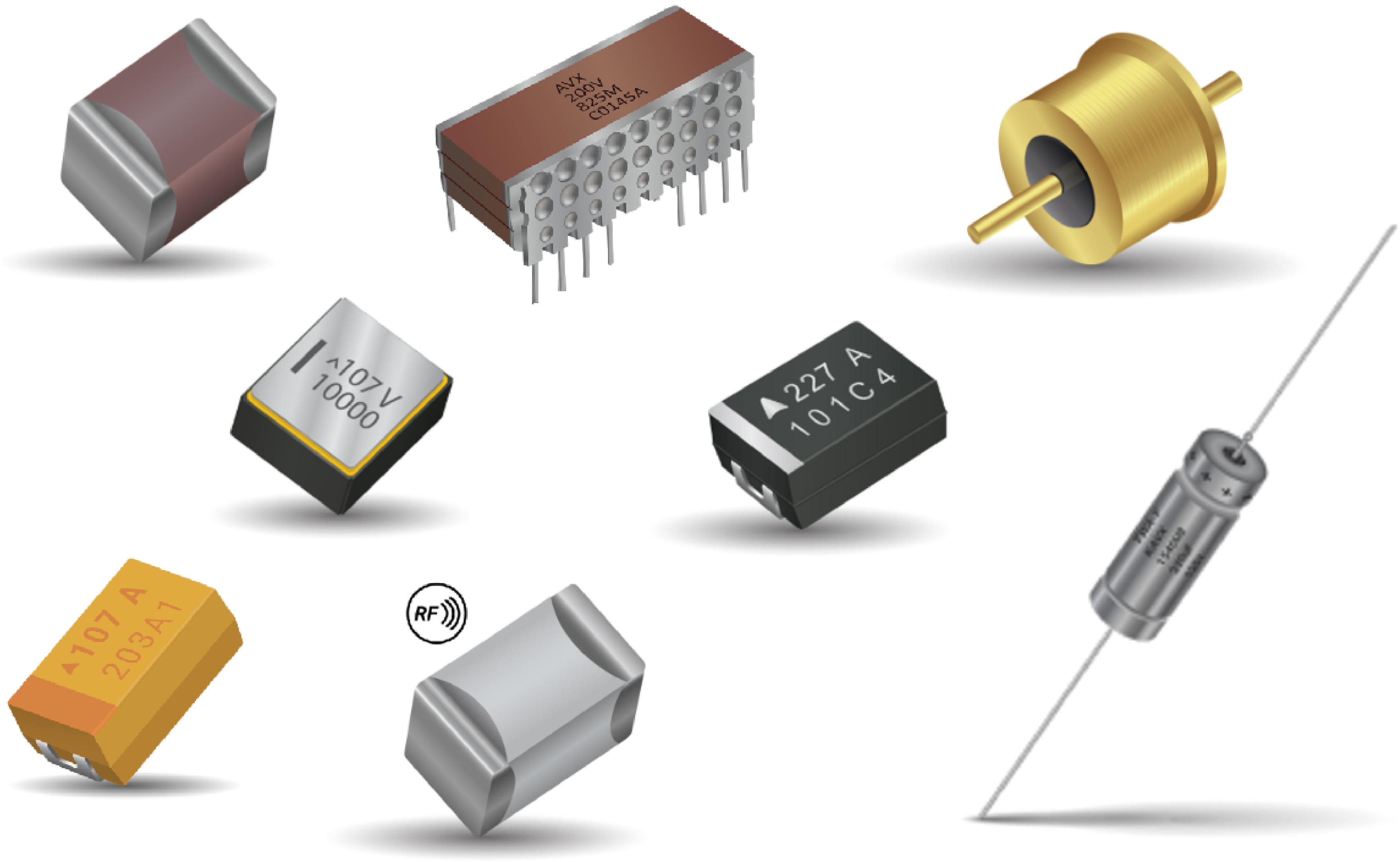
Update on High Temperature Passive Electronic Components and Emerging AEC-Q200 Temperatures

Outline

- Multilayer Ceramic Capacitors
  - X8R/X8L
  - X8G
  - VHT
- Tantalum Capacitors
  - Mn02, Polymer, Wet
  - SMD, Through-Hole, Modules
- Supercap
  - New electrochemical formulas exceeding Acetonitrile temperatures
- Multilayer Varistors
  - Comparison of high temperature performance vs. TVS diodes
- Thermal Conductors

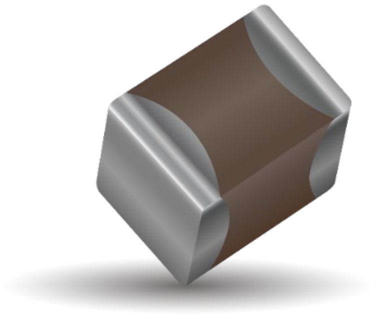
High Temperature Capacitor Options

Temperature Range	Capacitor Type
250°C	MLCC chip MLCC custom modules
230°C	Solid Tantalum Wet tantalum
200°C	MLCC chip MLCC stacked MLCC custom modules Wet tantalum Solid tantalum EMI filters
175°C	RF MLCC MLCC chip MLCC stacked Wet tantalum Solid tantalum
150°C	Solid tantalum MLCC chip
135°C	Solid tantalum



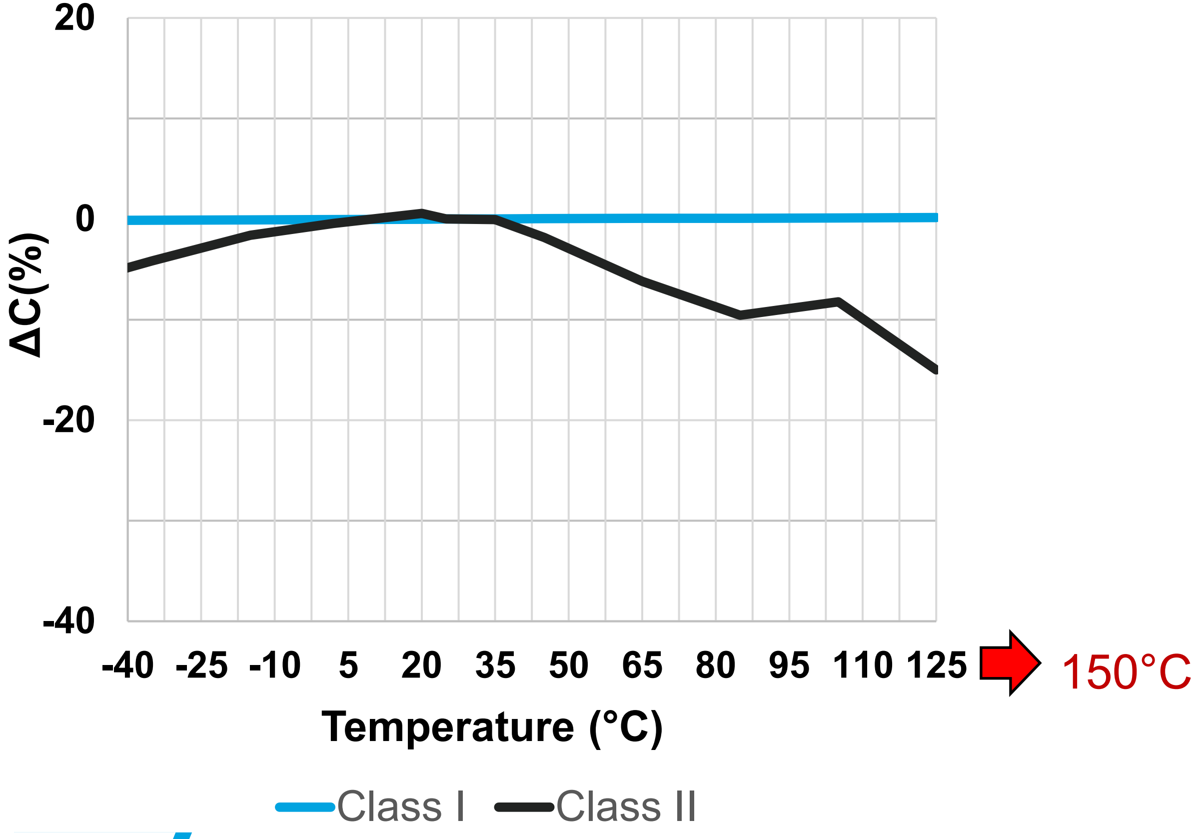
HIGH TEMPERATURE OPTIONS

Attribute	MnO_2	MLCC	Polymer	OxiCap®	Film	Wet Ta	Aluminum
Benefits	Indefinite lifetime	High temptuare	Low ESR	No noise	High Voltage	Very High CV	Very High CV
	Highest CV/cc	High CV (class 2)	High Energy J/cc	Self-healing	Self-healing	High Vibration/Shock	High voltage up to 600V
	High reliability	Lowest ESR	High Voltage	Highest Reliability	Very low ESR	Self-healing	Low ESR as Polymer and Hybrid
	-55°C / +230°C	High Stability +low losses	Surge resistant	Indefinite lifetime	High Current	Surge resistant	Available as SMD & Leaded
	Stable Cap V/T	No derating	10% or 20% derating	Surge resistant	cap stability	-55°C / +125/200/230°C	Low cost
	Mechanical Robust	wide voltage range	High reliability	20% derating	High Insulation Resistance	Hermetic Casing	Low derating
	Low DCL	Non polar	-55°C / +105/150°C	-55°C - +125°C		DCLmax<0.0002cv	DCLwet/hybrid≦0.01cv
	No noise	High Voltage >3kV	Stable Cap V/T	Stable Cap V/T	-40°C/ +90/105/125°C		DCLpolymer≦0.2cv
	Low profile	Low profile	Low profile	DCL_{max}<(0.02cv~0.1cv)			
	DCL_{max}(0.001cv~0.1cv)		DCL_{max}<0.1CV				
	Self Healing	High Ripple	No noise				
Check	≤ 50V ratings	DC Bias (Class 2)	Moisture sensitive MSL 3-5	≤ 10V ratings	Check size	Higher ESR than SMD	Humidity can decrease reliability
	derating rules	Aging vs capacitance	Aging can impact ESR and capacitance			Leaded	Case size
		Mechanically fragile					Heat can increase the aging effects
		Piezoelectric noise					



X8R and X8L Ceramic Capacitors

Typical TCC Characterization of Class I and Class II Dielectric



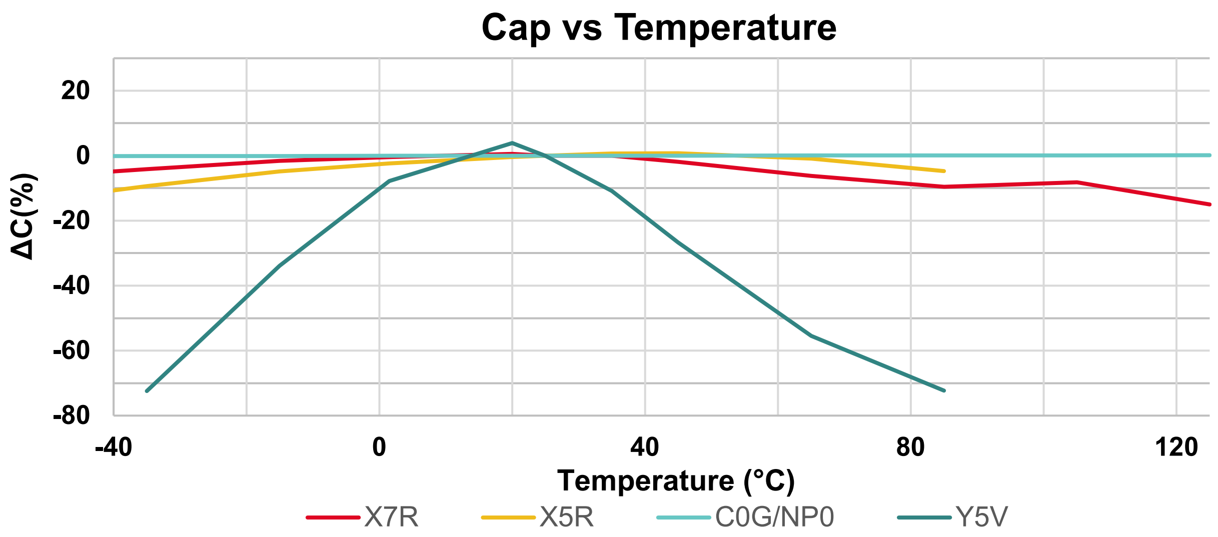
Code system regarding to EIA RS-198 for some temperature ranges and inherent change of capacitance

Letter code low temperature	Number code upper temperature	Letter code change of capacitance over the temperature range
X = −55 °C (−67 °F)	4 = +65 °C (+149 °F)	P = ±10%
Y = −30 °C (−22 °F)	5 = +85 °C (+185 °F)	R = ±15%
Z = +10 °C (+50 °F)	6 = +105 °C (+221 °F)	S = ±22%
	7 = +125 °C (+257 °F)	T = +22/−33%
	8 = +150 °C (+302 °F)	U = +22/−56%
	9 = +200 °C (+392 °F)	V = +22/−82%

Example:
X7R = -55°C to +125°C , ±15%
X8R = -55°C to +150°C , ±15%
X8L = -55°C to +125°C , ±15% then
+125°C to +150°C , +15% / -40%

MLCC Performance

Mostly Controlled by the Dielectric



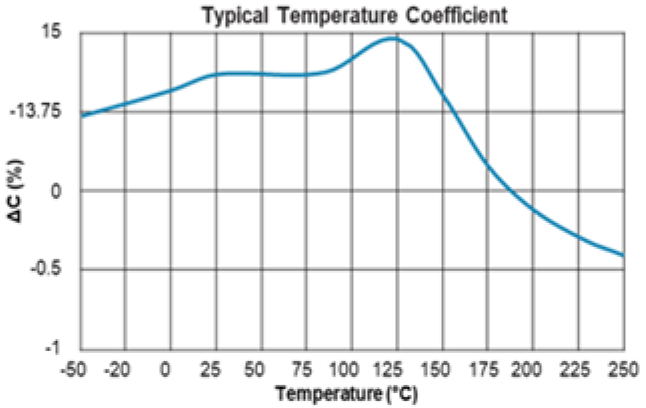
Example of Cap vs Temperature:

COMMON DIELECTRIC TYPES USED:

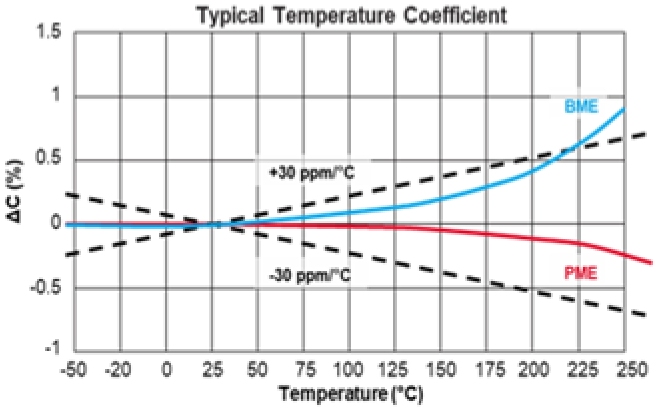
Type	Class	Temperature range	Variation due to temperature
C0G	Class I	-55°C to +125°C	+/-30ppm/°C
U2J	Class I	-55°C to +125°C	-750ppm/°C
X8R	Class II	-55°C to +150°C	±15%
X8L	Class II	-55°C to +150°C	±15%, then -40% from 125°C to 150°C
X7R	Class II	-55°C to +125°C	±15%
X7S	Class II	-55°C to +125°C	±22%
X6S	Class II	-55°C to +105°C	±22%
X5R	Class II	-55°C to +85°C	±15%
Y5V	Class III	-30°C to +85°C	+22% / -82%
Z5U	Class III	+10°C to +85°C	+22% / −56%

High Temperature MLCC Options

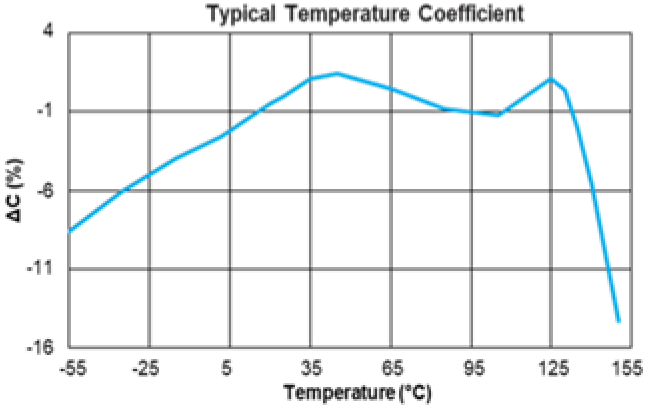
VHT PME 200 / 250



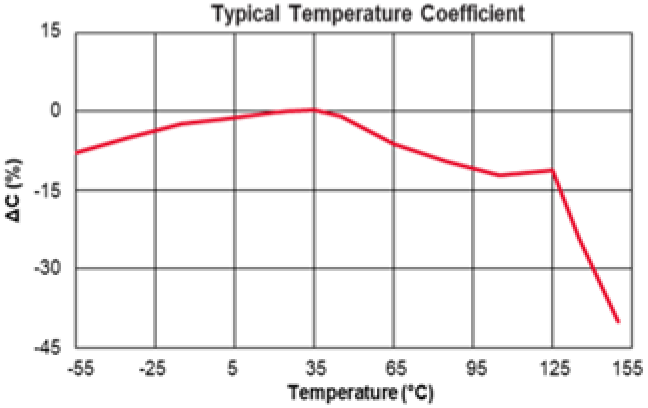
High Temp PME / BME



X8R



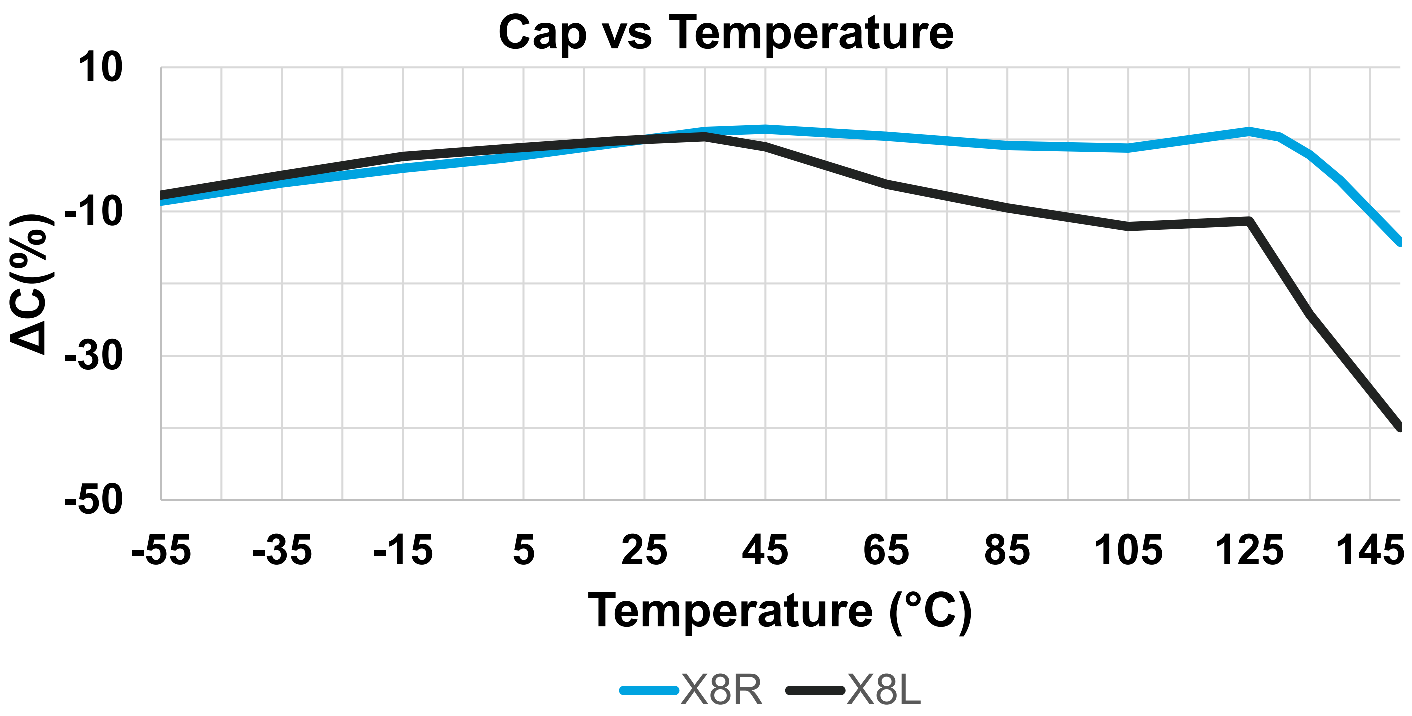
X8L



Ceramic Dielectric Type	Operating Temperature	Stability Characteristics
X8G	-55°C to +150°C	0 ±30ppm/°C
X8R	-55°C to +150°C	±15%
X8L	-55°C to +150°C	-55°C to 125°C: ±15% +125°C to +150°C: +15 / -40%
PME C0G High Temp	-55°C to +200°C	0 ±30ppm/°C
PME C0G High Temp	-55°C to +250°C	0 ±30ppm/°C
BME C0G High Temp	-55°C to +200°C	0 ±30ppm/°C
BME C0G High Temp	-55°C to +250°C	See Chart
VHT PME 200	-55°C to +200°C	-55°C to 150°C: ±15% >150°C: See Fig. 1
VHT PME 250	-55°C to +250°C	-55°C to 150°C: ±15% >150°C: See Chart

MLCC Performance

X8R and X8L Dielectric



- X8R uses a different material formulation to X7R/X5R etc
- X8L may use X7R materials or a different formulation
- Parts tend to have a thicker dielectric .
- High temperature reliability 150°C evaluations

X8G +/- 30 ppm 150°C

EIA	JIS	Cap pF	47	68	100	150	220	330	470	510	680	1000	1100	1500	1800	2200	3300	3900	4700	6800	10000	15000	18000	22000	33000
(inch)	(mm)	Code	470	680	101	151	221	331	471	511	681	102	112	152	182	222	332	392	472	682	103	153	183	223	333
0402	1005	25V				Q4 2025	Q4 2025	Q4 2025	Q4 2025																
		50V																							
		100V	Q4 2025	Q4 2025	Q4 2025																				
0603	1608	25V										Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025									
		50V										Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025									
		100V	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025									
		250V	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025													
		630V	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025													
0805	2012	25V													Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q4 2025	Q4 2025	Q4 2025	
		50V													Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025				
		100V	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025				
		200V	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025						
		250V	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025						
		630V	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025												
		1000V																							
1206	3216	50V						Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	
		100V						Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	
		200V						Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025				
		250V						Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025				
		500V						Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025						
		630V						Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025						
		1000V																							
1210	3225	50V							Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025
		100V							Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025
		200V							Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025
		250V							Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025	Q2 2025
		500V							Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025		
		630V							Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025	Q3 2025		
		1000V																							

MLCC Reliability Comparison

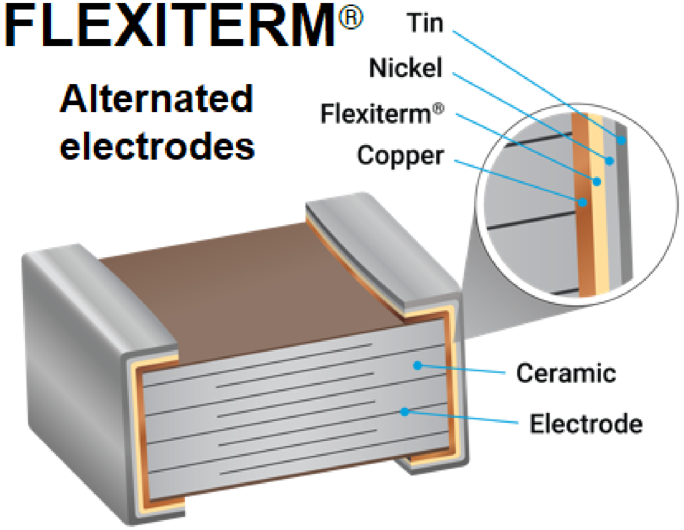
				AT RATED VOLTAGE & TEMPERATURE		AT TYPICAL USAGE CONDITION (0.5X RV & 50°C)			
DIELECTRIC GROUP	LOT TESTED	PIECES TESTED	DEVICE HOUR	EQUIVALENT DEVICE HRS	FAILURE RATE (1/)	EQUIVALENT DEVICE HRS	FAILURE RATE (1/)	FAILURE RATE FITS – (2/)	MTBF
X7R	1728	225490	1.08×10^{7}	8.66×10^{7}	0.15	6.93×10^{11}	1.89×10^{-5}	0.19	5.29×10^{9}
X8R/X8L	150	19000	9.12×10^{5}	7.30×10^{6}	0.18	5.84×10^{11}	2.23×10^{-6}	0.02	4.49×10^{10}
NPO	249	31087	1.49×10^{6}	1.19×10^{7}	0.02	9.55×10^{10}	2.41×10^{-6}	0.02	4.15×10^{10}

- 90% Confidence Level
- X8R/L has much higher reliability at typical use conditions
- Comparable to NP0/C0G (Class 1) when derated

FlexiTerm and FlexiSafe MLCCs

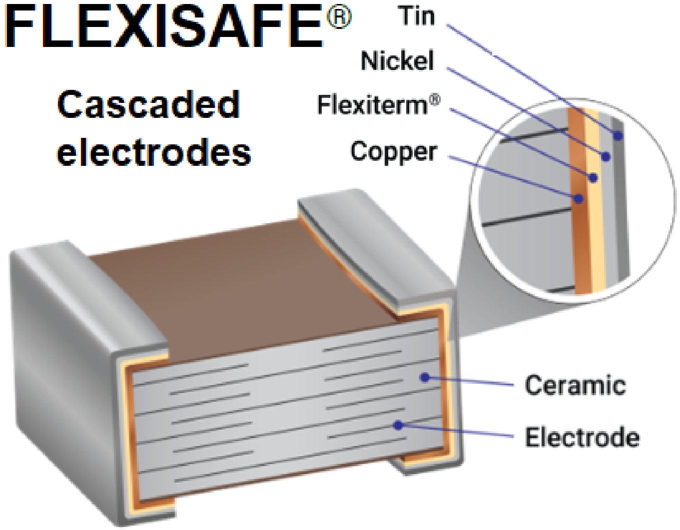
FLEXITERM®

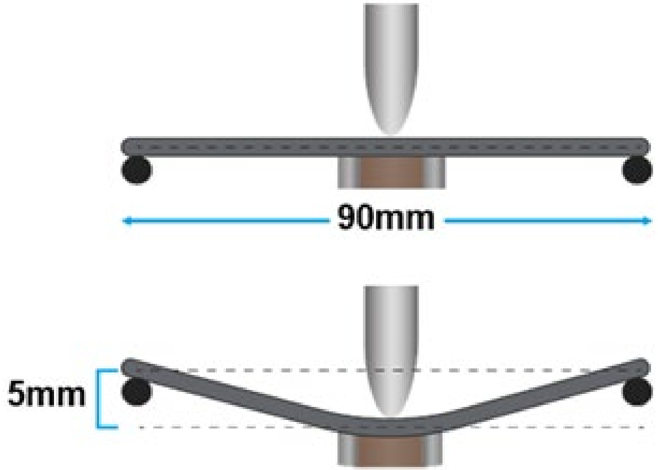
Alternated electrodes



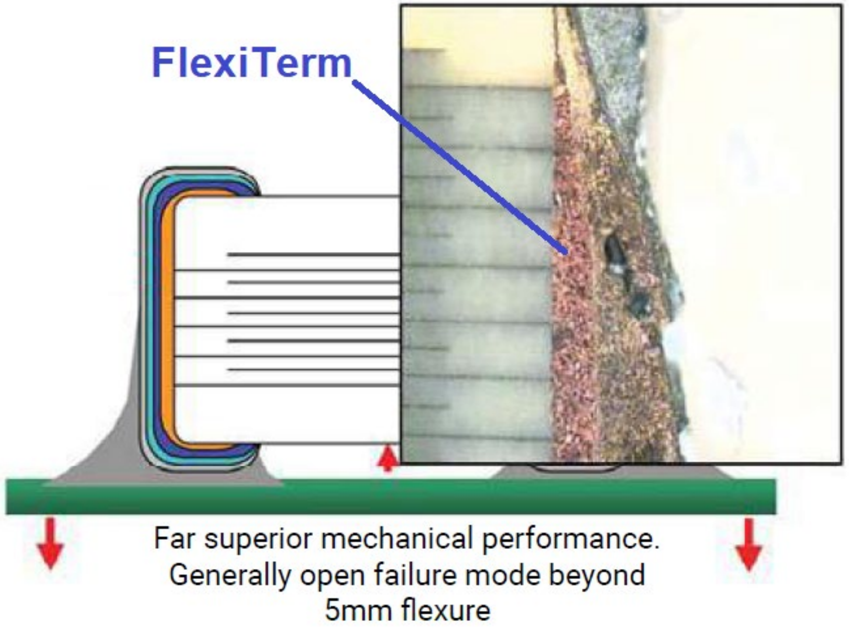
FLEXISAFE®

Cascaded electrodes





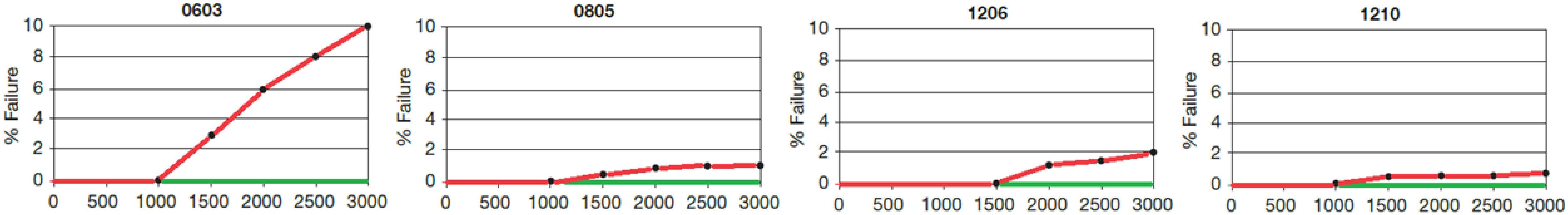
Mechanical Force Absorbed by the FLEXITERM® Layer



FlexiTerm and FlexiSafe MLCCs

BEYOND 1000 CYCLES: TEMPERATURE CYCLE TEST RESULTS

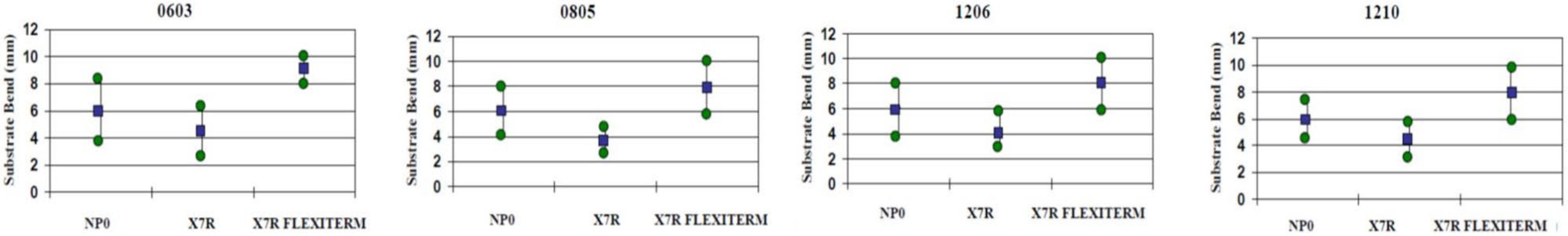
Green = Soft Term MLCC (Flexiterm)
Red = Standard MLCC



FlexiTerm - No Defects up to 3000 cycles

FLEXITERM® TEST SUMMARY

- FLEXITERM® provides improved performance compared to standard termination systems
- Board bend test improvement



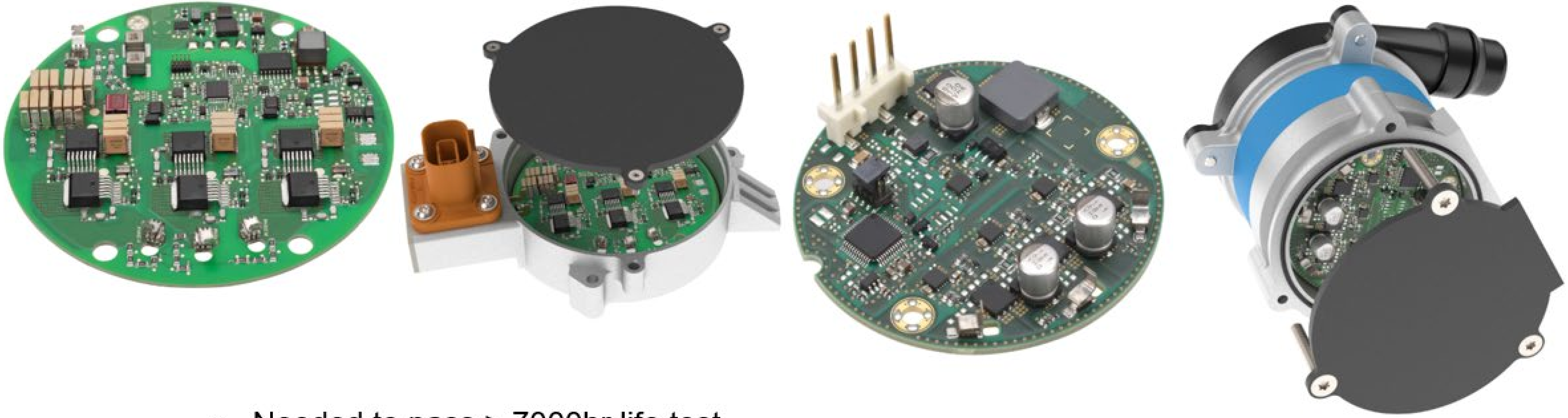
Board flex test is directly proportional to strain measurements on PCB

X8R/L Applications

Description
CAP CER 1000PF 50V X8R 0603
CAP CER 0.047UF 50V X8R 0603 Ceramic Capacitors

X8R/L Applications

Electric Water Pump Qualified for 150°C



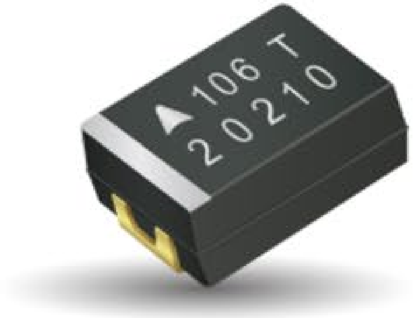
- Needed to pass > 7000hr life test
- Increased cost to pass
- Expect Class 8 requirements to follow

High Temperature Tantalum Capacitors

F97-HT3 series

THJ series 175C

THJ series 200C



TCO series 150C automotive

THH series 230C
Hermetic

TWA-X series 230C
Hermetic

TWA-Y series 200C
Hermetic

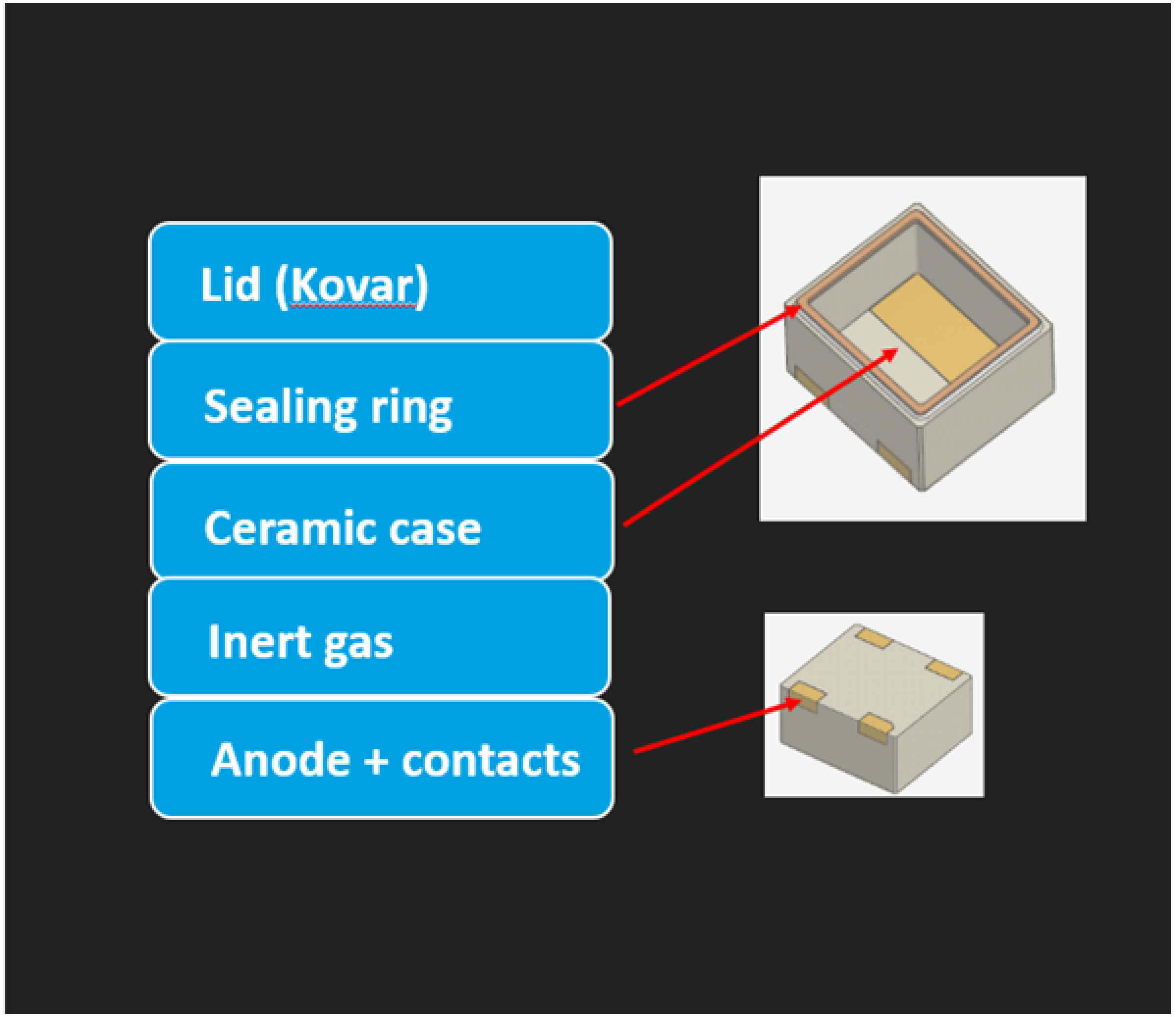
TWC-Y series 200C
Hermetic

Hermetic Ceramic Case

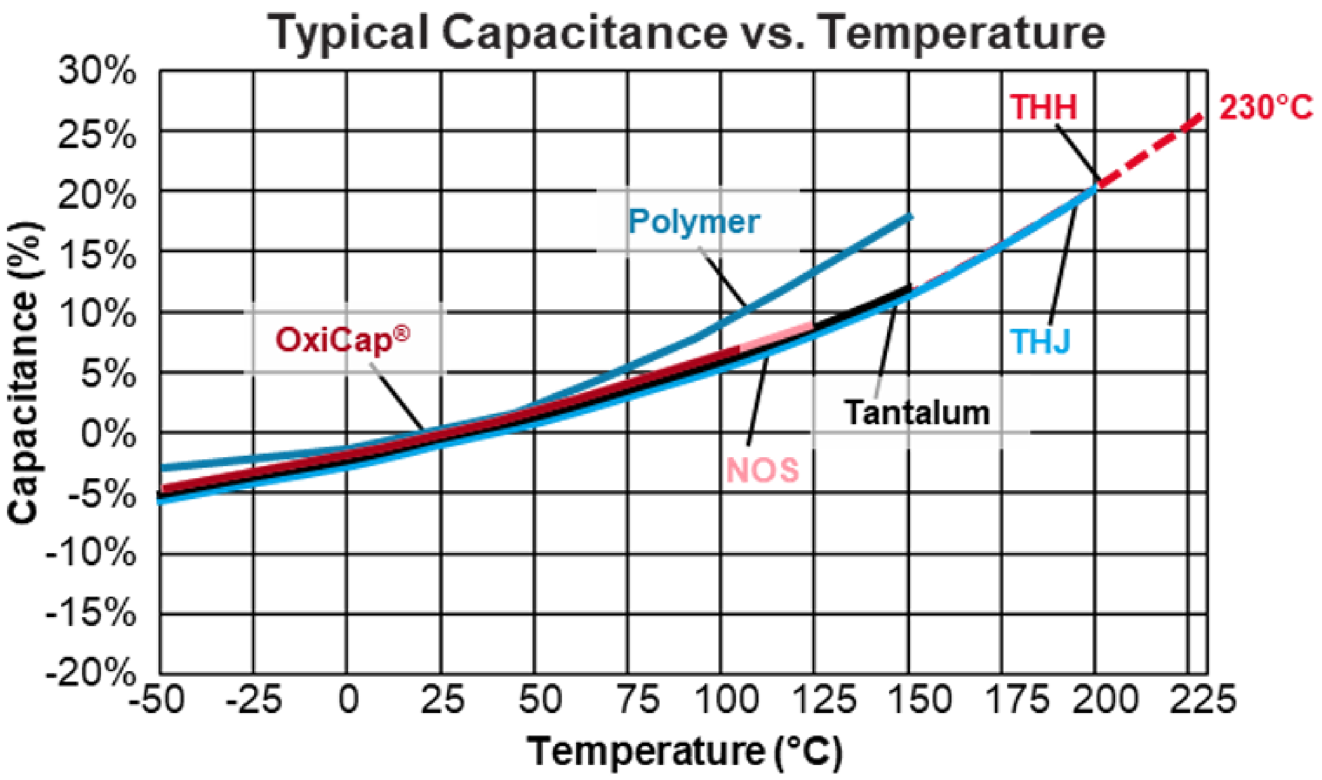
Why Hermetical Packaging?

Reliability improvements are possible by protecting the capacitor from external harsh conditions

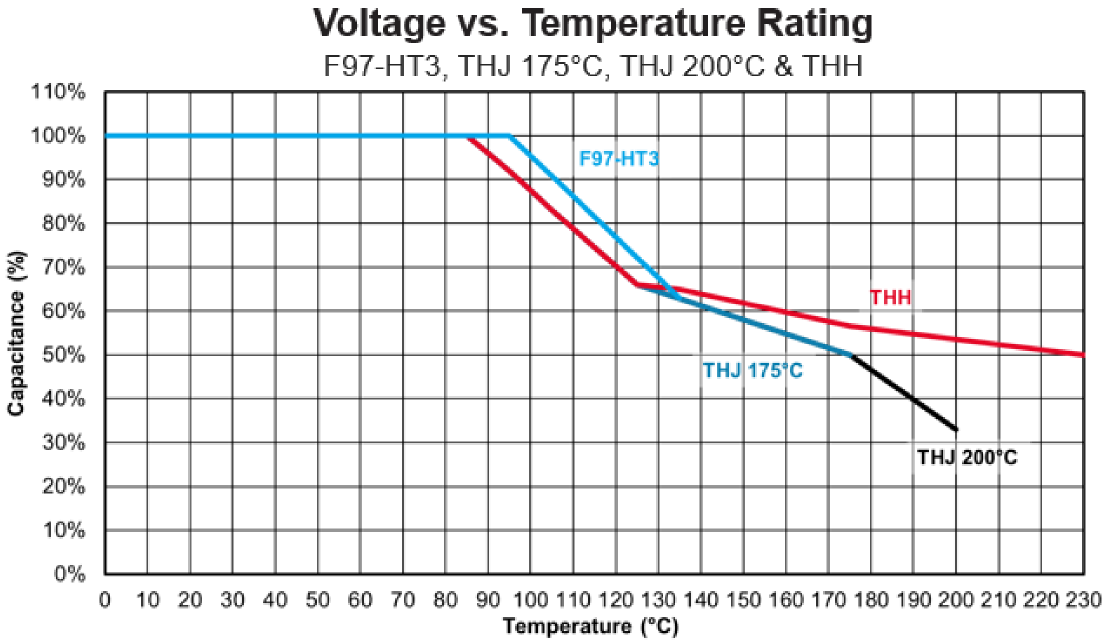
- Improves Parametric Stability
- Prolongs life over 10,000 hrs
- Maintains performance in extreme conditions
- MnO_2 for high temperature
- Conductive Polymer for Mission Critical Aerospace & Hi-Rel



High Temperature Tantalum Portfolio



	F97-HT3	THJ 175°C	THJ 200°C	THH
				
Packaging	SMD	SMD	SMD	Hermetic
Temperature	-55°C to +135°C	-55°C to +175°C	-55°C to +200°C	-55°C to +230°C
Voltage Rating	6.3 - 35V	3 - 25V	3.3V & 5.3V	8 - 25V

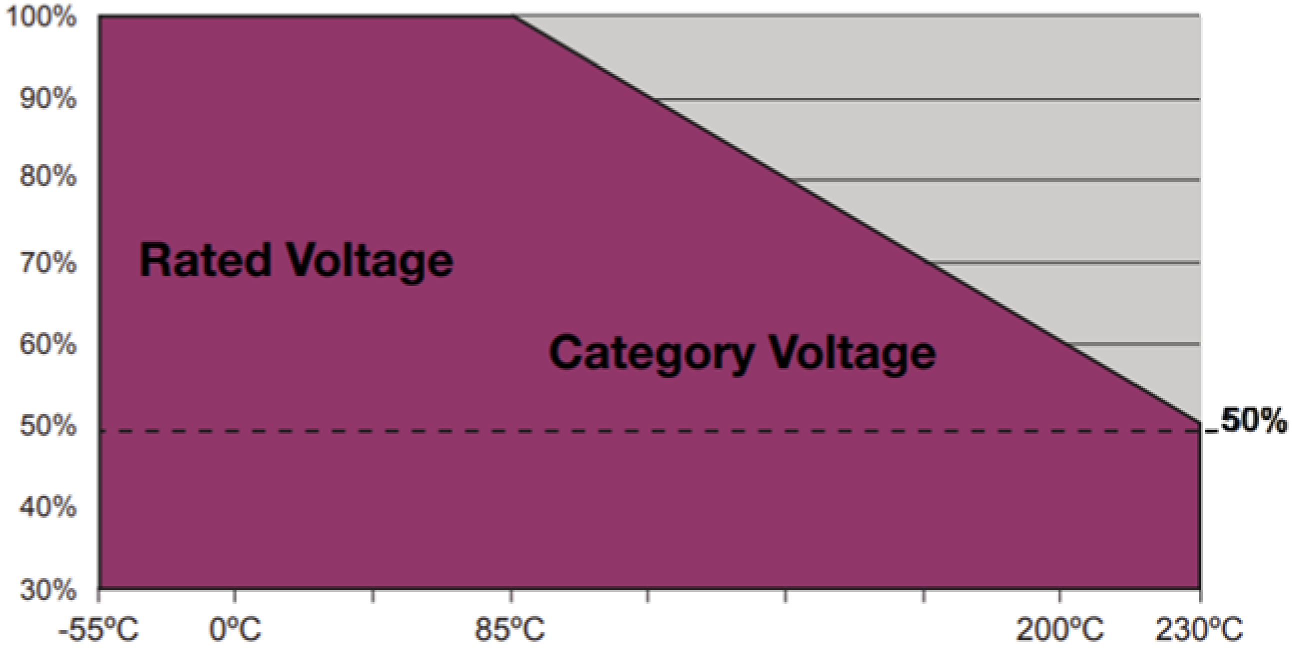


High Temperature Tantalum – THH 200C series

FEATURES

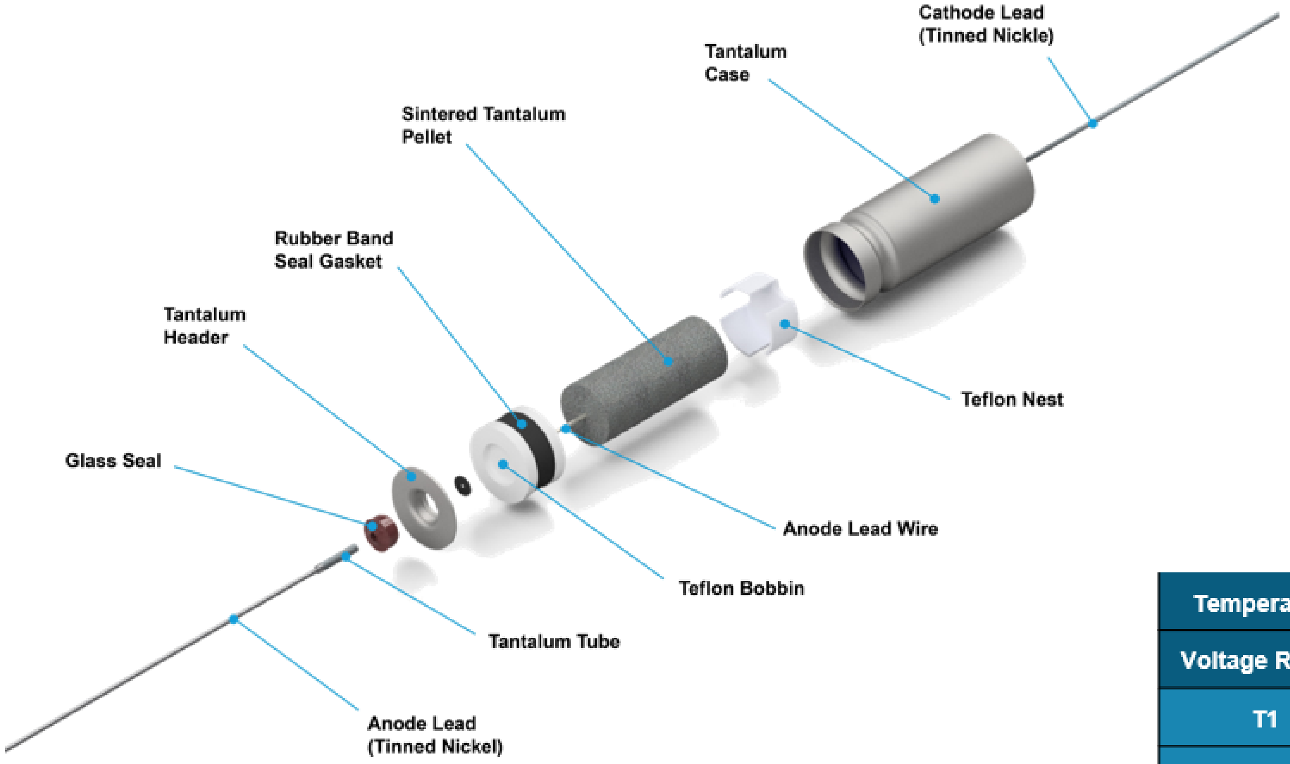
- High temperature applications
- Operational condition 230°C / 0.5UR / 1000hrs (2000hrs for selected codes) or 200°C / 0.5UR / 10.000hrs
- 100% surge current tested
- Ceramic case hermetic packaging
- Large case sizes including CTC-21D provide high capacitance values
- Manufacturing and screening utilizing KYOCERA AVX patented Q-Process to effectively remove components that may experience excessive parametric shifts or instability in operation life

230°C THH Tantalum Series



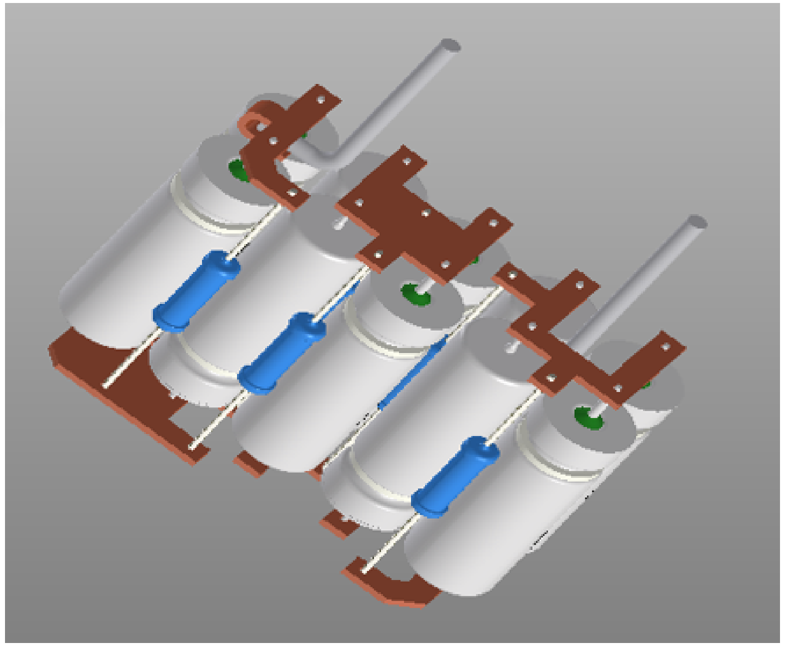
Capacitance		Rated Voltage DC (V_R) at 85°C		
μF	Code	16V (C)	35V (V)	50V (T)
6.8	685		I	I
10	106		I	
15	156			
22	226	I		
33	336			
47	476	I		9
68	686			
100	107		9	

High Temperature Wet Tantalum



	TWD	TWC-Y	TWA-Y	TWA-X
				
Temperature	-55°C to +175°C	-55°C to +200°C	-55°C to +200°C	-55°C to +230°C
Voltage Rating	3 - 10V @105°C	3.6 - 75V	9 - 75V	75 - 125V @85°C
T1		6.8 - 68 µF	10 - 120 µF	
T2		22 - 270 µF	22 - 560 µF	
T3		50 - 560 µF	82 - 1200 µF	
T4	25 - 100 mF	82 - 560 µF	82 - 4700 µF	220 - 470 µF

High Temperature Wet Tantalum Module



Features

- Super High capacitance up to 50mF (150mF roadmap)
- Temperature range -55ºC to 230ºC
- Reflow compatible
- High electrical and mechanical stability
- Small capacitance change at low temp
- Low DCL and high voltage

SuperCapacitor – Temperature Limits

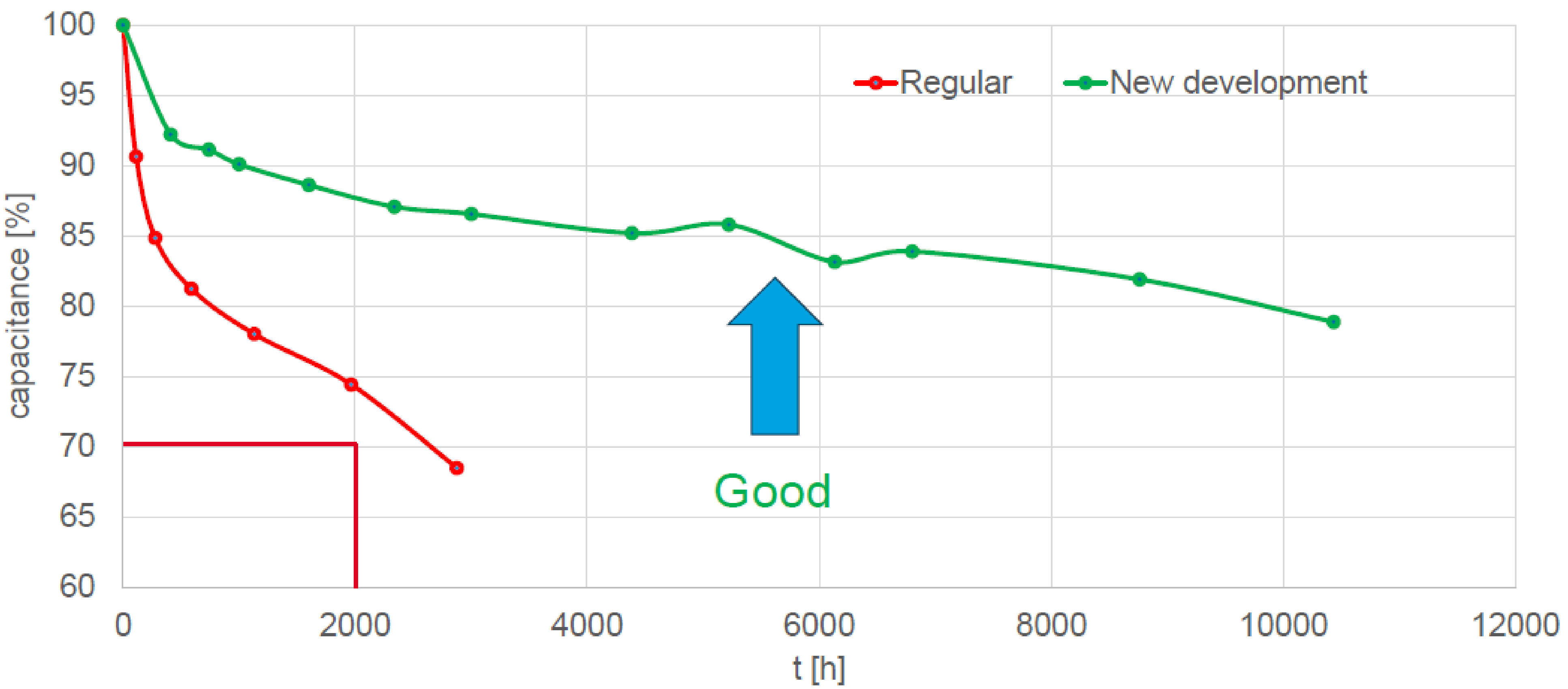
	Automotive Cylindrical					
	SCCU25B256SRBLEQ	SCCV60B107SRBQ	SCCT20E106SRBQ	SCCU30E356SRBLEQ	SCCV40E506SRBQ	SCCV60E107SRBQ
						
Temperature	-40°C to +65°C -40°C to +85°C***	-40°C to +65°C -40°C to +85°C***	-40°C to +65°C -40°C to +85°C***	-40°C to +65°C -40°C to +85°C***	-40°C to +65°C -40°C to +85°C***	-40°C to +65°C -40°C to +85°C***
Rated Voltage	2.7 V : 2.3 V ***	2.7 V : 2.3 V ***	3 V : 2.5 V ***	3 V : 2.5 V ***	3 V : 2.5 V ***	3 V : 2.5 V ***
Max Energy [Wh]	0.0253	0.1013	0.0125	0.0438	0.0625	0.125
Energy Density [Wh/kg]	3.47	5.06	3.68	5.09	4.81	6.05
Power Density [W/kg]	4793	2430	4235	5023	4154	2904
Capacitance	25 F	100 F	10 F	35 F	50 F	100 F
DCL Max @ 72Hrs	60 µA	260 µA	30 µA	85 µA	75 µA	260 µA
ESR Max @ DC	25 mΩ	18 mΩ	75 mΩ	25 mΩ	20 mΩ	18 mΩ

For More Information, Please Visit: Automotive Supercapacitors

SuperCap - New Electrochemical Formula

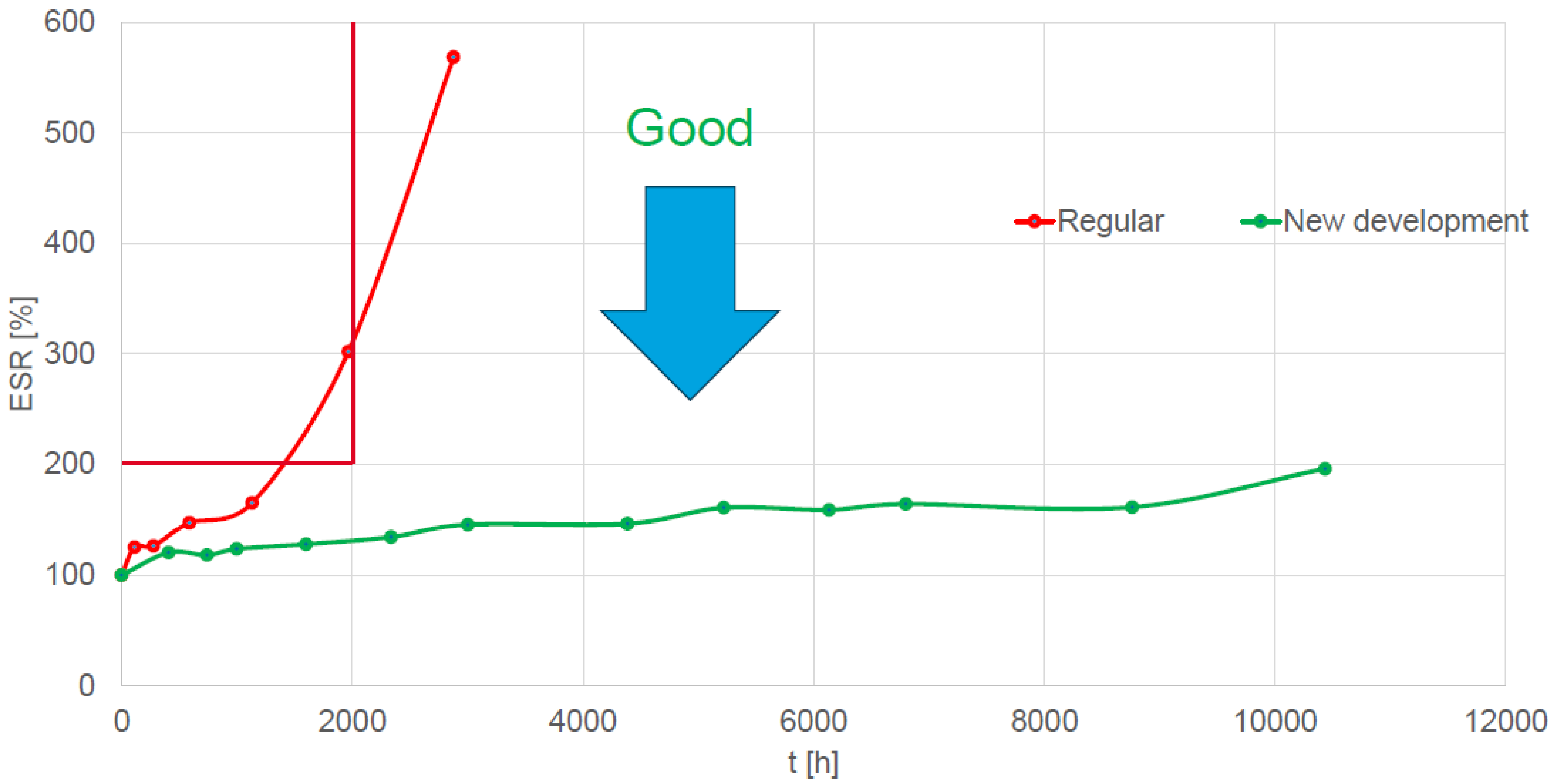
Preliminary Life Test Performance: Capacitance

25F@ 85C/2.7V



SuperCap - New Electrochemical Formula

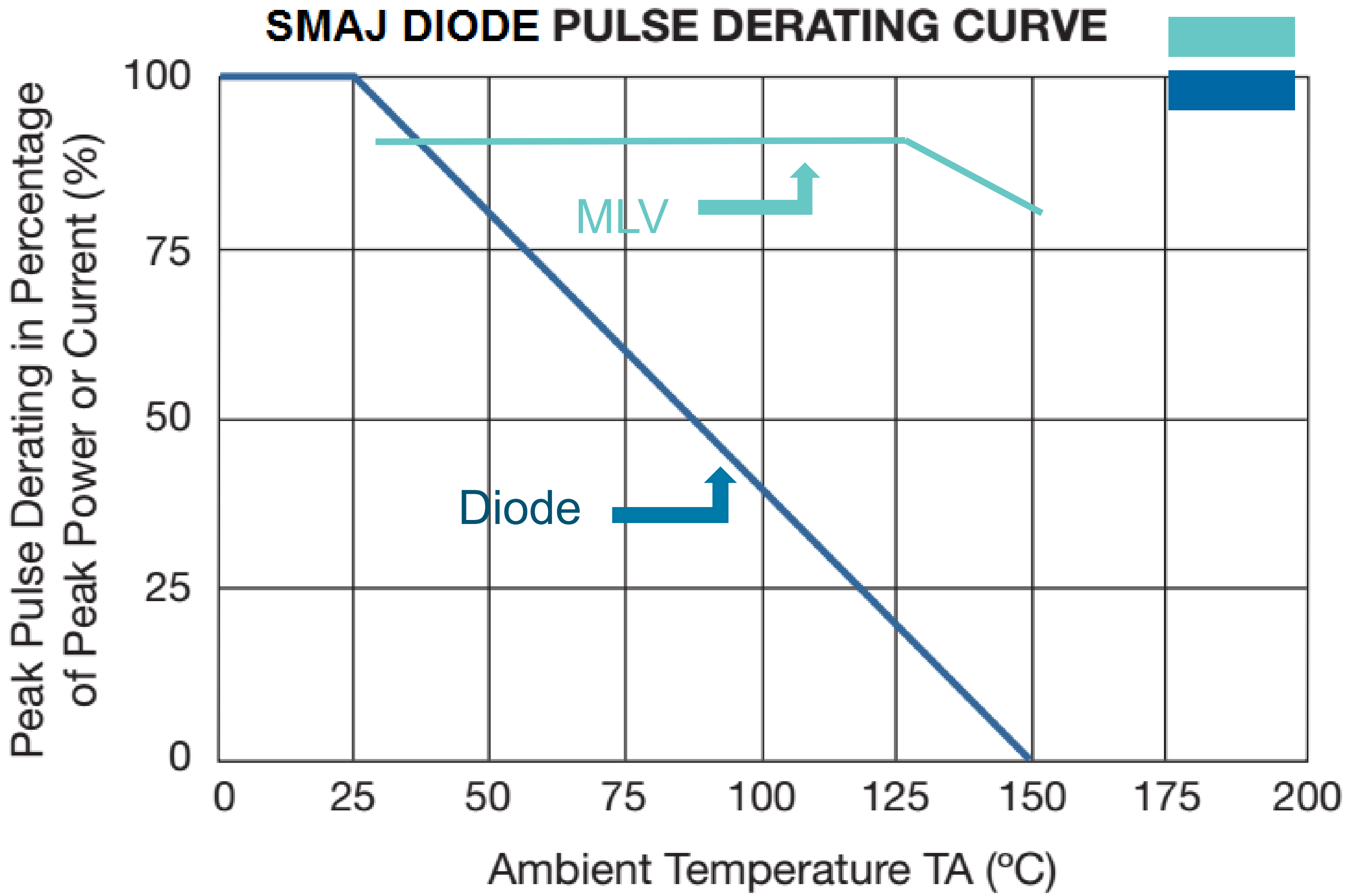
Preliminary Life Test Performance: ESR



Multilayer Varistors and Transient Voltage Suppressor Diodes

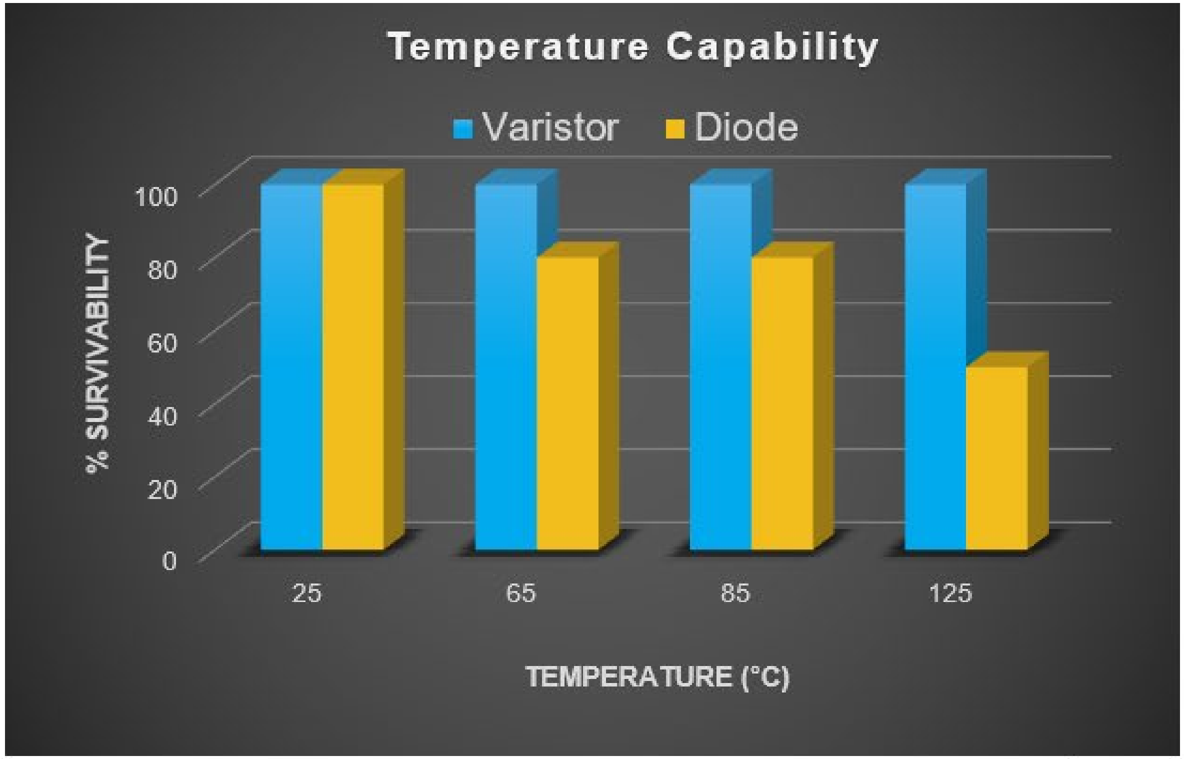
Derating of MLV and TVS Diode

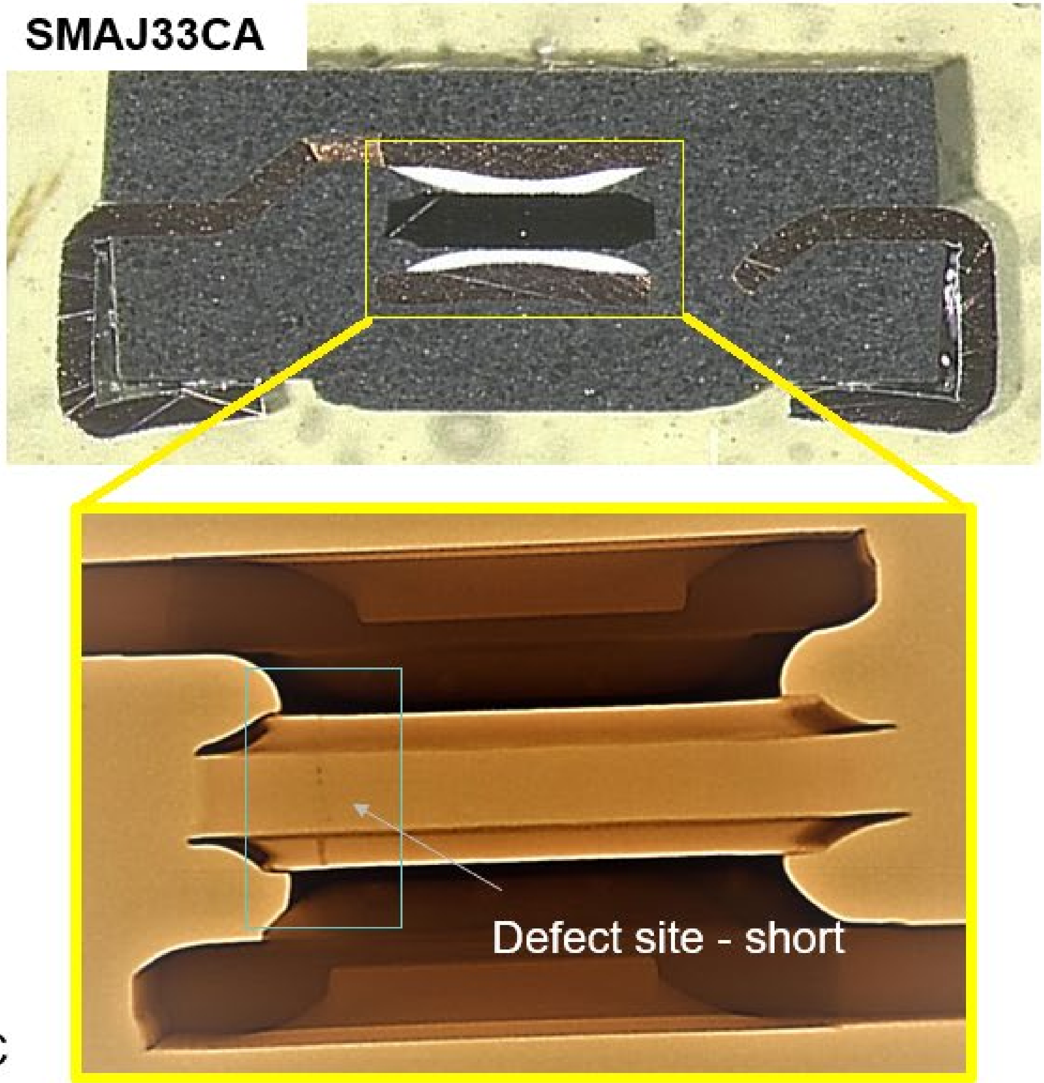
Typical MLV, - 55 to 125ºC Rated Temp.



MLV vs. TVM – derating for temperature

Derating Analysis





- 10x1000µs surge test @ 25 °C rated I_{PP}
- Diodes saw initial failures at 65 °C. 50% failed at 125 C
- All defects were short
- **Derating is absolutely necessary with temperature → Larger TVS diode will be needed for same I_{PP}**

MLV / TVM Diode

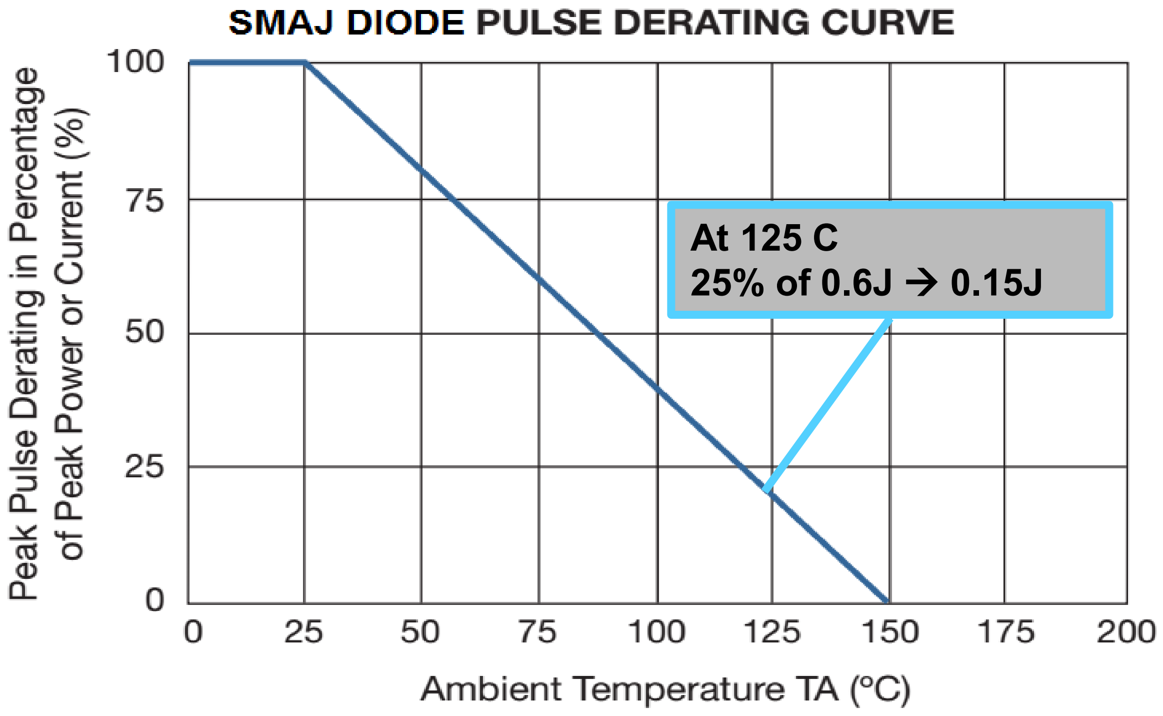
Temperature Derating Example

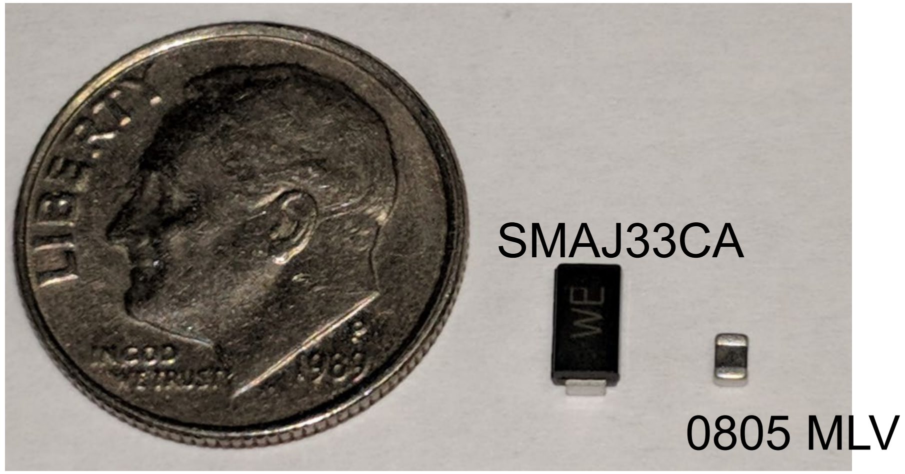
SMAJ33CA
Energy Rating = 0.6 J

0805 MLV
Energy Rating = 0.3 J

Temperature (ºC)	Diode Derating	Maximum Energy (J)	Varistor Derating	Maximum Energy (J)
25	100%	0.6	100%	0.3
55	75%	0.45	100%	0.3
85	50%	0.3	100%	0.3
125	25%	0.15	100%	0.3
150	0%	0	85%	0.25

- Design had strict size constraints
- Application exposed to 125 ºC or greater
- Needed device that maintained energy handling capability at temperature

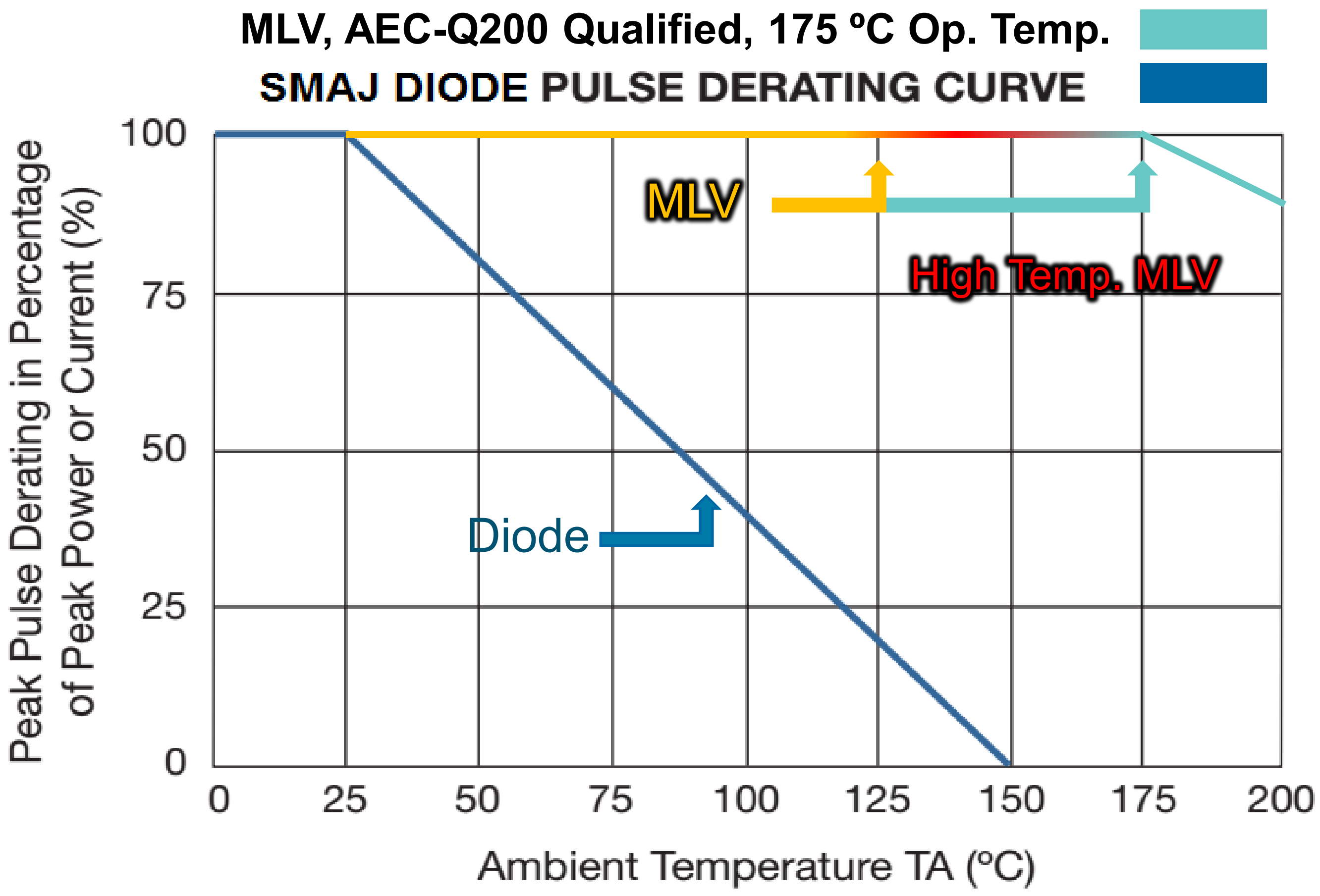




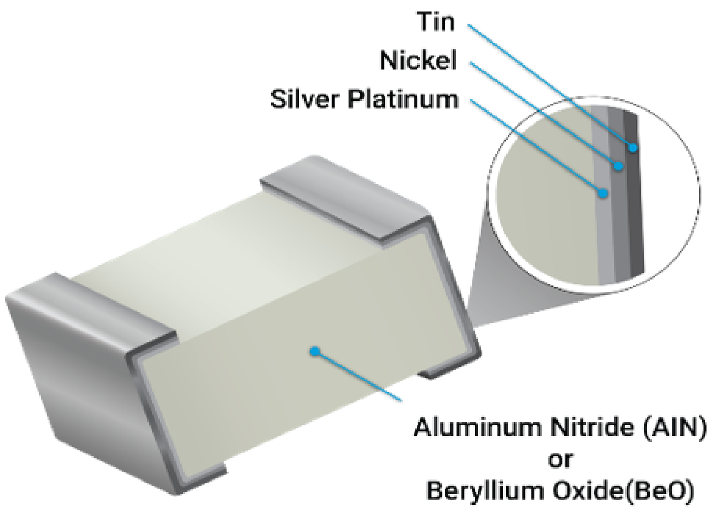
MLV Temperature Improvements

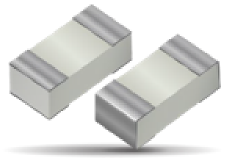
New Developments for Automotive

- High Temp. 175ºC MLV Available
- New dielectric materials – grain boundary modified for higher temperature applications
- More options for designers as more electronics go under hood
- No derating within operating temperature range



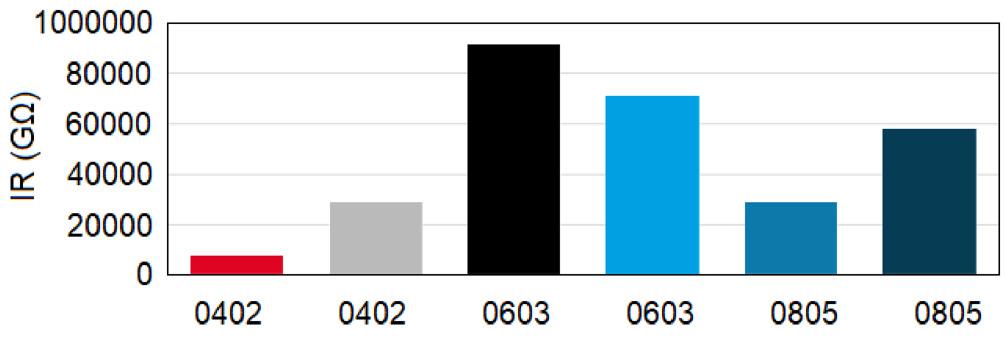
SMT Heat Pipe: Q Bridge

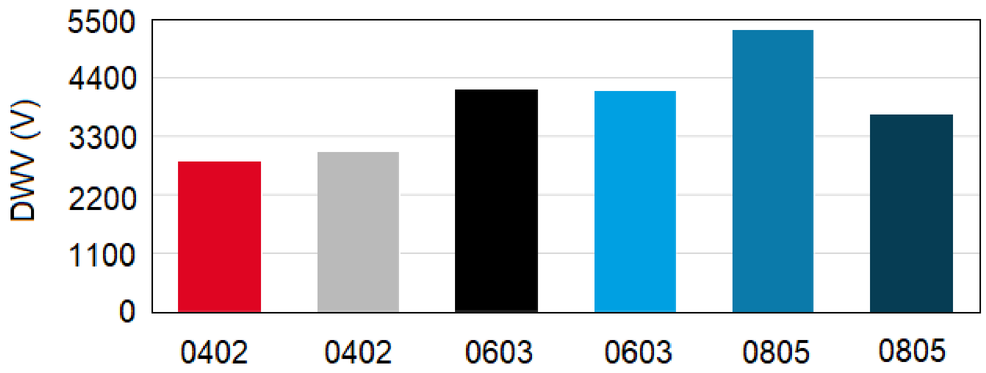


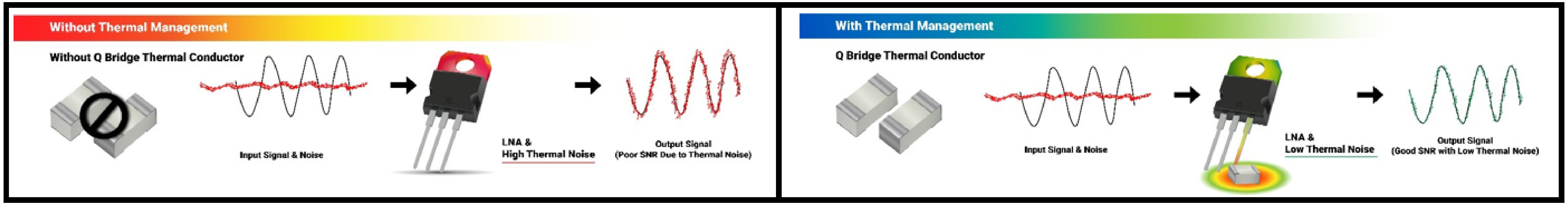
	Q Bridge	
	AIN	BeO
		
Working Rating	100 - 4000 V	100 - 4000 V
Thermal Resistance (°C/W)	4 - 25	3 - 16
Thermal Conductivity (mW/°C)	40 - 320	61 - 508

Case sizes: 0302, 0402, 0505, 0603, 0805, 1005, 1020, 1111, 2010, 2525, 3725, 3737

Electrical Characteristics

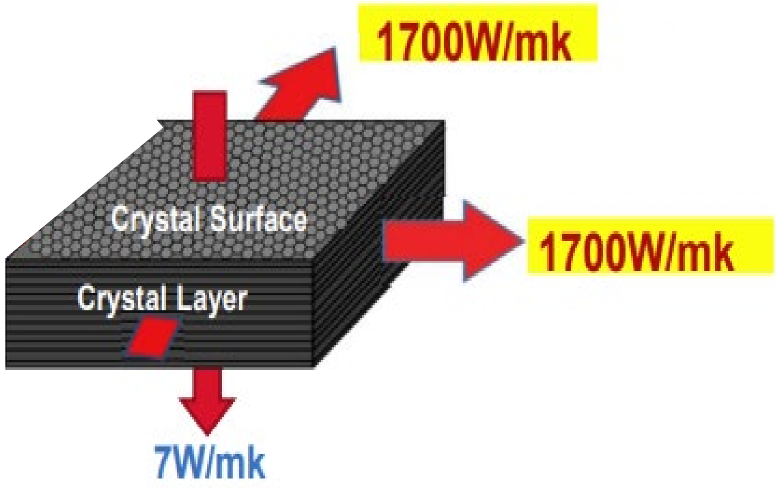


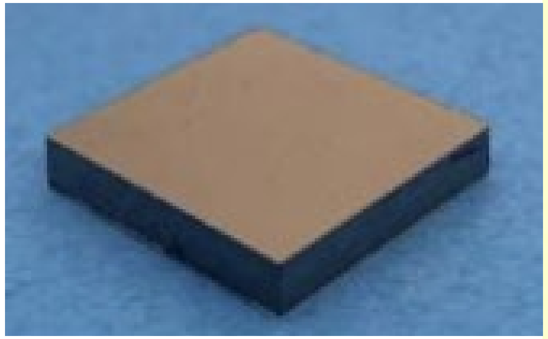


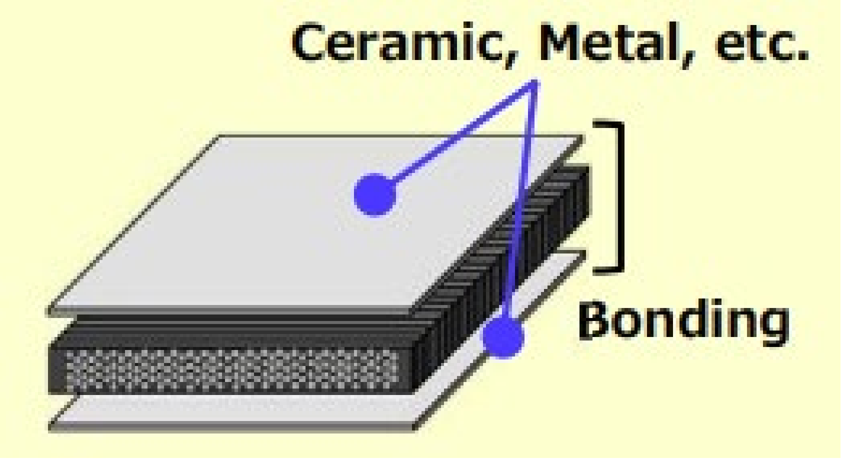


Graphite Heat Spreaders

Direction of Thermal Conductivity







Physical Property	Direction	Unit	Graphite	Copper (Oxygen-Free Copper C1020)	Aluminum
Density	–	G/cc	2.22	8.94	2.71
Thermal Conductivity	X-Y	W/ (mK)	1,700	391	204
	Z		7		
linear expansion coefficient	X-Y	1/K	-0.6×10^{-6}	17.7×10^{-6}	23.9×10^{-6}
	Z		25.0×10^{-6}		
Electrical Resistivity	X-Y	Ohm cm	0.0005	1.68×10^{-6}	2.82×10^{-6}
	Z		0.6		
Tensile Strength	X-Y	M Pa	28.9	195.0	55.0
Elastic Modulus	X-Y	G Pa	50.0	102.9	69.0
Young's Modulus of Elasticity	X-Y	G Pa	33.2	129.8	70.3
Specific Heat	–	J/Kg deg.C	691.0	385.0	900.0

Summary

- Ceramic Capacitors
  - Emerging high temperature automotive applications on rotors and wheels but require use of expensive ceramic boards.
- Tantalum Capacitors
  - Higher capacitance values and voltage ratings are in development.
  - Mn02 achieves highest temperature abilities.
- Supercaps
  - New electrochemical formulas need to be validated and go through extensive testing throughout the manufacturing process before entry to automotive industry.
- Multilayer Varistors
  - MLVs have stable reliability at high temperatures. Short circuit failure mode is low, but possible, with both MLV or TVS Diode. MLV is much lower risk.
  - As IC transient susceptibility increases along with temperatures it is crucial to include repetition of transient events in risk assessment.
- Heat Pipes & Spreaders
  - Innovations continue for thermal management solutions and integration into high temperature passive electronic components.

THANK YOU.

KYOCERA AVX®

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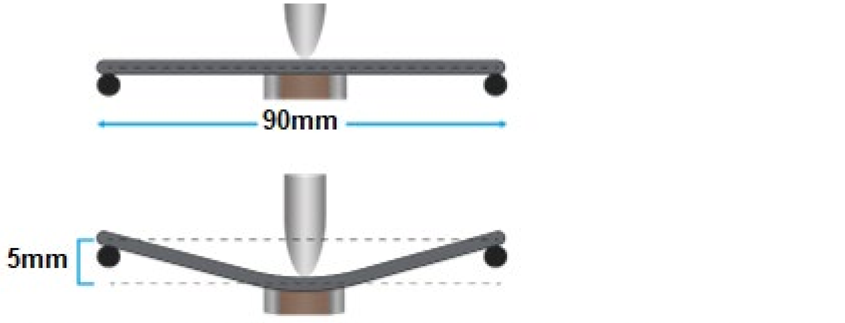
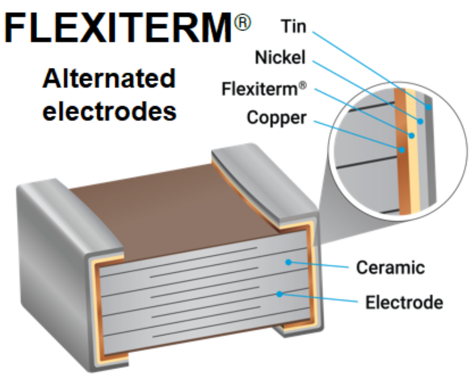
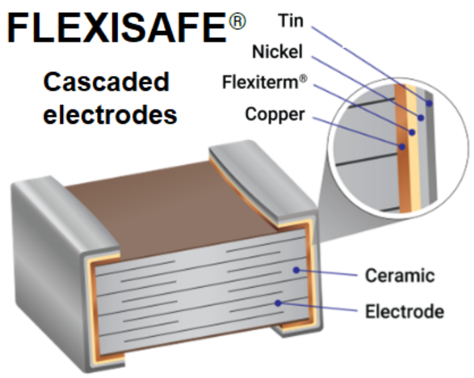
BACK UP SLIDES

FlexiTerm and FlexiSafe MLCCs



Mechanical Force Absorbed by the FLEXITERM® Layer



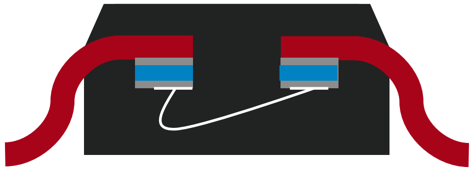


	FLEXITERM											FLEXISAFE
	NP0/C0G			X7R				X8R		X8L		X7R
Temperature	-55°C to +125°C			-55°C to +125°C				-55°C to +150°C		-55°C to +150°C		-55°C to +125°C
Qualification	STD	HIGH V STD	AUTO	STD	HIGH V STD	AUTO	HIGH V AUTO	STD	AUTO	STD	AUTO	STD / AUTO
Voltage Rating	25 - 500V	630 - 5000V	25 - 630V	4 - 500V	630 - 5000V	4 - 500V	630 - 3000V	25 - 100V	25 - 100V	25 - 100V	25 - 100V	16 - 1000V
0402				0.22 - 100nF				0.27 - 4.7nF				
0603	1 - 10nF		0.5pF - 10nF	1 - 220nF		1 - 220nF		0.27 - 68nF	0.27 - 68nF	0.27 - 100nF	0.27 - 100nF	1 - 22nF
0805	0.5 - 470pF	1.5 - 820pF	0.5 - 470pF	1nF - 2.2µF	0.1 - 22nF	1nF - 10µF		0.33 - 220nF	0.33 - 220nF	330pF - 2.2µF	330pF - 2.2µF	1 - 100nF
1206	2.2 - 10nF	1.5pF - 10nF	2.2 - 10nF	1nF - 10µF	0.1 - 33nF	1nF - 10µF	0.1 - 10nF	1nF - 1µF	1nF - 1µF	1nF - 1µF	1nF - 1µF	1 - 150nF
1210	2.2 - 33nF	10pF - 33nF	1 - 33nF	100pF - 10µF	0.1 - 100nF	100pF - 10µF	0.27 - 27nF					1 - 470nF
1808		2.7pF - 6.8nF			0.22 - 68nF		0.22 - 1nF					
1812		10pF - 18nF		1nF - 10µF	0.27 - 220nF	1nF - 10µF	0.33 - 47nF					1 - 10nF
1825		10pF - 8.2nF			1 - 56nF							
2220		10pF - 8.2nF		0.1 - 22µF	1nF - 1µF	0.1 - 22µF	1 - 150nF					1 - 22nF
2225		10pF - 68nF			1nF - 1µF							
3640					1 - 56nF							

TRANSIENT VOLTAGE SUPPRESSION OPTIONS

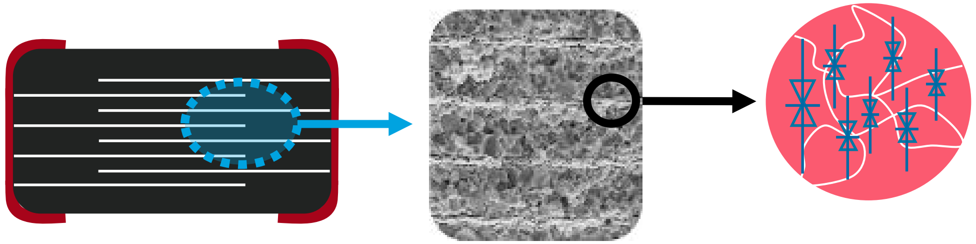
PHYSICAL DIFFERENCES BETWEEN MLVS AND TVS

TVS Diode Construction



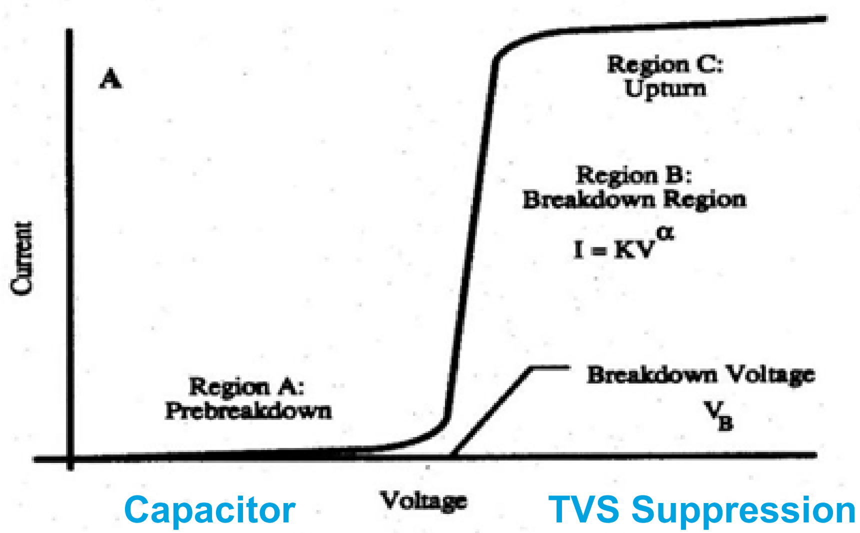
- Transient is absorbed within the P-N Depletion Zone
- Absorption creates heat within depletion zone
- Basis for Low Pulse Resistance/High Derating
- Long Leads - High parasitic inductance
- One P-N Junction (<5% of Volume of device)

Multilayer Varistors

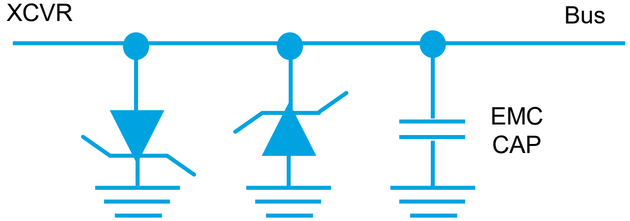


- The ceramic material is doped Zinc Oxide where every grain is a Schottky Diode. The structure between the plates gives series/parallel diodes.
- Even distribution/dissipation of transient energy
- Nearly entire volume dissipates energy – Millions of “P-N junctions”

TRANSIENT VOLTAGE SUPPRESSION OPTIONS



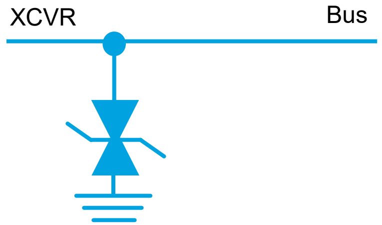
TVS Diodes



Diode protection method three component solution

TVS + EMI

Multilayer Varistors (MLVs)

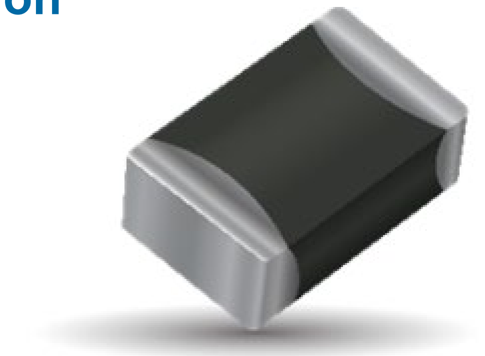


MLV protection method single component solution

TVS + EMI

One Varistor Can Replace 2 Diodes and a Capacitor

MLV Cross Section



MLV Package