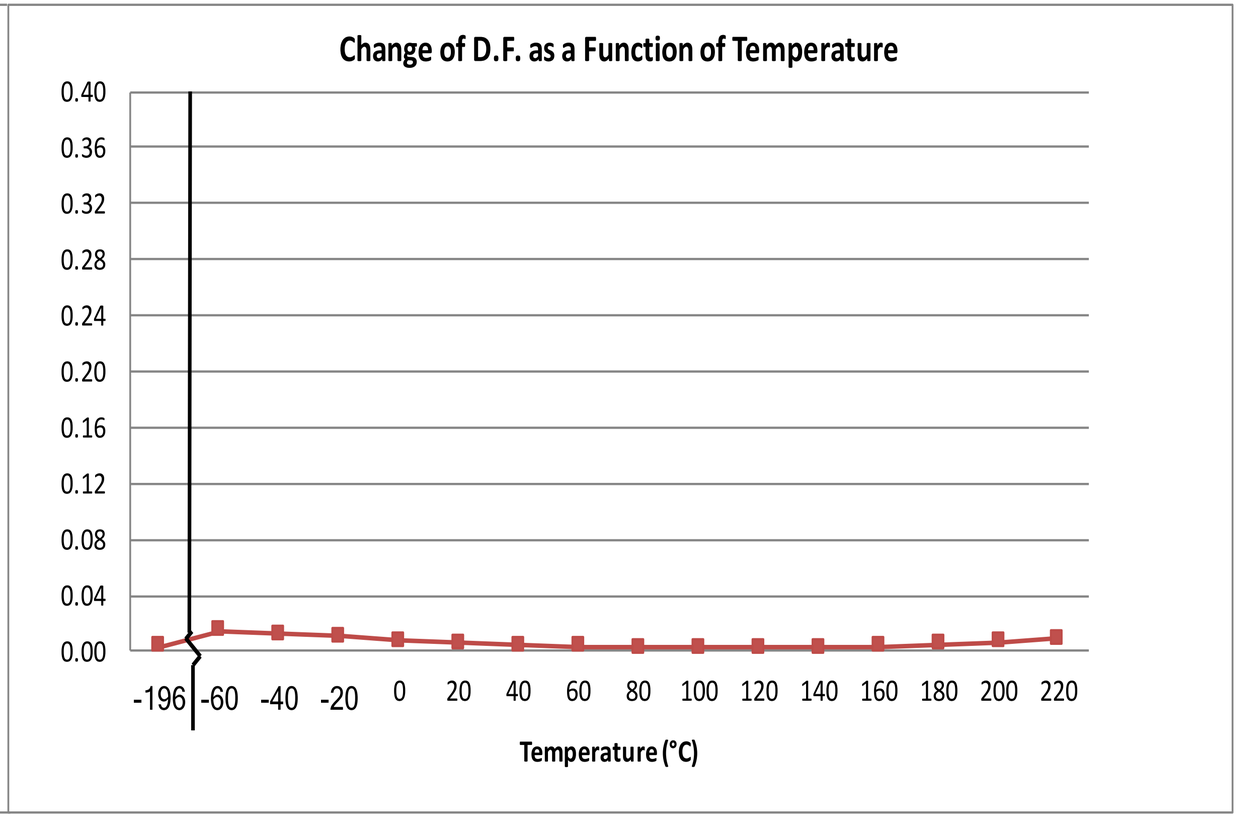
500µF/600V Volume Comparison

- Polycharge VaporFilm Capacitor is 1/3 the volume and weight of an equivalent polypropylene (PP) capacitor



Stability of the VaporFilm Capacitor Dielectric as a Function of Temperature





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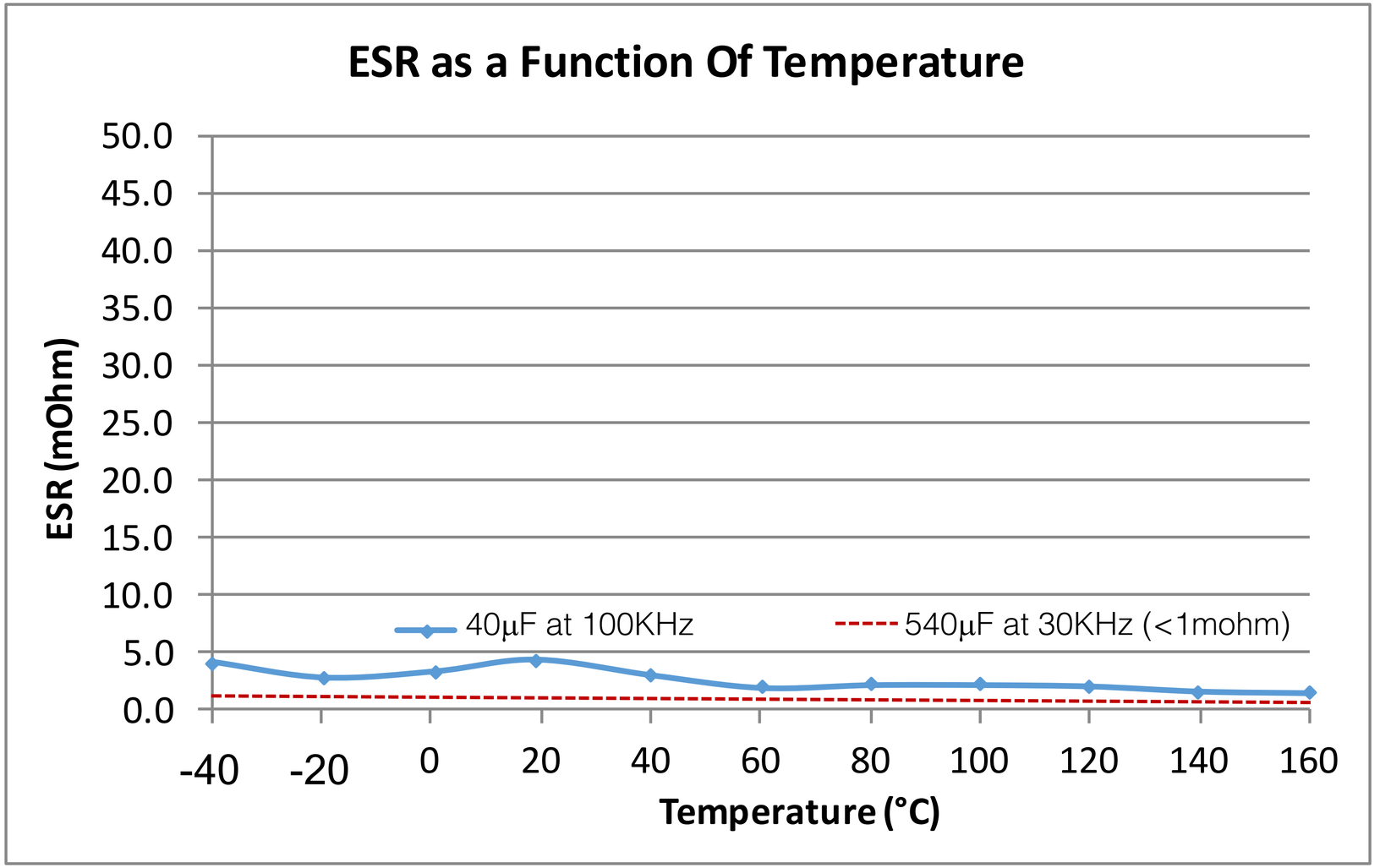
ESR as a function of Temperature Close to Resonance



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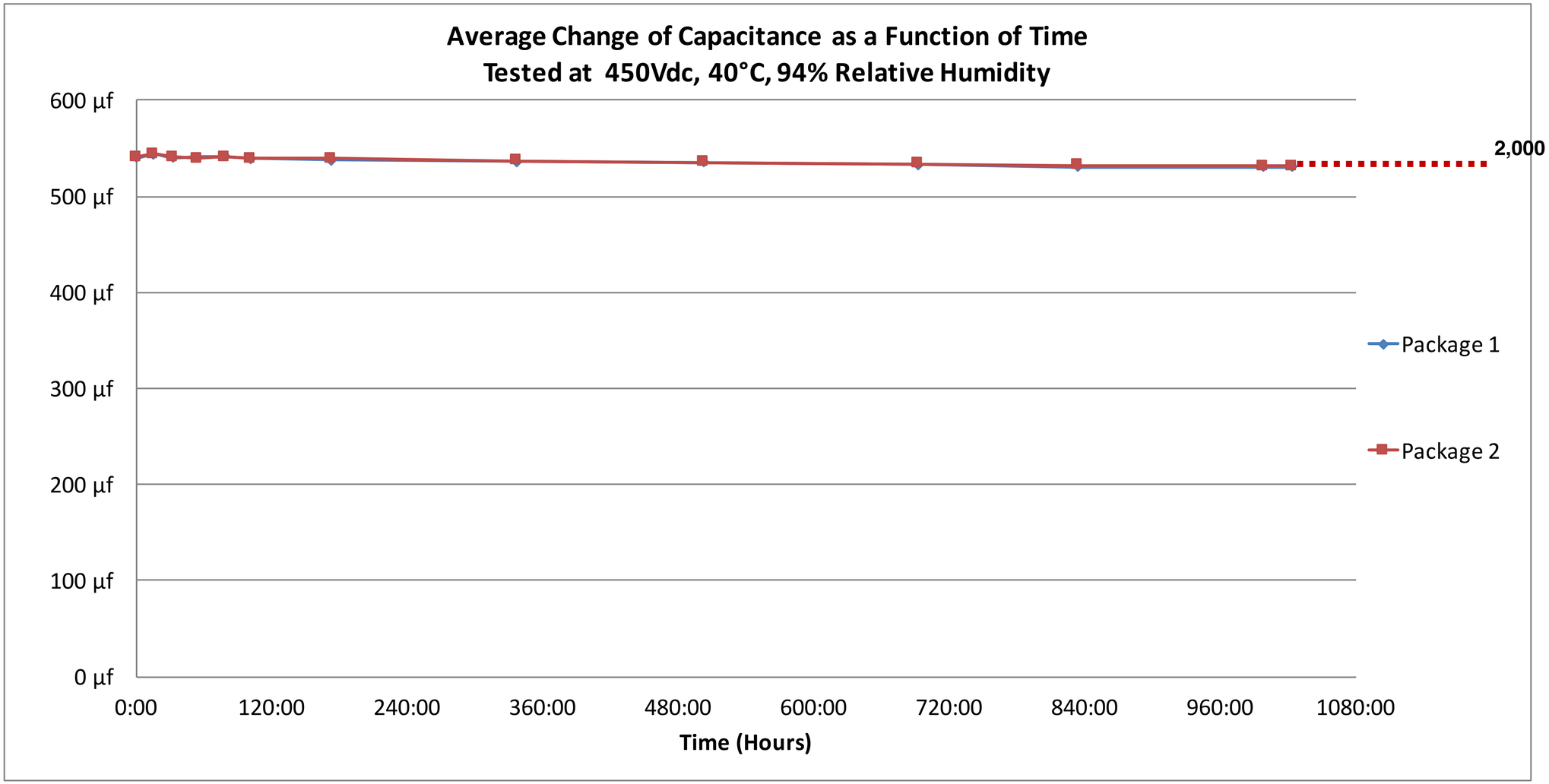
Life Test Using an Epoxy Potting Packaging Process

Preliminary Process - Performed in Air (will be Done in the Vacuum in The Future)



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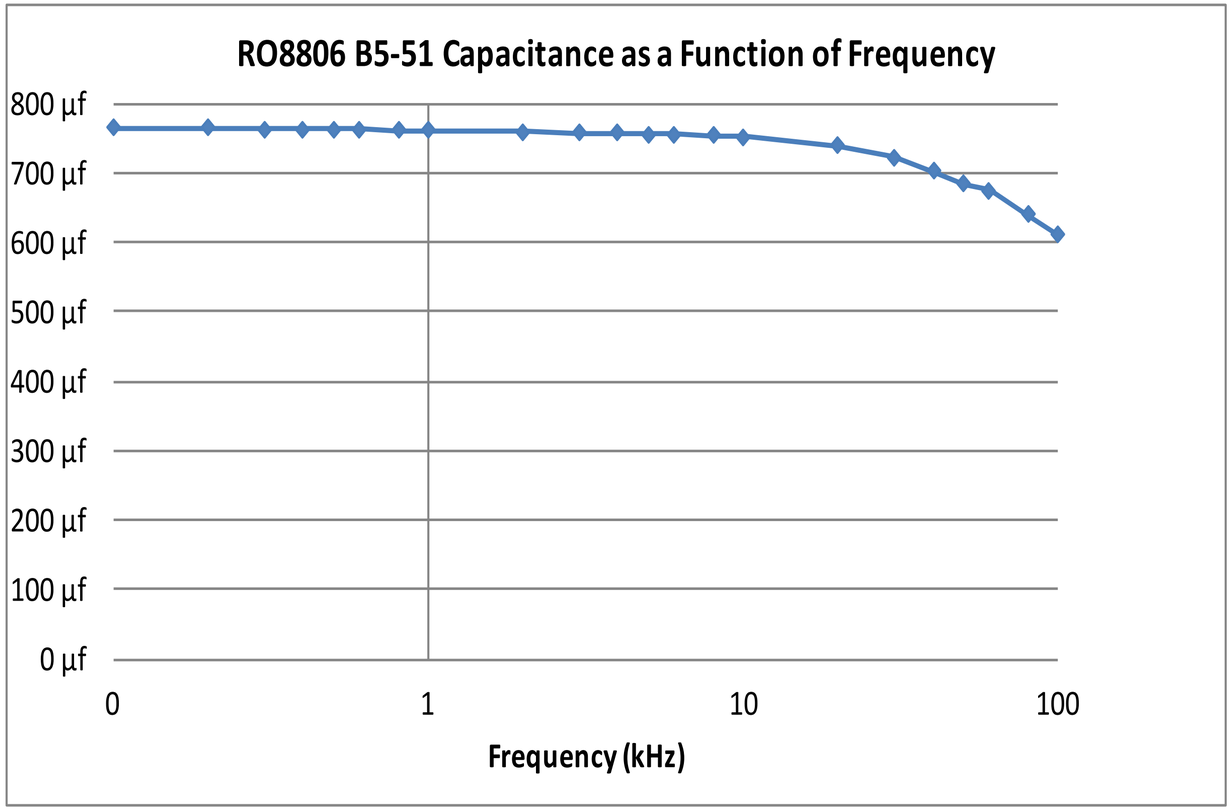
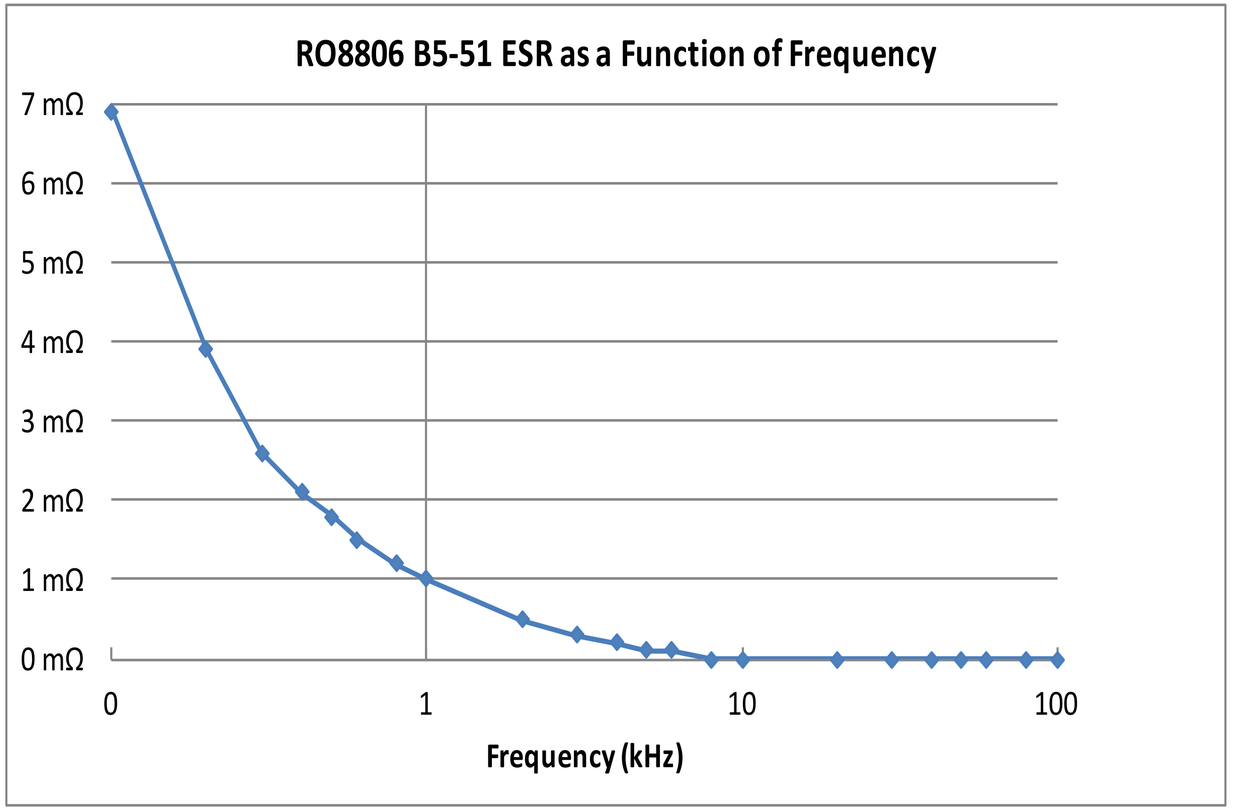
Capacitance and ESR as a Function of Frequency 770µF/600Vmax





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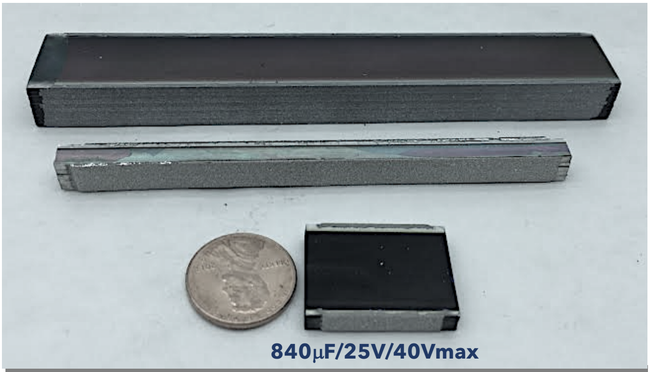
Voltage Ratings

Higher Voltage VaporFilm Capacitors to Replace Metallized PP Capacitors

- Most of the development has focused on 700μF/400/600$_{max}$ Capacitors
- VaporFilm capacitors ratings up to 1,200V are under development

Lower Voltage VaporFilm Capacitors to Replace Aluminum Electrolytics

- Electric steering, Start and Stop Systems (compressor, water pump), Electric turbos
- At 25V and 48V, VaporFilm Capacitor have even a bigger advantage
  - ✓ Unlike PP films that have a thickness limit of 2.0μm-2.5μm, VaporFilm dielectrics have a thickness limit of 0.1μm which can address low voltage applications
  - ✓ Electrolytic capacitors have high Equivalent Series Resistance (ESR) and more capacitors are used in a parallel configuration, to reduce the ESR, which reduces dissipation and improves the life and reliability of the inverter
  - ✓ The 840μF/25V/40V$_{max}$ VaporFilmresonates at 300KHz and has an ESR of 0.8mohm, which cannot be matched by any eletrolytic capacitor even at 5X the capacitance



Low voltage VaporFilm capacitor to replace electrolytics in high frequency switching circuits, 18,000 Layers 0.2um thick

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