EnerHarv 2024

PSMA International Workshop | 26-28 June, 2024 | Perugia, Italy

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EnerHarv 2024 Workshop:

Reflowable Supercapacitors for Energy Harvesting and IoT Applications

Presented By –

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FastCap Ultracapacitors Story

Key Investors

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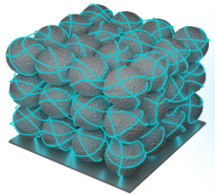
Overview

- Founded by MIT graduates in 2009 following a DOE ARPA-E award
- Developed and commercialized the world's first harsh environment supercapacitors in Oil & Gas drilling
- Established rapid commercialization business model, expanded product lines
- Repeated successes in product licenses and business line exits
- Transferred core innovations to Lithium-ion Batteries in 2019
- Spin off FastCap Ultracapacitors in 2024

Technology

- Neocarbonix® at the Core 3D nanocarbon electrode
- Advanced electrolytes especially designed for harsh environments
- Unique ultracapacitor designs

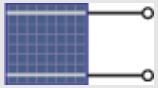


Business Model & Commercialization

- Capital light, IP licensing business model
- Focus: Rapid commercialization
- Over 140+ granted and pending patents worldwide

Why FastCap Ultracapacitors?

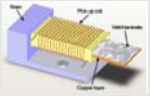
Energy Harvester



Photovoltaic Cell
10uW – 10mW /cm²

Thermoelectric Module
10uW – 10mW /cm²

RF Harvesting
10uW – 10mW /cm²



Vibration Energy Harvesting
10uW – 10mW /cm²

Power Management

Input Regulator Charge

Devices / Sensors

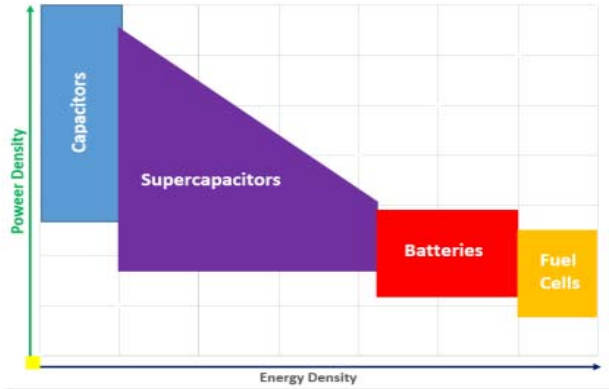
Radio Module

Sensors

FastCap
Chip Ultracapacitor

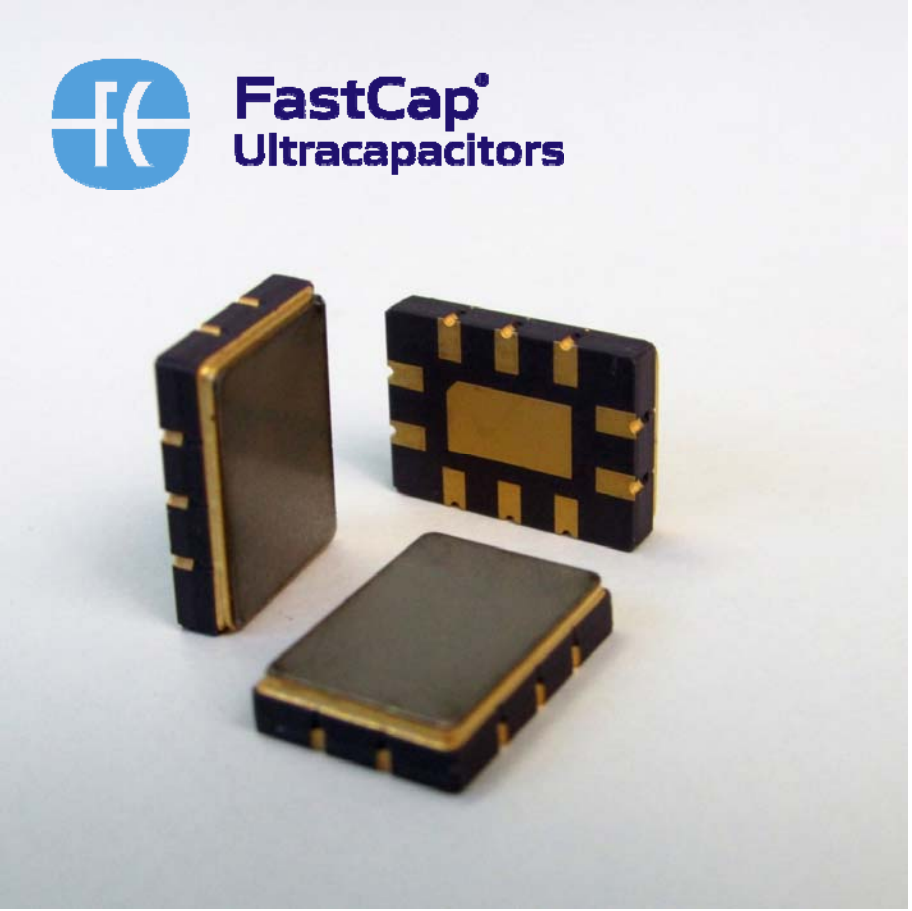
- Improves customer market fit - eliminates need for battery and/or increases battery run time in the field vs battery alone
- Higher power transmissions due to higher pulse current
- Expand applications with higher performance and extended temperatures

Why FastCap Ultracapacitors?



- Capture small amounts of energy effectively – charge/discharge quickly
- Energy available for weeks
- Easy to incorporate in the manufacturing operation
- Operate from -55 °C to +150 °C
- Reduce size – better energy density than tantalum or electrolytic capacitors
- Safer than batteries and tantalum capacitors
- Increases the number of applications/markets for EH

FastCap Ultracapacitors



REFLOWABLE SMD ULTRACAPACITOR

PROBLEM:
Ultracapacitors are needed as energy storage in high volume electronics

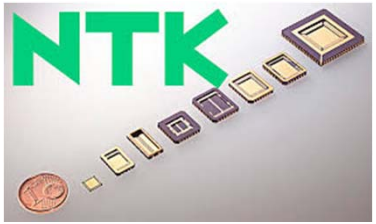
UNTIL NOW:
No practical ultracapacitor could survive the high-volume electronics manufacturing process

SOLUTION:
Nanoramic's Nanocomposite Electrode and advanced electrolytes enable the SMD Chip Ultracapacitor

APPLICATIONS:
- IoT and Smart Meter Devices
- Solid-State Drive (SSD)
- Non-volatile (NV) Memory
- Mobile devices

Key Innovations

Enabling components and processes are all required for the success of the Chip Ultracapacitor



High and Low Temperature Electrolytes
Low ESR, highly stable, no pressure, ideal for hermetic

PVDF-free Composite Electrode
High power and high temperature. No melting of binder during reflow. Long lifetime.

Ceramic package
Inert and compatible with our electrolyte, hermetically sealed, leadless and low profile.

World's First Reflowable EDLC with no compromises

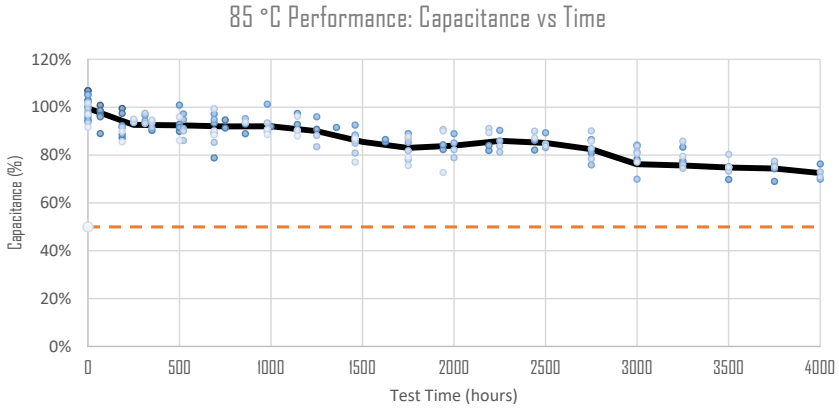
FastCap Solution: Reflowable Ultracapacitor

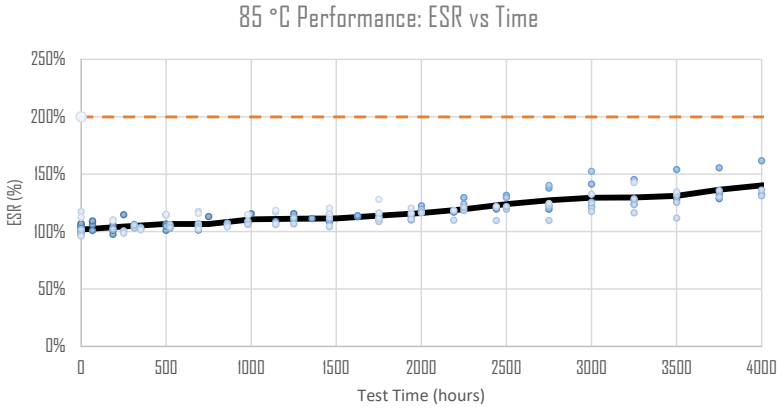
- Wide Temperature Range -40 °C to +85 °C
- Reflowable
- Low ESR
- Long lifetime
- Surface mount design
- Pick-and-place compatible
- RoHS compliant
- Pb-free reflow compliant
- Greater flexibility for energy harvesting designs

World's First low ESR
Reflowable Ultracapacitor

Long Lifetime

SERVICE LIFE 85 °C, 2.1V





- More than 4000 hours at 85 °C, 2.1V
- Capacitance reduction less than 30% after 4000 hours
- ESR degradation less than 40% after 4000 hours

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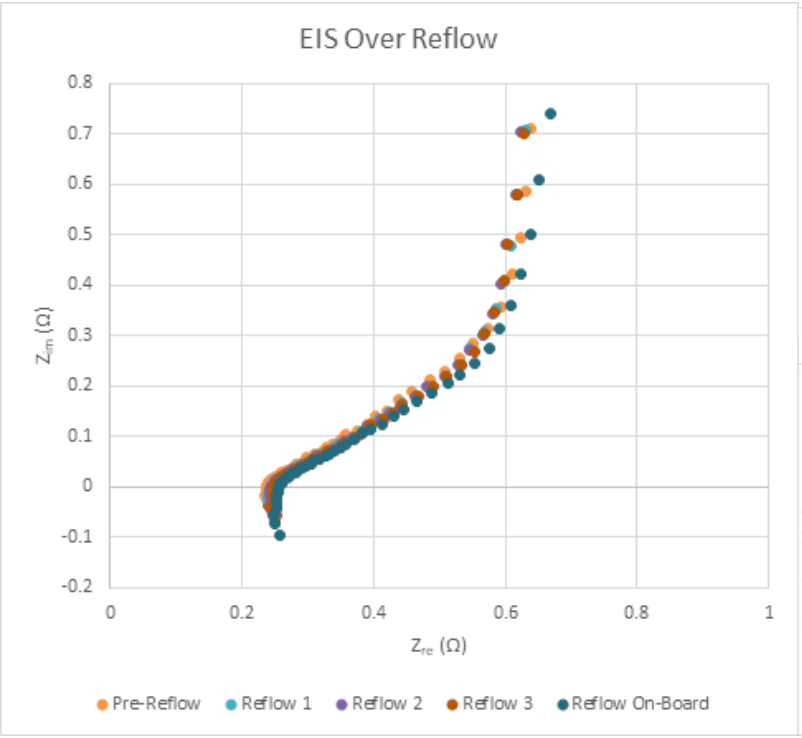
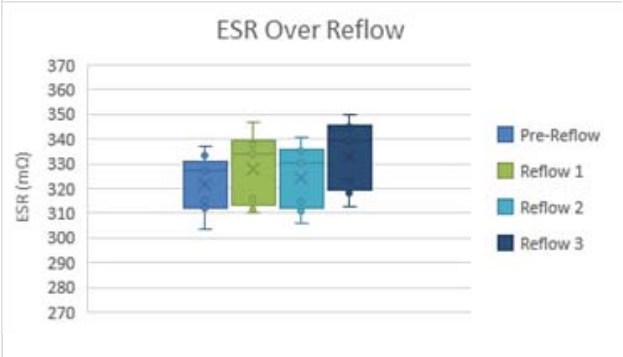
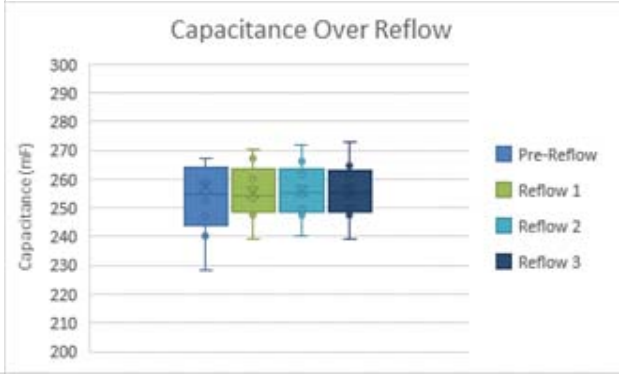
A Nanoramic® Labs Technology

Chip Ultracap Reflow Performance

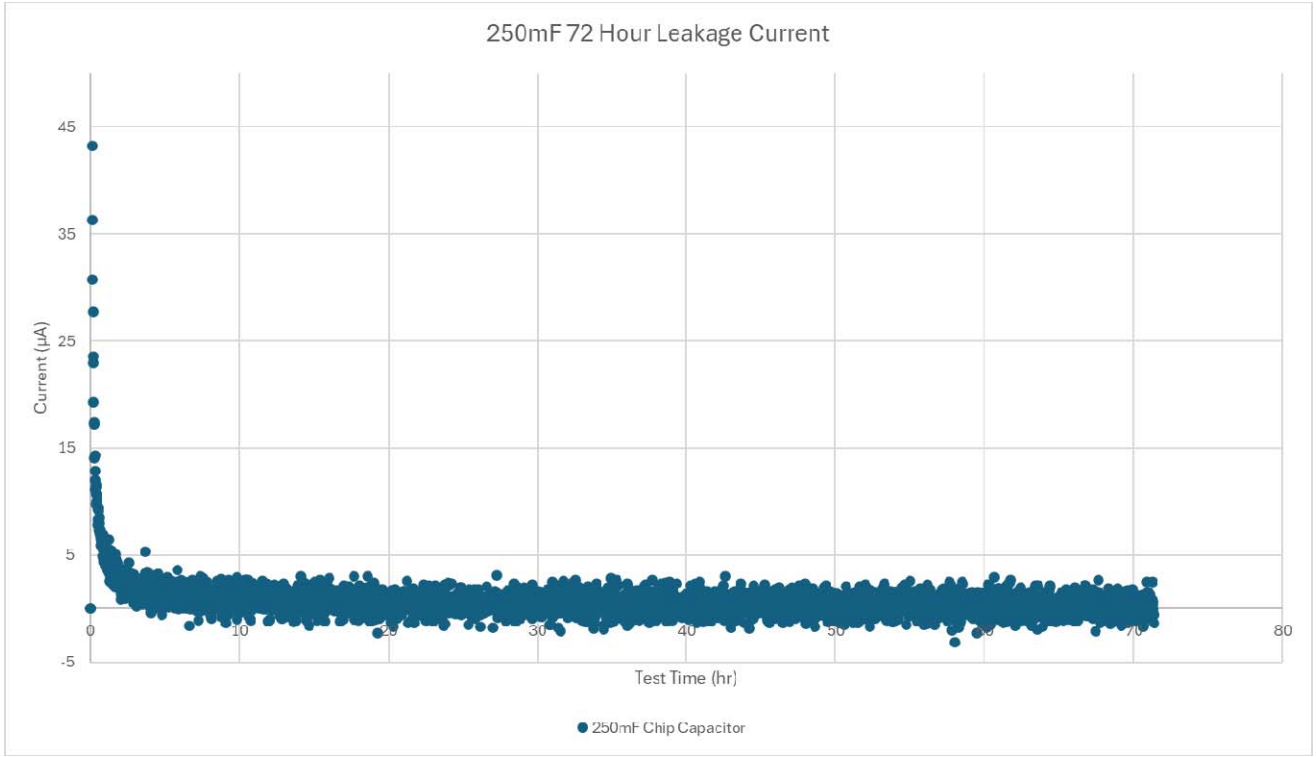






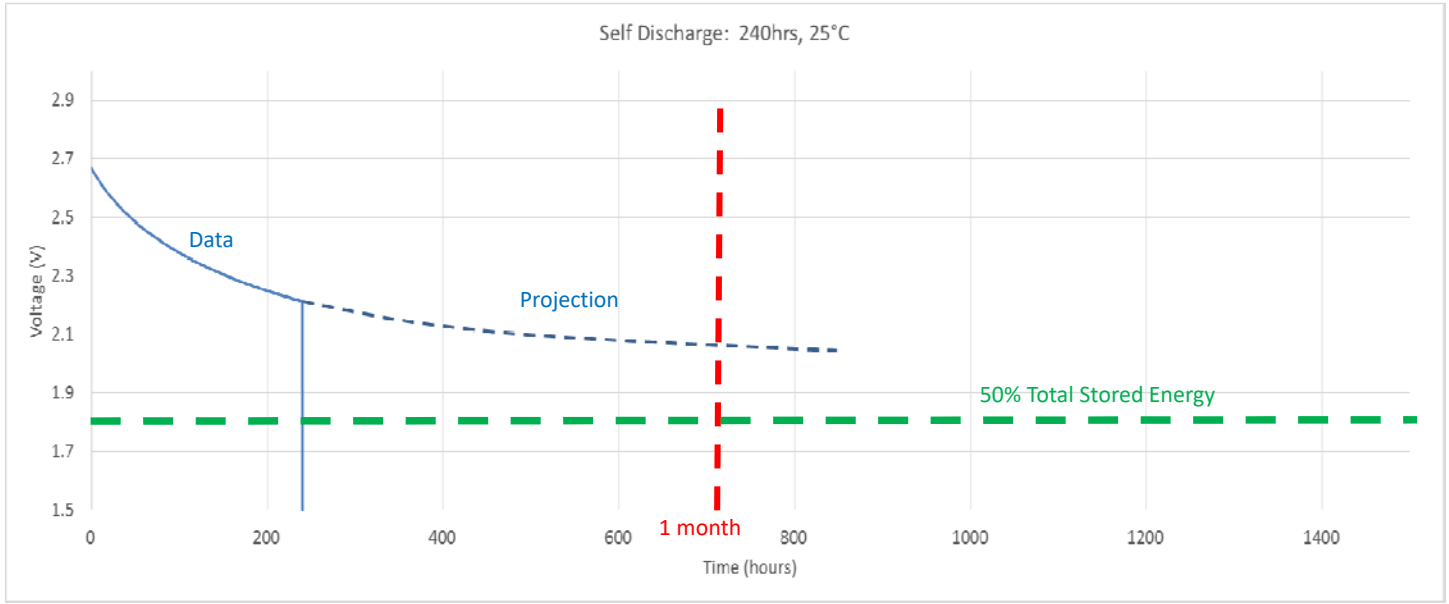
- Stable impedance over a wide frequency range
- Reflowable at 260° - Pb-Free reflow compliant
- No change in electrical performance after 4 reflow cycles

Chip Ultracap Leakage Current



Ultra Low Leakage Prototype

ULTRACAP RETAINS MORE THAN 50% CAPACITANCE AFTER 30 DAYS



TYPICAL APPLICATION IN IOT INDUSTRIAL SENSORS

Primary Battery Support

-or-

Energy Harvester Storage

Boost Converter → 2.8 V → Accelerometer, Low Power MCU

Buck Converter → 1.8 V → Bluetooth Module, Biometric Sensors

Boost Converter → 3.0 V → GPS, Pressure Sensor

Chip Supercapacitor

- Extends temperature range
- Increases battery life
- Low leakage current
- Surface mountable

- Improves customer market fit (smaller, slimmer, wider temperature range)
- Increases time in the field (vs. battery)
- Reduces customers cost to manufacture (10x reduction in assembly time)

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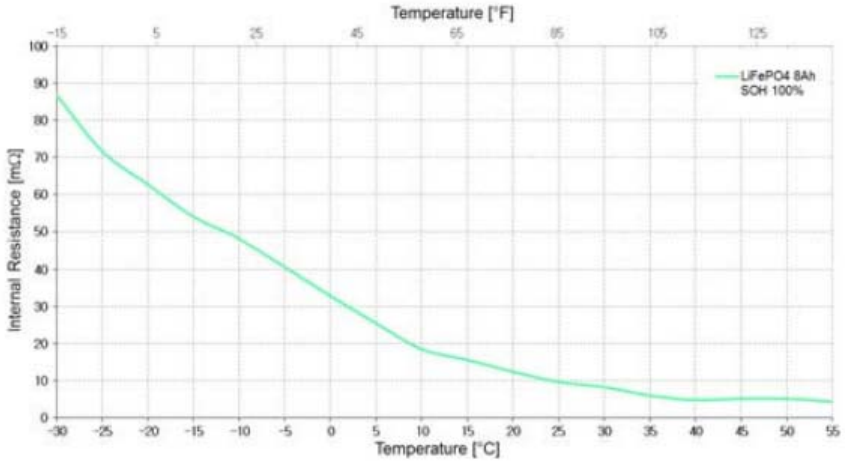
Industrial Sensor Comparison

Industrial Sensor Application Needs	Chip Ultracapacitor	Alternative Ultracapacitor
Industrial and Condition monitoring sensors • High vibration → 40 g peak • Intense temperature cycling • High pressure encapsulation process	✔ **Compact, ruggedized construction** Reflowable, Capable of withstanding high levels of shock/vibration, temp cycling, high pressure encapsulation	X **Not rated for harsh environments** • Short lifetime, swelling/leaks • Not reflowable
-55°C to + 150°C operating temperature • Must deliver peak currents at low temps	**Wide operating temperature range**	X **Narrow operating temp range**
5 – 10 year device lifetime	✔ **High stability over DC life** Better cycle life at even at elevated temperatures (Neocarbonix PVDF-free electrode)	X **Faster degradation at elevated temperatures**
	✔	

FastCap® Chip Ultracapacitor can improve customer reliability and functionality

Poor Battery Performance at Low Temp

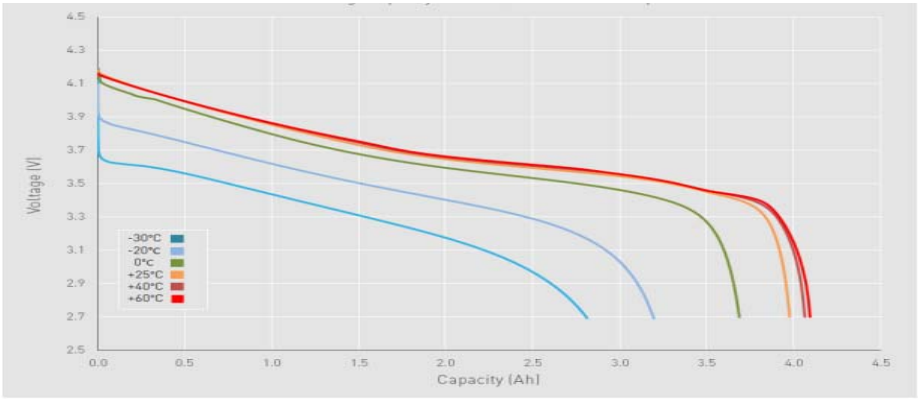
Battery Resistance with Temperature



Lithium ion FePO4 8 Ah battery

More than 8x increase at -30/C

Battery Capacity with Temperatures

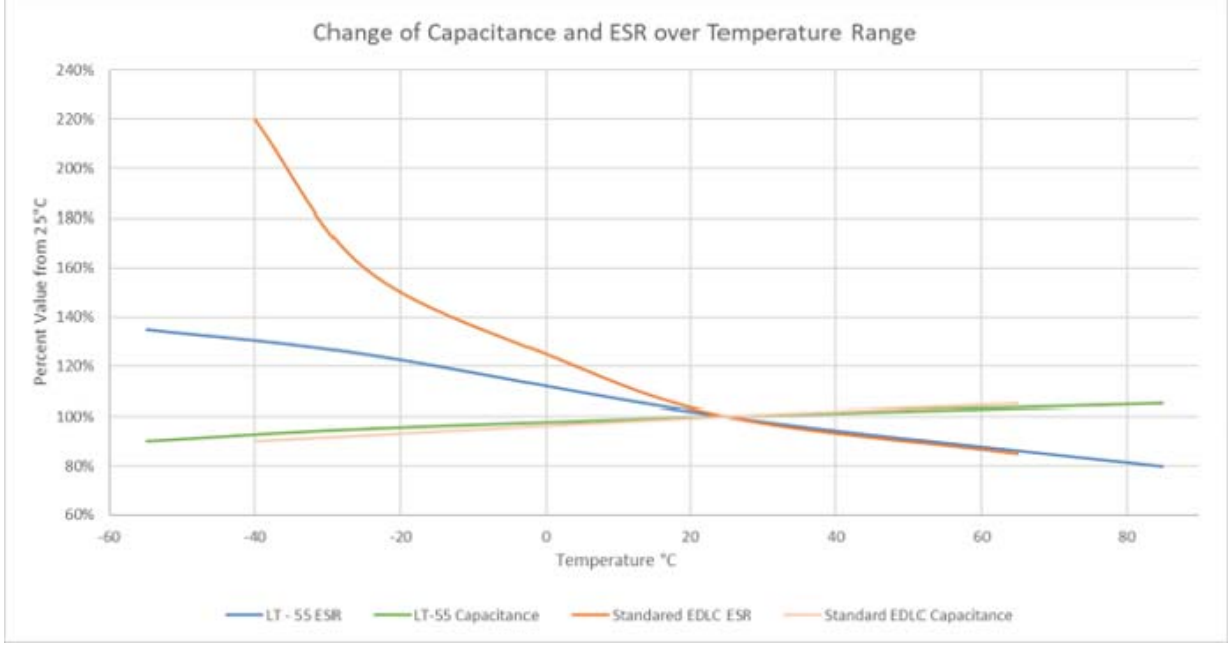


Lithium ion NMC 4.0 Ah battery

More than 30% capacity loss at -30C

FastCap Low Temp Performance

Nanoramic LT55-35 AA Ultracapacitor Comparison



Capacitance reduction of less than 20% at -55C

ESR increase of less than 40% at -55C

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Low Temperature Ultracapacitor Technology

- **Allow sensors & transmitters to work at -55 °C and below**
- **Tested and verified by a major aerospace company**
- **Extreme durability - Meets MIL202G in the AA size**
- **Enables use of EH in winter/artic conditions, high altitude, cold chain**

FastCap High Temperature Technology

- **Allow sensors & transmitters to work at +150 °C and above**
- **Rechargeable prototypes up to +300 °C**
- **Extremely safe - no explosion or fire hazard**
- **Ruggedized for high shock and vibration**
- **Product in use by Halliburton for downhole drilling**
- **Enables use of EH in extreme summer conditions, high temp industrial applications**

Product Offerings

Product Code	Capacitance (F)	Voltage (V)	ESR (mΩ)	Max Temp (˚C)	Format
EE100-350	370	2	8	100	D Cell
EE125-350	350	1.5	8	125	D Cell
EE150-350	345	1.0	8	150	D Cell
EE100-35	38	2	18	100	AA Cell
EE125-35	35	1.5	20	125	AA Cell
EE150-35	33	1	22	150	AA Cell

D Cell

AA Cell

Endurance of Nanoramic Ultracapacitors

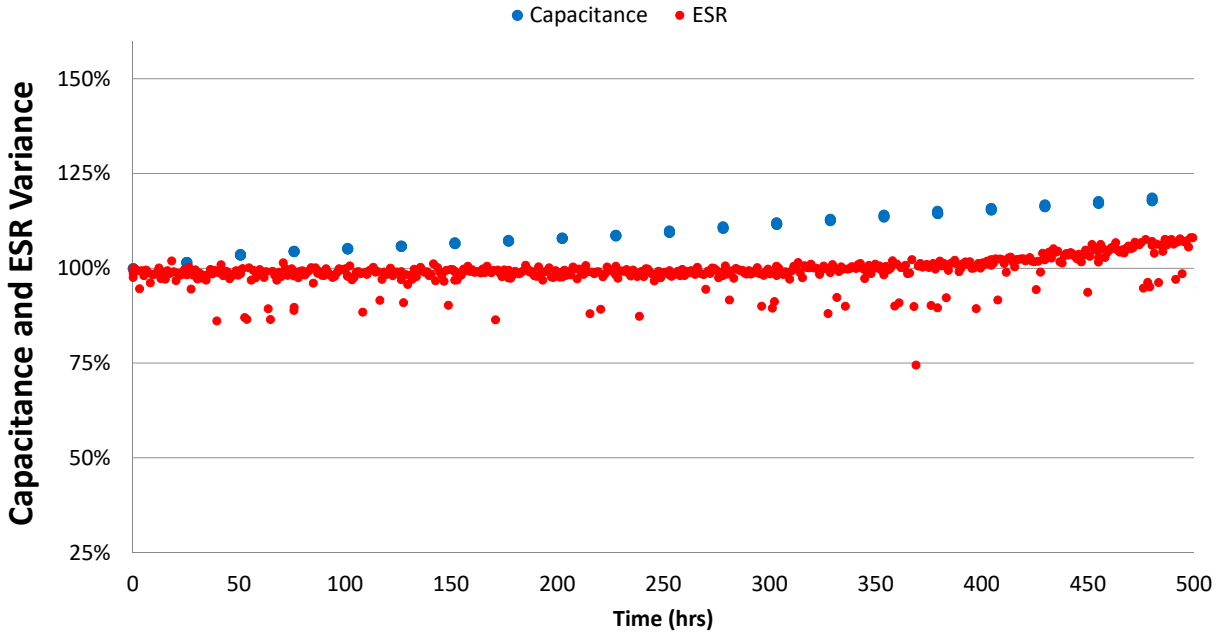
- Lifetime at rated voltage and temperature of 1500 hours
- Cycle life at 25°C >1,000,000 cycles
- Lifetime at 25 °C > 15,000 hours
- Shock and vibration 500Gpeak & 20Grms

FastCap High Temp Performance

Sandia National Lab Validation:

250 °C Ultracapacitor Performance

Minimal Degradation after 500 hours at 250 °C



Conclusions

- **EH applications can enjoy extended battery life, or in some cases replace batteries in IoT applications, by using Ultracaps**
- **Small, mass manufacturable, energy harvesting devices can be improved with chip ultracapacitors**
- **Surface mount design and reflow soldering allow unlock design flexibility**
- **EH temperature ranges can be expanded dramatically with operations down to -55 °C and up to +150 °C**
- **Improved “burst current” for transmitting data**

Q & A

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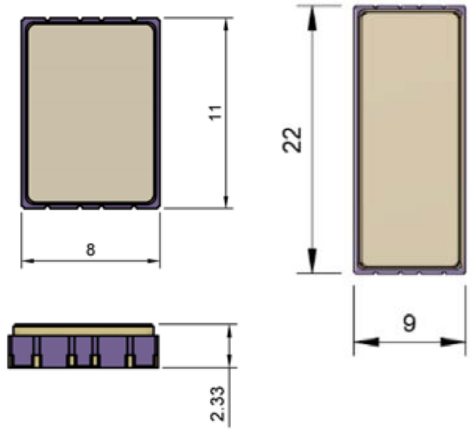
Thanks very much for your time and attention!

Questions/comments???

Appendix

Nanoramic Chip Capacitor Specifications

Model	Parameter	Description	Min	Typ	Max	Units
SD85-500	Rated Capacitance	25°C	200	210		mF
	Operating Voltage			2.1		V
	Surge Voltage			2.5		V
	ESR	25°C		280	300	mΩ
	Leakage Current @ rated voltage	96hrs. @70°C		<5		µA
	Operating Temperature		-40		85	°C
	Storage Temperature		-45		135	°C



Dimensions are in mm

High Temperature Battery Technology

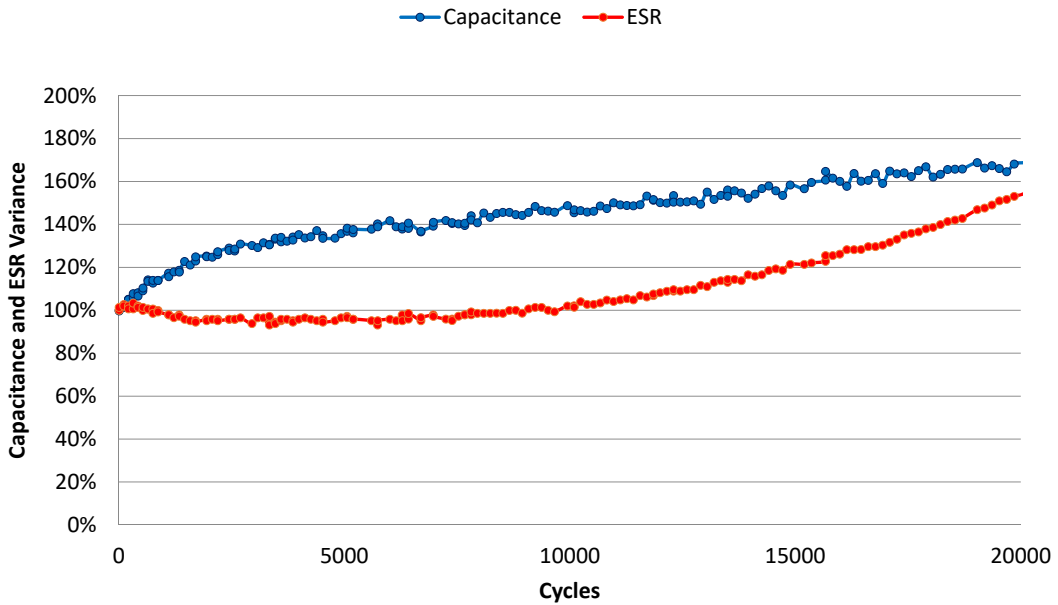
- **Non rechargeable batteries can work up to +180C**
- **Rechargeable batteries can work up to +125C**
- **These high temperatures degrade battery performance**
- **Batteries usually require extra safety measures**
- **Rechargeable cycle life limited at high temps**

FastCap High Temp Performance

In-House Prototype: Extended Test

300°C Ultracapacitor Performance

Minimal degradation after 20,000 charge discharge cycles



FastCap High Temperature Technology

ESR Increase and Capacitance Decrease over 1500 hours at 150 C