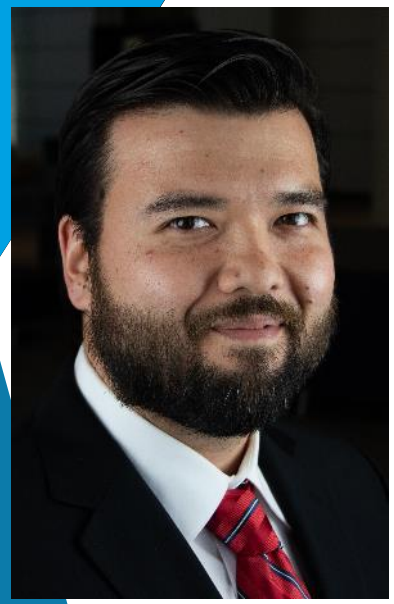
Board Level Bulk Capacitor Characteristics, Reliability, Applications & Trends

Daniel West
Field Application Engineer
daniel.west@kyocera-avx.com

KYOCERA AVX

PSMA/PELS Capacitor Workshop 2022

Biography



Daniel West is a Field Application Engineer in the Technical Sales Group at Kyocera-AVX. After two years of supporting the connector division, he transferred to the Technical Sales Group, where he's been a team member for over four years. In this role, he is responsible for engineering support across N.A. on all Kyocera-AVX products. He regularly conducts training at end customer sites, internal technology trainings, and has published numerous articles from energy storage capacitor selection to passive components for WBG applications.

Previously, Daniel served in the U.S. Army 82nd Airborne Division where he was a team leader and combat veteran. He received a BSEE from Mercer University and currently resides in Greenville SC with his wife and two children and is an amateur radio operator. He can be reached at daniel.west@kyocera-avx.com.

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Outline

- Comparison of Internal Designs and Performance
  - High CV Ceramics
  - Tantalum (MnO_2 & Polymer)
  - Aluminum Electrolytics (Wet, Polymer & Hybrid)
  - Supercapacitors
- Comparison of Capacitor Technologies
  - Reliability
  - Applications
  - Trends

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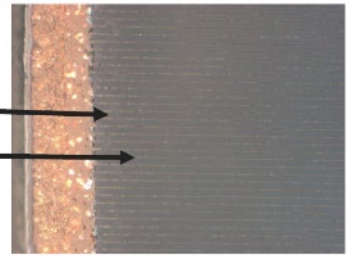
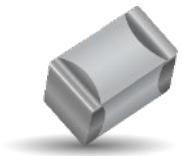
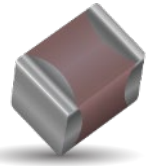
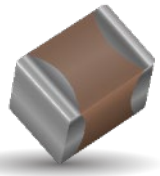
01005 CASE SIZE MLCC
High CV Ceramics

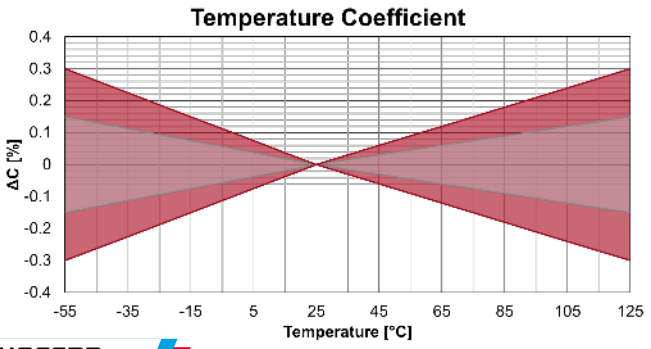
- EIA Case Size: 0.4mm x 0.2mm Footprint
- Capacitance Range: 0.2pF to 0.47µF
- Voltage Range: 6.3V_{DC} to 25V_{DC}
- Operating Temperature Range: -55°C to +85°C; -55°C to +125°C

- Various Shapes/Forms
- Fixed Value
- Ceramic Dielectric
- Metal Electrode

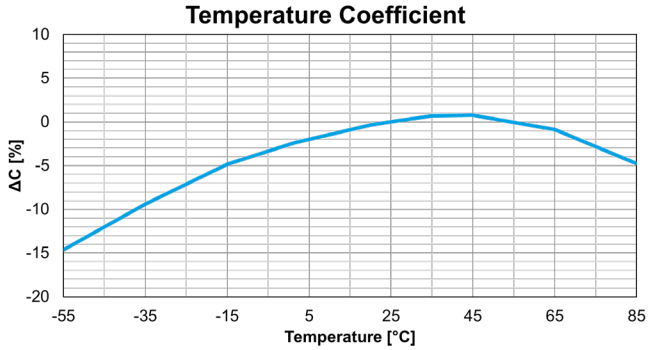


	NP0/C0G		X5R	X7R
	CU Series	CM Series	CM Series	CM Series
	Class I	Class I	Class II	Class II
				
Temperature	-55°C to +125°C	-55°C to +125°C	-55°C to +85°C	-55°C to +125°C
Voltage Rating	16V & 25V	16V & 25V	6.3V, 10V & 16V	16V
Capacitance	0.2 - 22pF	1 - 220pF	0.1 - 470nF	2.2nF
Tolerance	± 0.1pF ± 0.25pF ± 5%	± 0.1pF ± 0.25pF ± 5%	± 10% ± 20%	± 10% ± 20%

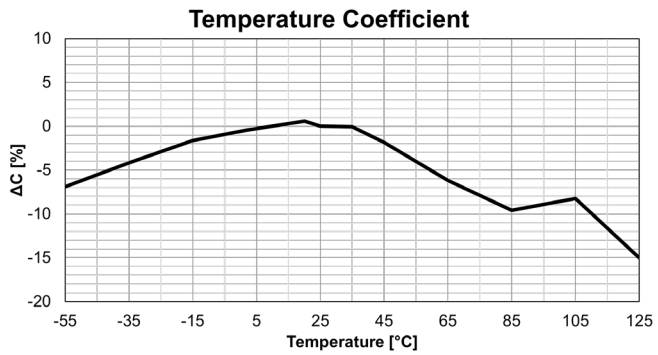
C0G/NP0



X5R



X7R



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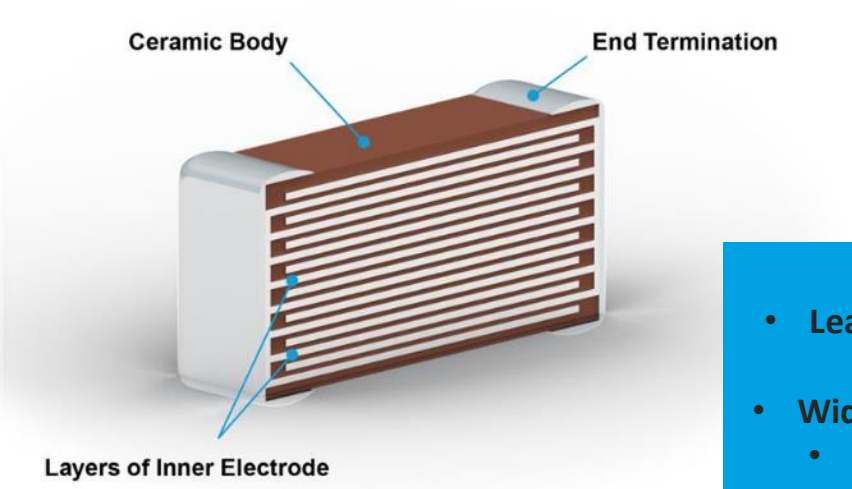
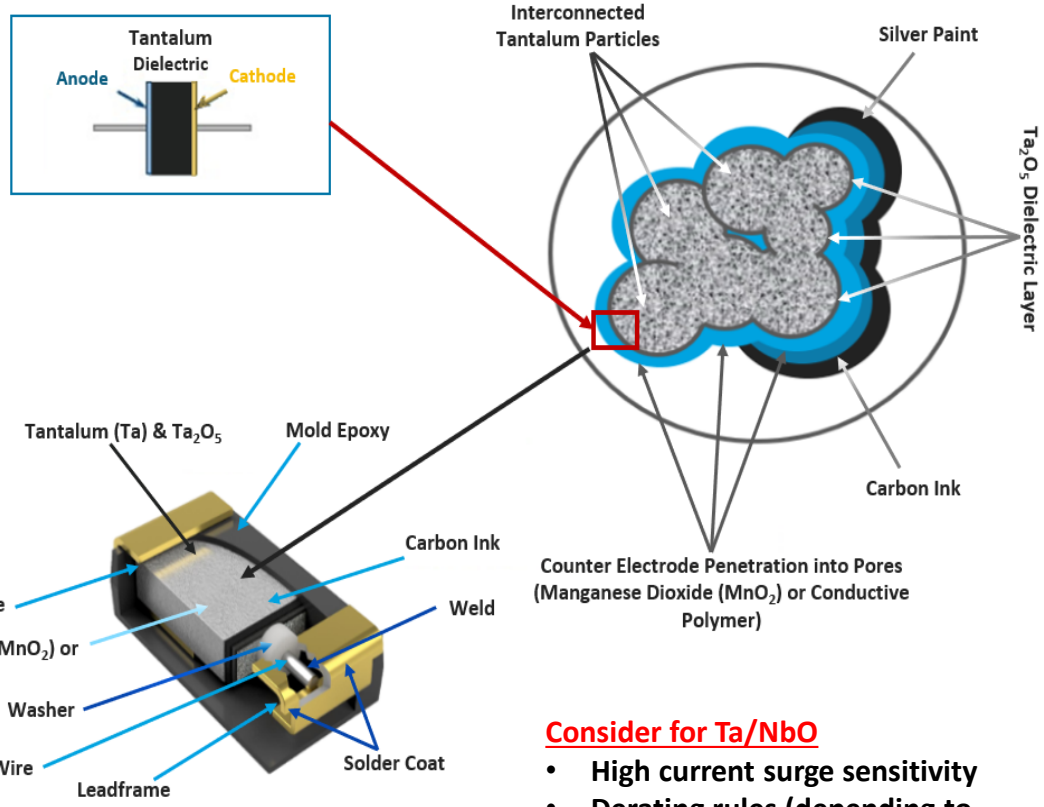
High CV MLCC vs Tantalum: Construction & Key Features



Common Strong Points

- Lead-free design and reflow compatibility
- ROHS friendly standard design
- Wide temp. range (-55/+125°C basic range)
- Relatively very good basic reliability
- High capacitance in small dimensions



MLCC Class II Advantages

- Low ESR
- High ripple load
- Non-polarized
- Low DCL

Consider for MLCC Class II

- Capacitance dependency to AC/DC voltage and temp
- Piezo noise
- Mechanical robustness

Tantalum/NbO Advantages

- No piezo noise
- Stable capacitance with voltage BIAS and temperature
- High mechanical strength and vibration resistance

Consider for Ta/NbO

- High current surge sensitivity
- Derating rules (depending to technology and application different rules may apply)
- Conflict-free tantalum source (addressed by leading mfgs)

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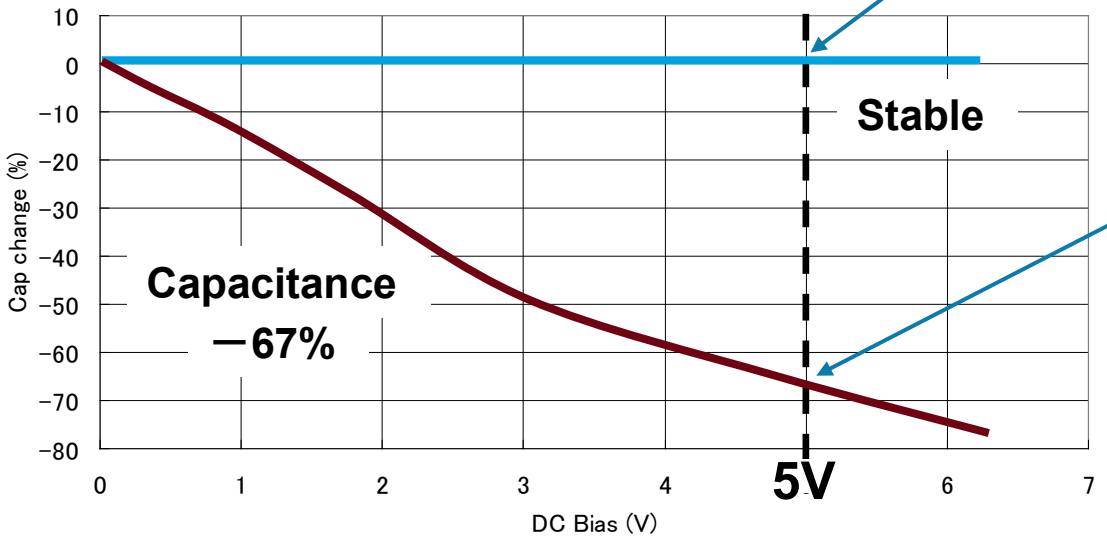
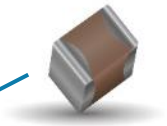
DC Bias – Capacitance Change

Tantalum: 100uF, 6.3V, 1206
MLCC: 100uF, 6.3V, 1206

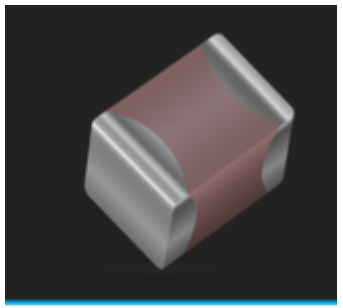
100uF Tantalum
Available cap @
voltage = 100uF





100uF MLCC
Available cap @
voltage = 33uF

Quick ESL Comparison



MLCC

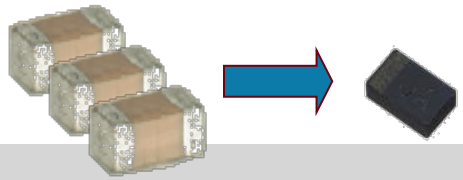
EIA SIZE	ESL(pH)
1206	1000
0805	525
0603	450
0402	300
0201	120

Molded Ta/Poly

Case Size	Typical Self-Inductance value (nH)
K	1.0
L	1.0
M	1.3
N	1.3
O	1.0
S	1.0
T	1.0
X	1.8
3	2.0
4	2.2
6	2.5

*Facedown Terminations

Potential of replacing several MLCCs with one Ta/Polymer cap.



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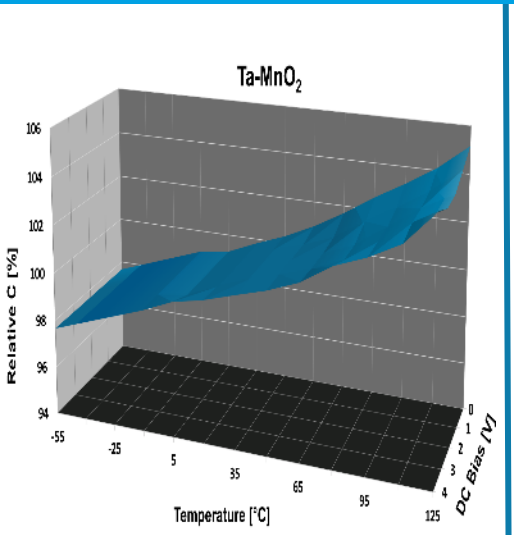
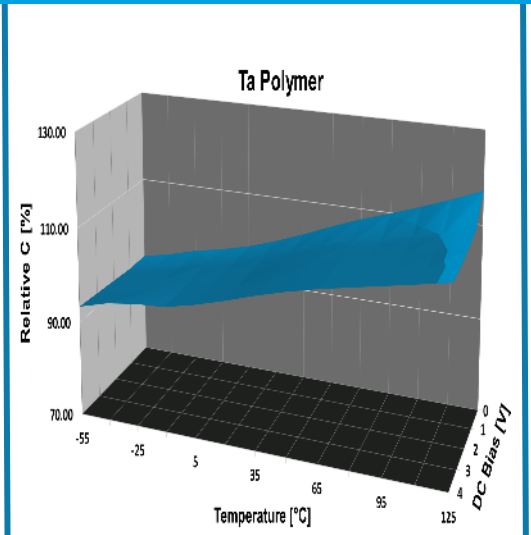
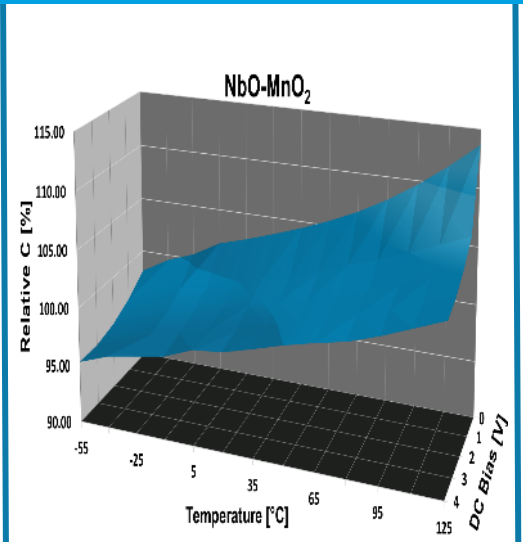
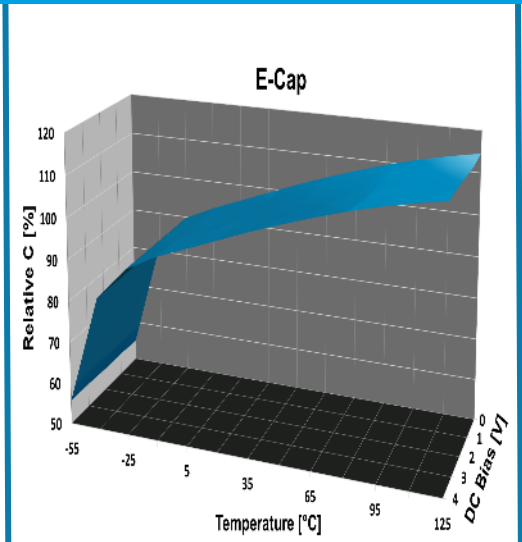
CAPACITOR STABILITY |

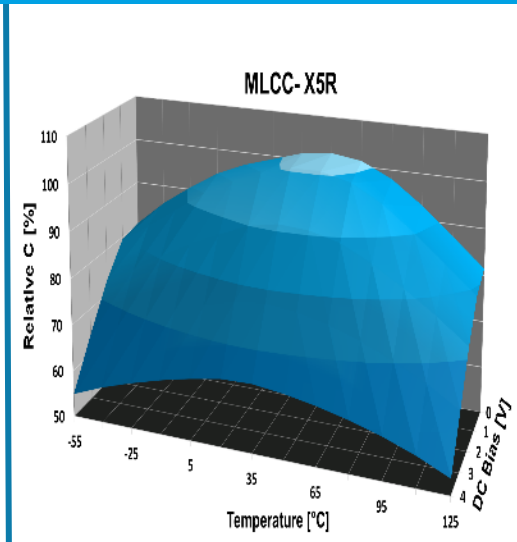
TEMPERATURE AND DC BIAS

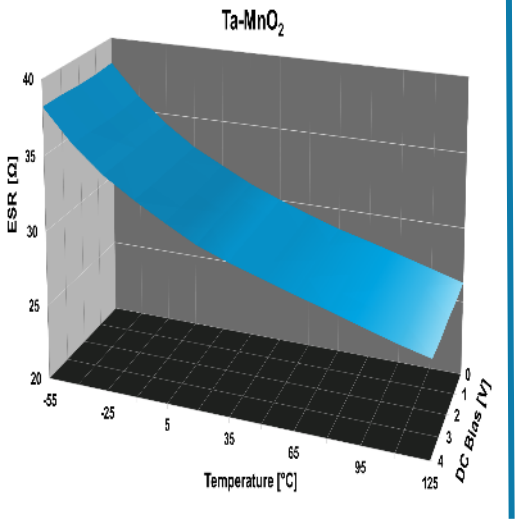


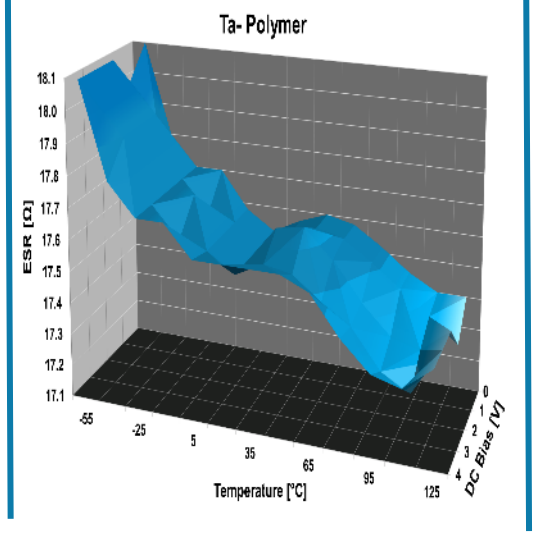


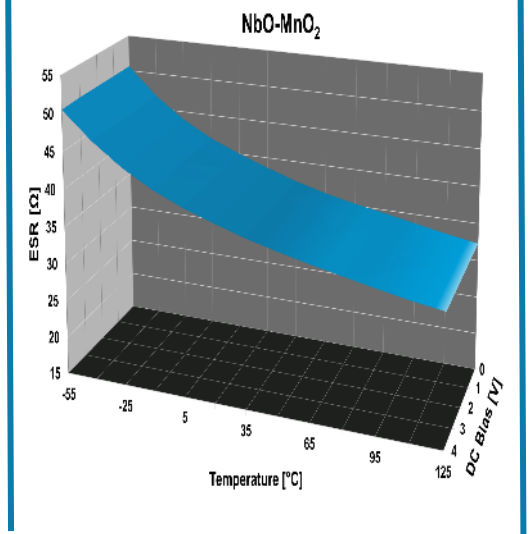


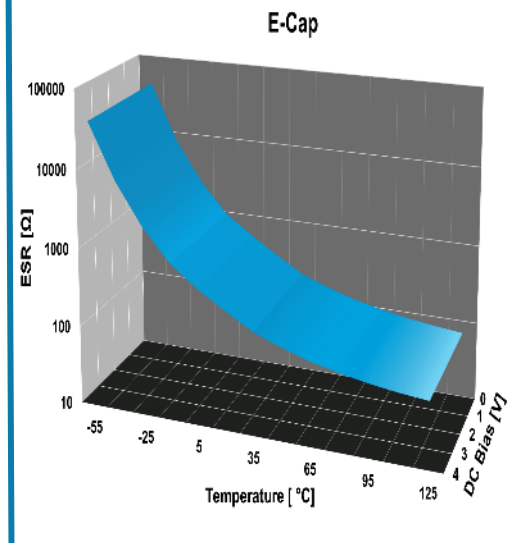


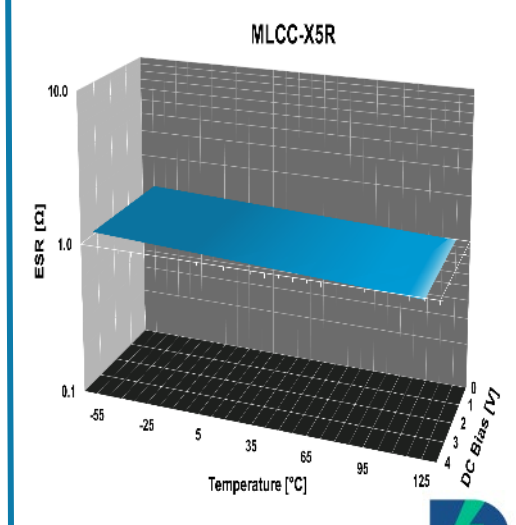












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General Bulk Cap Spec Comparison – 1210 Equivalent

	MLCC		Standard Ta Chip		Polymer Ta Chip		NbO Chip OxiCap®	
Attributes	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**
Max Capacitance 1210	100uF	10uF	150uF	100uF	220uF	47uF	47uF	47uF
Voltage Range 1210	4v - 50v	16v - 100v	4v - 50v	4v - 50v	4v - 50v	4v - 50v	4v - 10v	4v - 10v
Typical ESR 1210	2 - 15mOhms	10 - 40mOhms	300 - 800mOhms	300 - 800mOhms	30 - 200mOhms	70 - 250mOhms	300 - 600mOhms	300 - 600mOhms
Temperature Range	-55°C - +85°C	-55°C - +125 / +150°C	-55°C - +125°C	-55°C - +125 / +200°C	-55°C - +105 / +125°C	-55°C - +125°C	-55°C - +105°C	-55°C - +125°C
Base Reliability	1% / 1000hrs	1% / 1000hrs	1% / 1000hrs	(0.05 - 1%) / 1000hrs	1% / 1000hrs	1% / 1000hrs	0.02 - 0.05% / 1000hrs	0.02 - 0.05% / 1000hrs
Primary Failure Mode	Short	Short	Short	Short	Short	Short	Resistive	Resistive
Lifetime (10% Cap loss @ Tmax / Vmax)	Indefinite	Indefinite	Indefinite	Indefinite	10,000hrs	10,000hrs	Indefinite	Indefinite
Recommended Voltage Derating	20%	20%	50%	50%	20%	20%	20%	20%
Disadvantages	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**
Voltage Coefficient	Cap Loss vs V	Cap Loss vs V						
Piezo Noise	@ Audio Frequencies	@ Audio Frequencies						
Reverse Voltage			Not Allowed	Not Allowed	Not Allowed	Not Allowed	Not Allowed	Not Allowed

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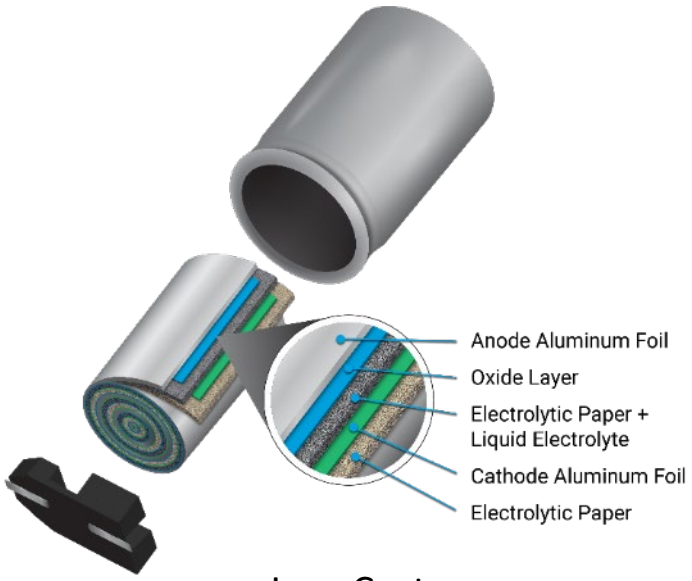
SMT ALUMINUM ELECTROLYTIC

Construction & Type

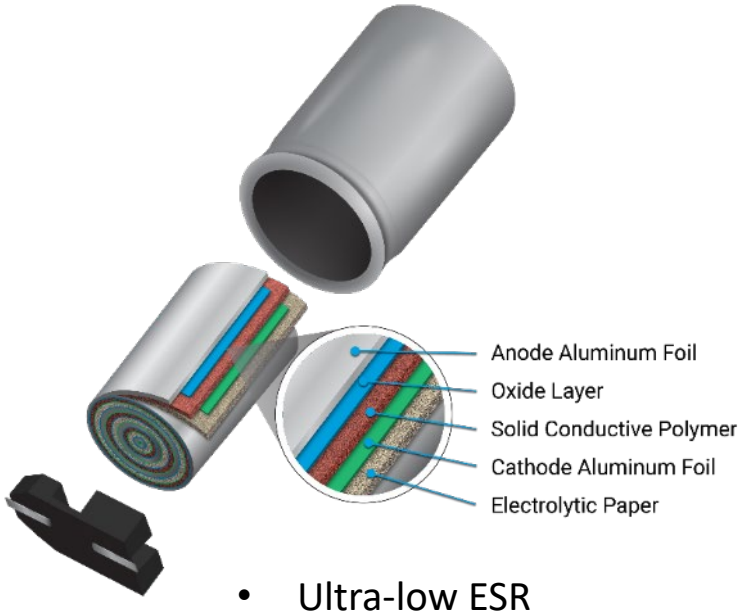
Electrolyte System Controls Device Characteristics

Wet Electrolytic



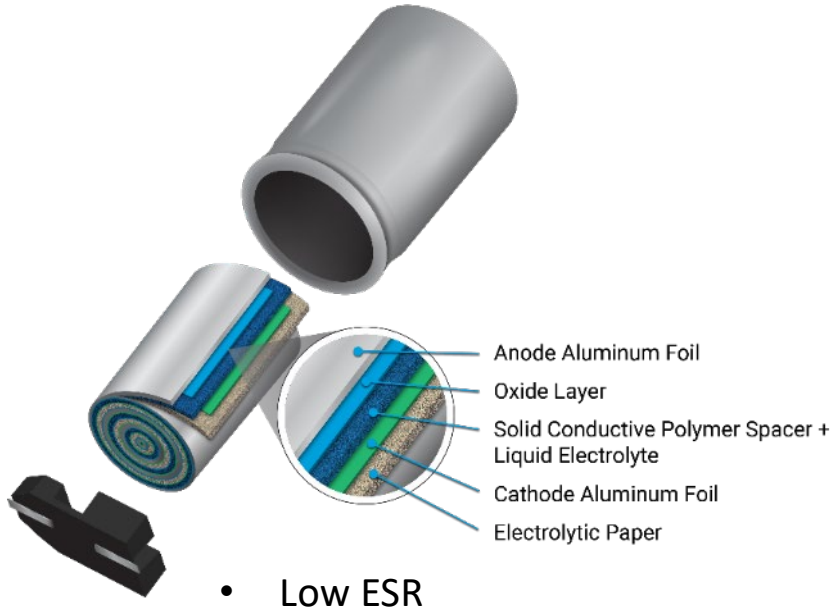
- Low Cost
- Low DCL
- Broad Value Range
- Reliability
- ESR

Polymer Electrolytic



- Ultra-low ESR
- Higher Ripple
- Enhanced Life
- Higher DCL
- Higher Cost

Hybrid Electrolytic



- Low ESR
- Low DCL
- Higher Reliability
- Range Limits
- Higher Cost

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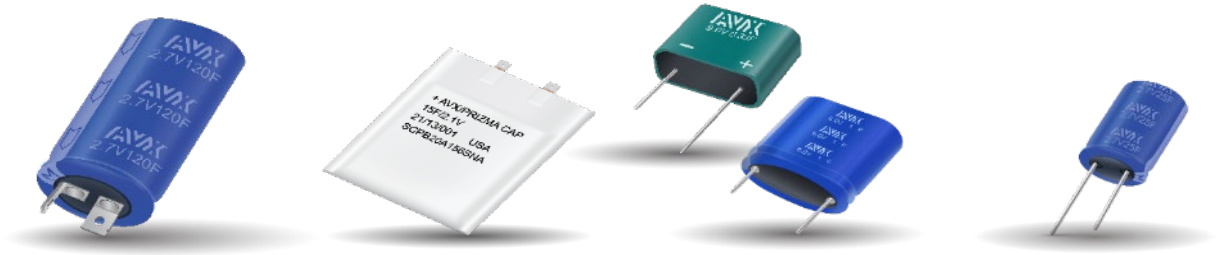
SUPERCAPACITORS

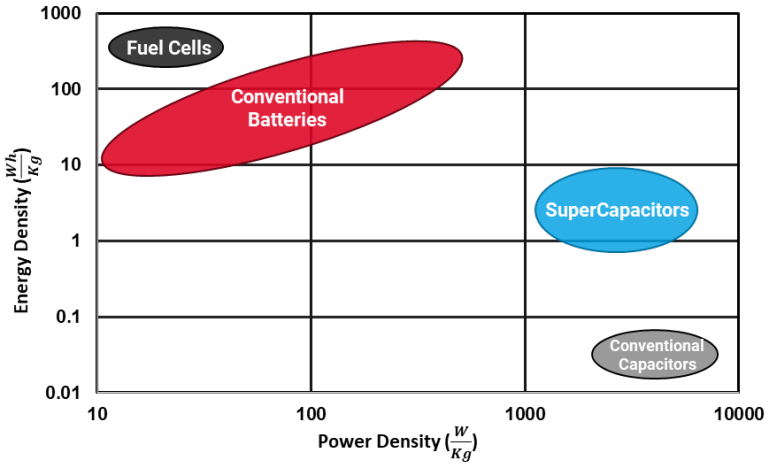


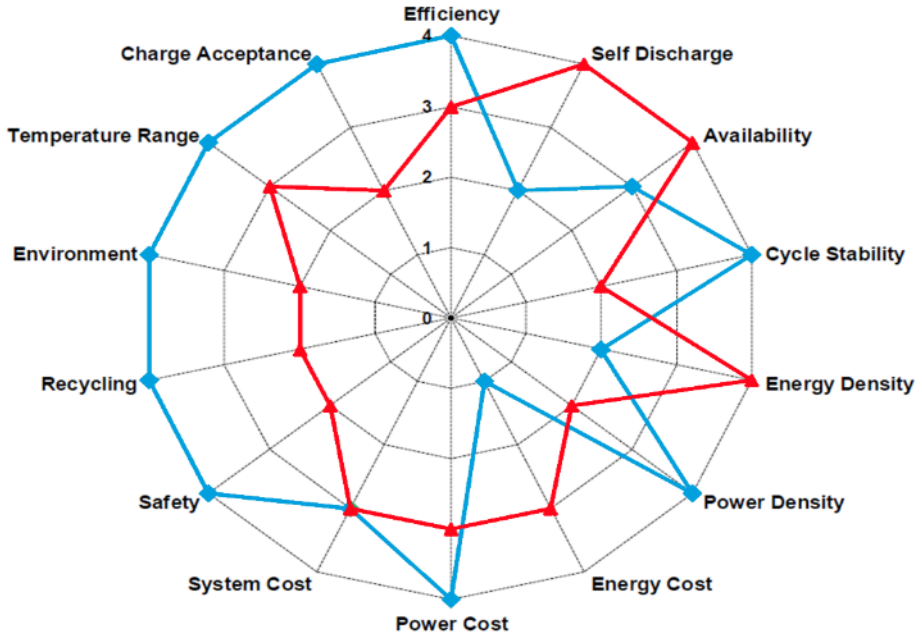
BATTERIES

Operate on a chemical reaction which means they are "slow energy storage"

SUPERCAPACITORS

Store Energy in an electric field and are known as "fast energy storage"





Parameter/Characteristic	Supercapacitor	Li-Ion Battery
Charge Time	1To 10 Seconds	10 To 60 Minutes
Charge Cycle Life	1 Million	>500
Cell Voltage	2.1 To 3.3 Volts	3.6 To 4.2 Volts
Specific Energy (Wh/Kg)	5	100 To 200
Specific Power (W/Kg)	~10,000	1000 To 3000
Temperature Range $_{Charge}$	55°C To +90°C	0°C To +45°C
Temperature Range $_{Discharge}$	55°C To +90°C	-20°C To +60°C

MARKETS:

- Power Hold Up Applications
- Pulse Power Handling
- Energy Harvesting
- Lithium-Ion Replacement

STYLES:

- Cylindrical
- Modules
- Large Prismatics
- Small Prismatics

ADVANTAGES:

- Low ESR Cylindrical
- PC & ACN Electrolytes
- Long Lifetime Performance
- Custom Modules

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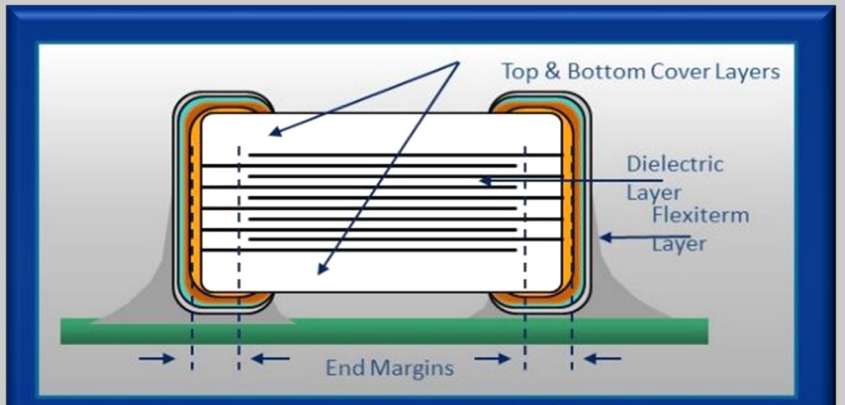
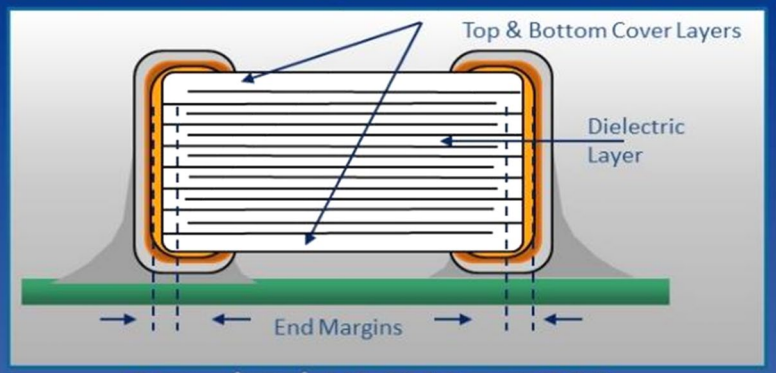
Capacitor Reliability, Applications, & Trends

MLCC

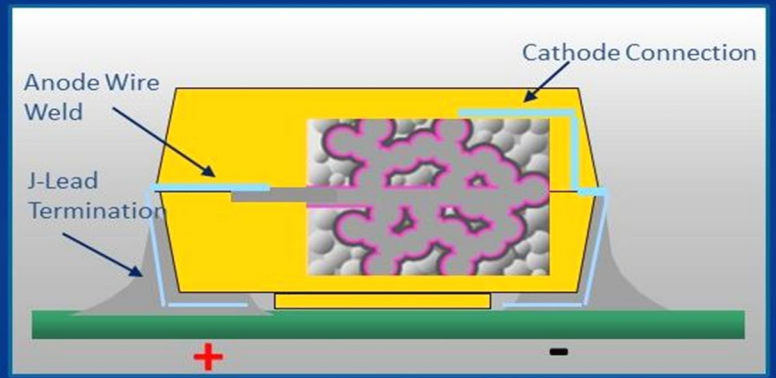


AEC-Q200 – High Shock / Vibration

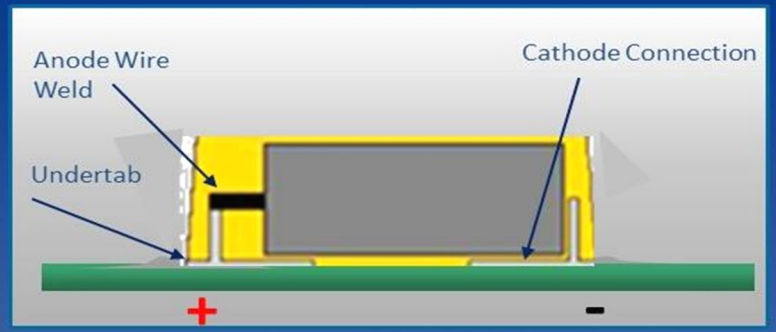


Standard Hi CV Low ESR

Tantalum/Polymer/Niobium



AEC-Q200 – High Shock / Vibration



Standard Hi CV Low ESR

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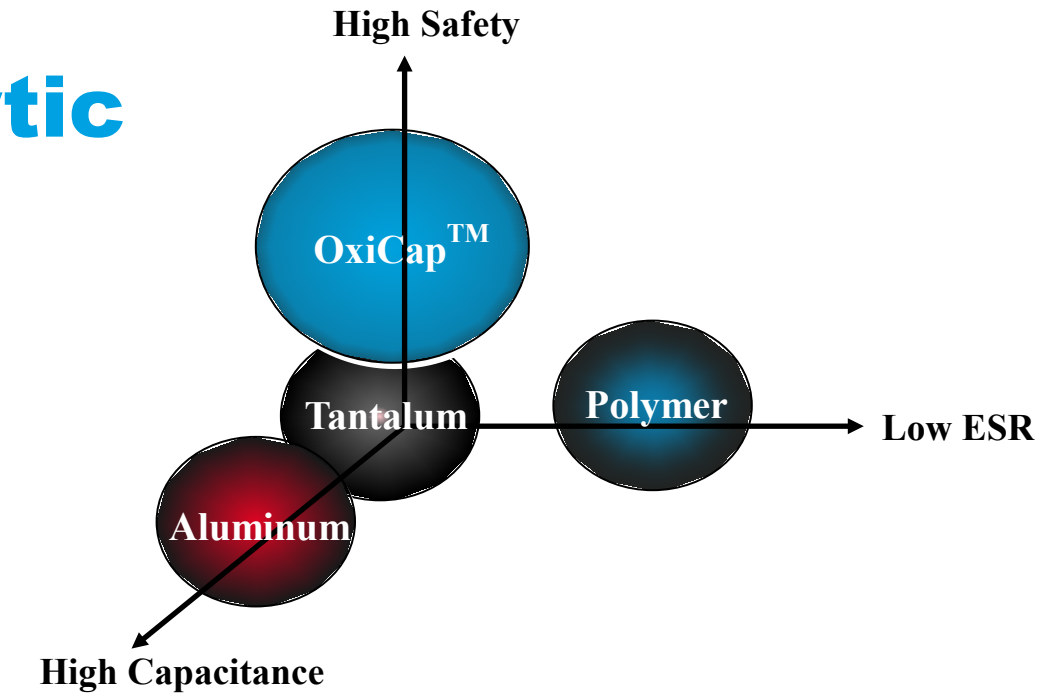
Electrolytic Guide



	MnO_2	Polymer	OxiCap®	Aluminum Polymer	Aluminum Hybrid	Aluminum Wet
Benefits	▪ Indefinite lifetime ▪ Highest CV/cc ▪ High reliability ▪ -55°C to +230°C ▪ Stable Cap V/T ▪ Mechanically robust ▪ No noise	▪ Low ESR ▪ Benign failure ▪ High Voltage ▪ Surge resistant ▪ 10% or 20% derating ▪ High reliability ▪ -55°C to +105/125°C ▪ Stable Cap V/T ▪ No noise	▪ Fail safe ▪ Self-healing ▪ Highest Reliability ▪ Indefinite lifetime ▪ Surge resistant ▪ 20% derating ▪ -55°C to +125°C ▪ Stable Cap V/T ▪ No noise	▪ Super Low ESR ▪ Lifetime: 2000-5000 hours ▪ Higher ripple ▪ High Voltage ▪ -55°C to +105°C	▪ Low ESR ▪ Higher Reliability ▪ High Ripple Current Resistance ▪ Low DCL ▪ High Voltage ▪ Long Life: 4000 - 10000 hours ▪ -55°C to +105/125°C	▪ Low Impedance ▪ Low Cost ▪ Low DCL Broad Value Range ▪ -40/-55°C to +105/125°C ▪ Lifetime: 2000-5000 hours
Check	▪ <63V ratings ▪ 50% derating	▪ Moisture sensitive ▪ Limitation at long time Temp lifetime	▪ ≤ 10V ratings	▪ Higher DCL ▪ Higher Cost	▪ Higher Cost ▪ Range Limits	▪ Reliability ▪ ESR

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ALUMINUM ELECTROLYTIC
Comparison & Application

	Wet	Polymer	Hybrid
			
Benefits	• Low Cost • Low DCL • Broad Value Range	• Ultra Low ESR • Higher Ripple • Enhanced Life	• Low ESR • Low DCL • Higher Reliability
Points to Check	• Reliability • ESR	• Higher DCL • Higher Cost	• Higher Cost • Range Limits
Power Conversion	++	+++	+++
Filtering	+++	+++	+++
Battery	+++	+	+++
Audio	+++	+++	+++
Base Station	+	++	+++
Industrial	+	+++	+++
Low Temperature	+	+++	++
High Temperature	++	+	+++
Extended Reliability		++	+++
High Vibration	+++	+	+++

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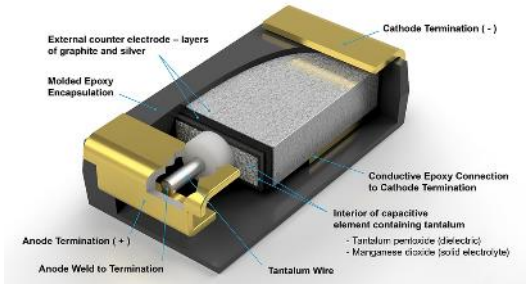
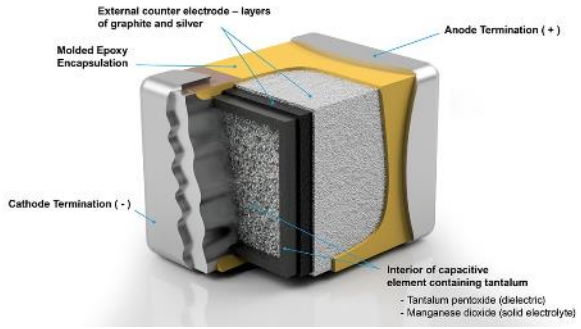
Most Efficient Ta Capacitor Worldwide

NO CASE MATERIAL = Efficient

- New options exist when selecting Tantalum capacitors
- MIL-PRF-55365/4 & /11 – CWR09/19/29 calls out lead frame tantalum devices
- MIL-PRF-55365/8 – CWR11 calls out EIA case size lead frame tantalum devices
- MIL-PRF-55365/12 – CWR15 Calls out the smallest tantalum devices available



Military J Lead SMT Package



0603, 0805, 1206 EIA case size

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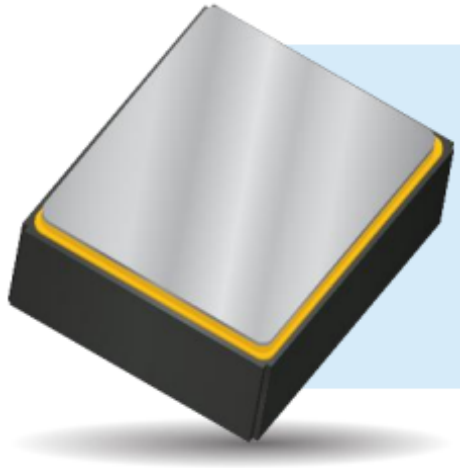
IN PROGRESS – MIL TANTALUM AND POLYMER CAPACITOR OPTION



High CV Capabilities
Cap Range - 330uF
Voltage Range - 10v-100v

Low ESR and Surge Capable

NASA / ESA Specifications Under Preparation

** **Hermetic Package** – Ceramic Can*

Technology Comparison

Hermetic SMD Polymer Tantalum:

- Hermetic design eliminates oxidation effects to cathode and results in no parametric degradation over time.

MnO_2 Tantalum:

- No known wear out mechanism.
- Provides infinite parametric lifetime.

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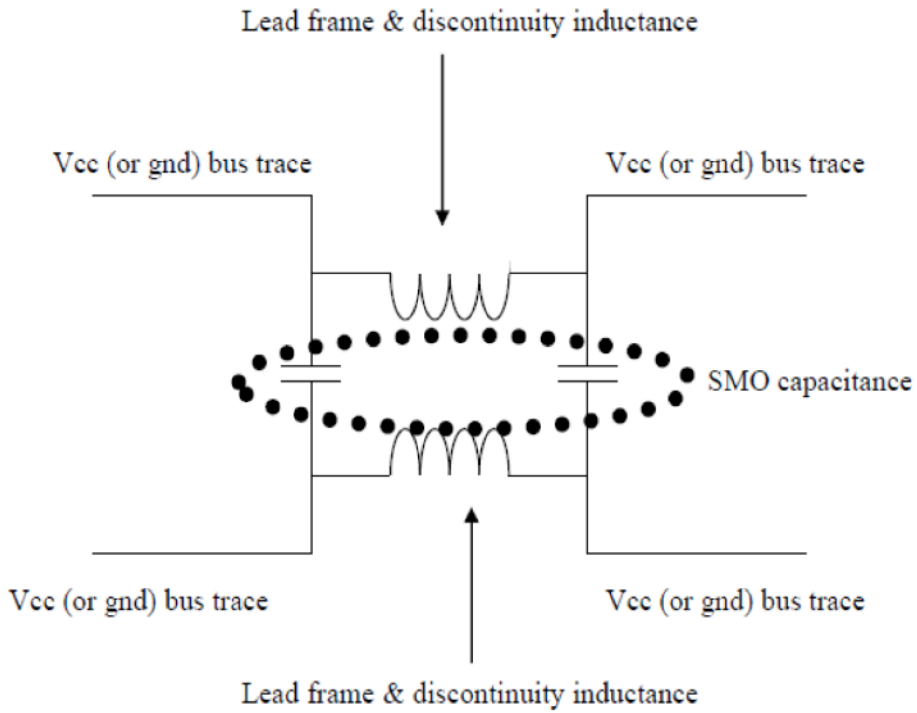
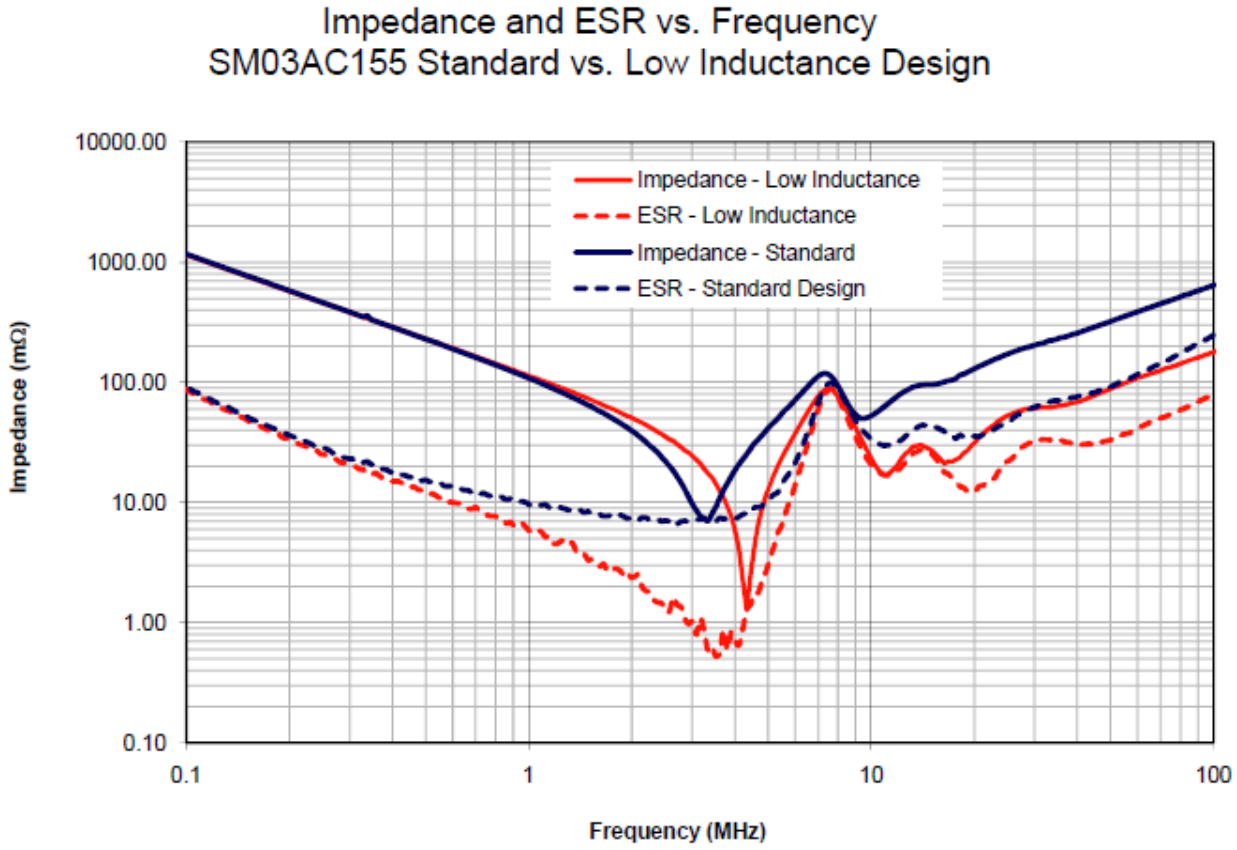
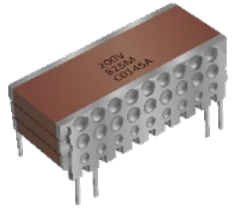
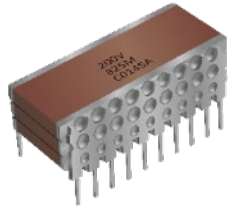
Lowering Inductance on Stacked Capacitors







Self-Resonant Frequncy =4.33 MHz
ESR @ Self-Resonance = 1.28 mΩ
Self-Inductance = 0.894 nH
Capacitance = 1.51 µF



Self-Resonant Frequncy =3.25 MHz
ESR @ Self-Resonance = 7.38 mΩ
Self-Inductance = 1.61 nH
Capacitance = 1.49 µF

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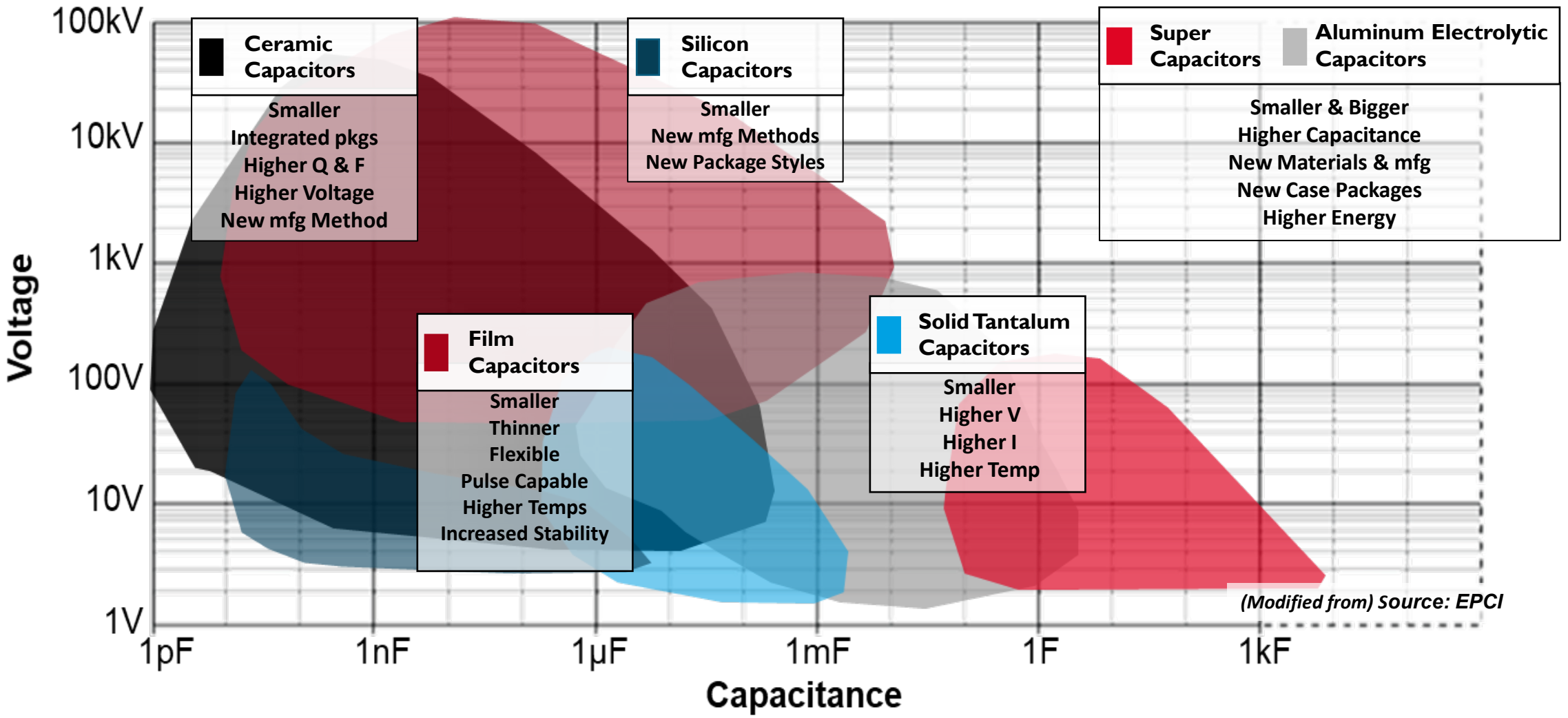
Future Trends By Capacitor Technology



WBG Driven Industry Trends: 400V ⇢ 800V | 105°C ⇢ 150°C

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THANK YOU.

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