

How Capacitors Behave Under High Humidity

Philip Lessner

KEMET Electronics

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PRESENTER

DR. PHIL LESSNER



Ph.D in Chemical Engineering

33 years in Electronics Industry

25 years at KEMET

KEMET's Chief Technology Officer

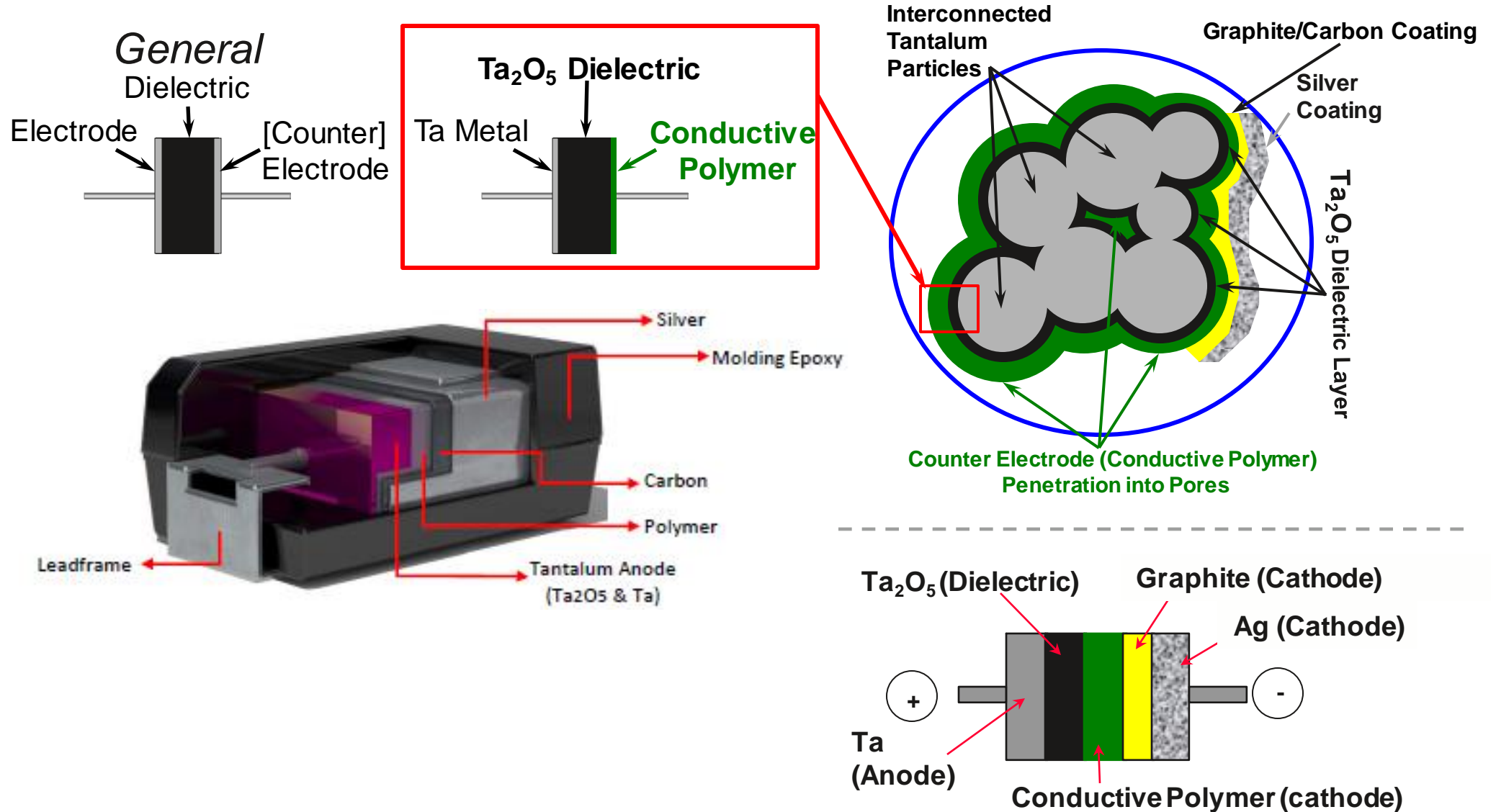
Product, Material, and Process Development

Outline

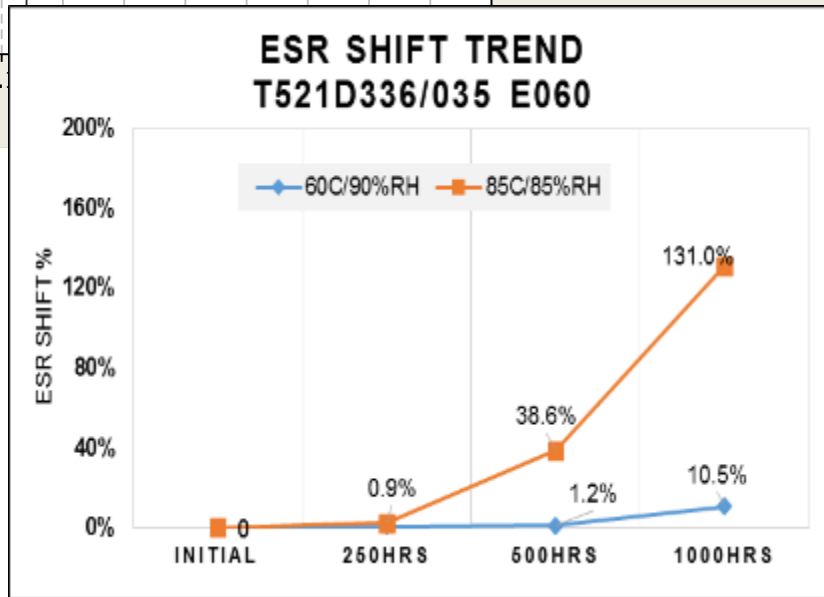
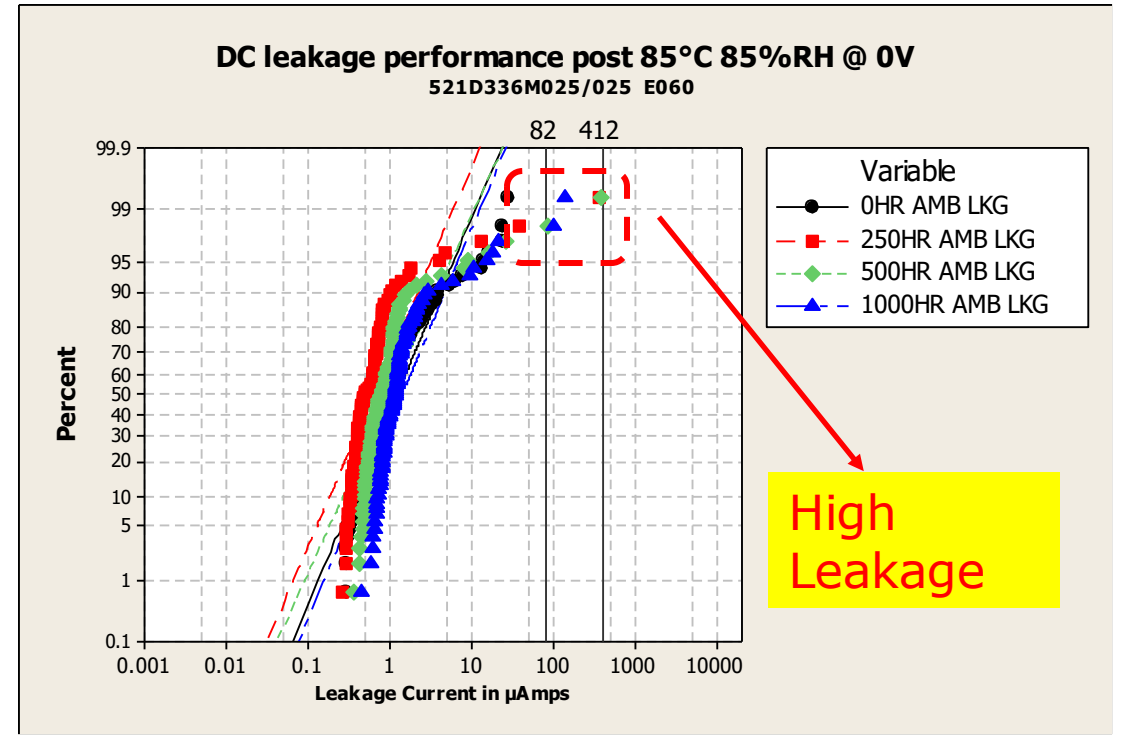
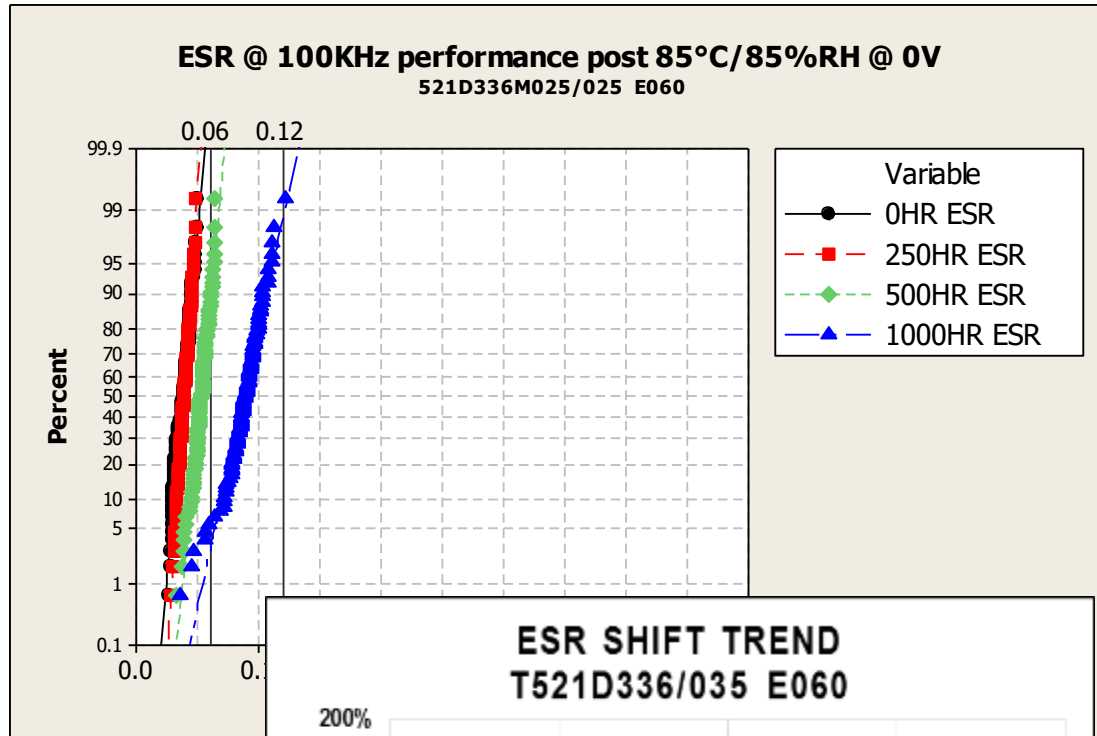
- Tantalum-Polymer Capacitors
- Aluminum-Polymer Capacitors
- Supercapacitors
- Film Capacitors



Tantalum-Polymer Capacitor Construction

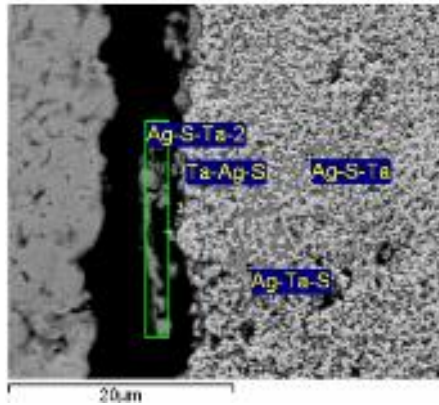


Tantalum Capacitor Behavior Under Temperature/Humidity



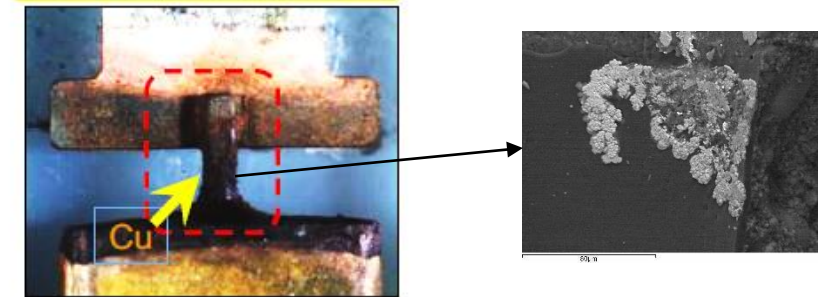
Leakage Increase in Tantalum-Polymer Capacitors Due to Humidity

Cathode



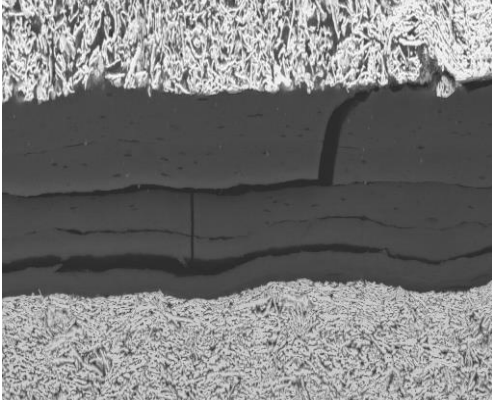
1. H₂O gets into the parts via moisture sorption.
2. Corrosion of silver metal by the acidic solution of Fe³⁺, p-TS⁻, O₂, etc.
3. Transportation of Ag⁺ towards conductive polymer via diffusion.
4. Reduction of Ag⁺ to Ag by conductive polymer
5. Silver in direct contact with dielectric causes increase in parametric leakage and/or failure.

Anode



1. Cu-containing lead frame corrodes in presence of electrolyte and bias and forms Cu ions
2. Cu ions migrate to cathode.
3. Cu ions are reduced at cathode to Cu metal
4. Cu dendrites grow
5. Dendrites grow making a conductive bridge between anode and cathode.

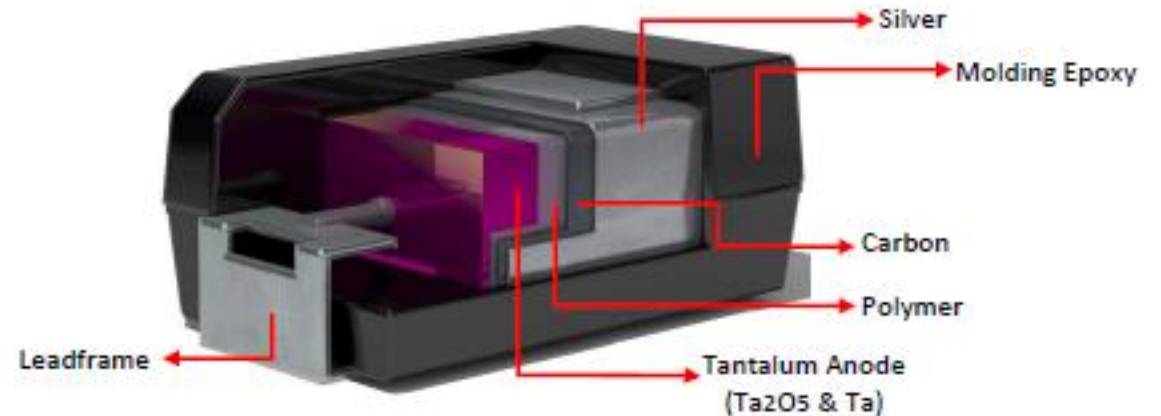
ESR Increase of Tantalum-Polymer Capacitors Due to Humidity



- Poor adhesion of polymer
- Thermomechanical Stress on polymer from adjacent cathode curing/process, Assembly, molding
- Reflow stress (CTE mismatch)
- Poor adhesion of LF/Mold Epoxy interface
- Higher moisture sorption mold epoxy
- Moisture ingress stress (CME mismatch)
- Higher moisture sorption of polymer and swelling
- Bias causing stress increases delamination
- Bias across delaminated interface cause dedoping

Solutions to Tantalum-Polymer Humidity Degradation

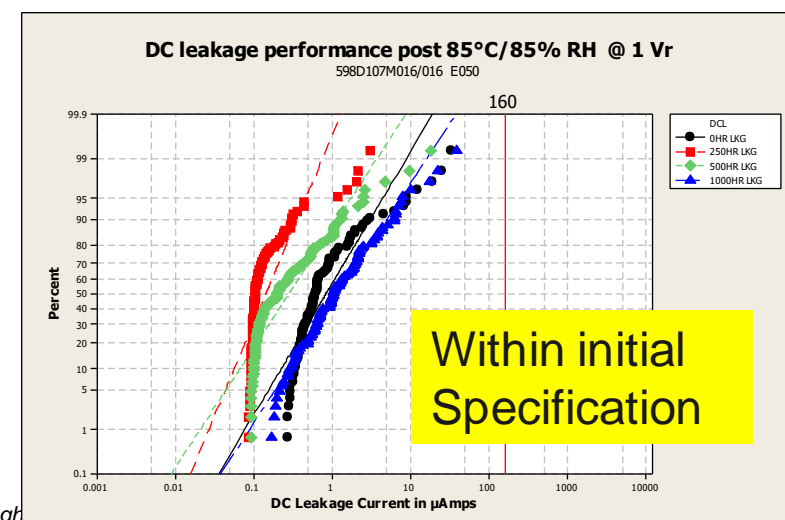
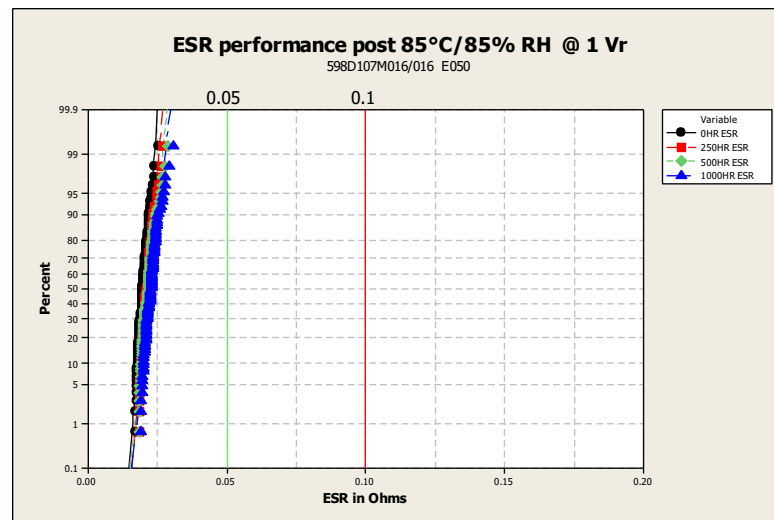
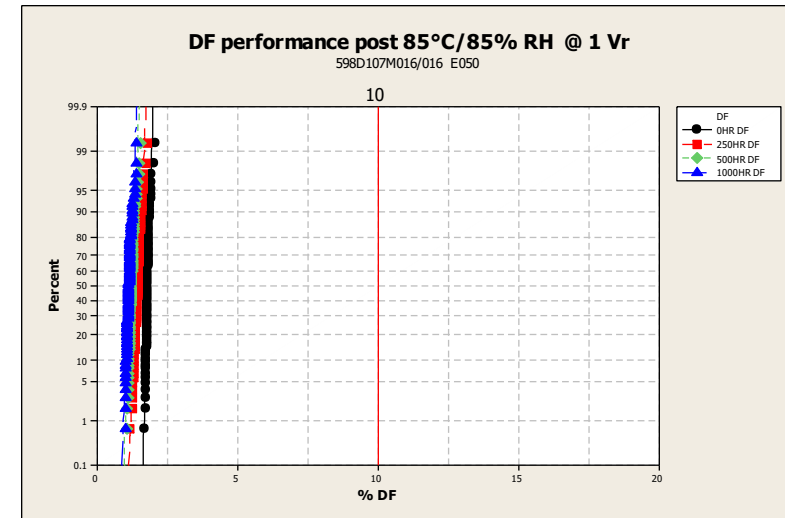
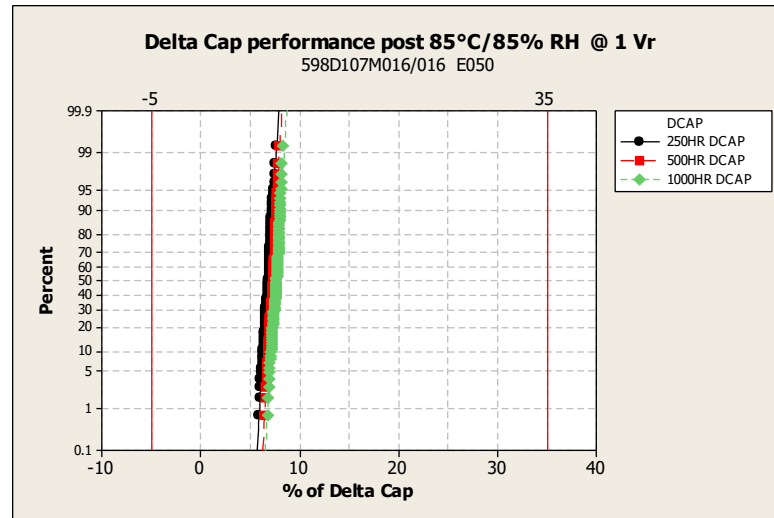
- Reduce moisture penetration through epoxy case
- Protective coatings
- Improve interfacial adhesion
- Low stress curing
- Low/non-Copper lead frames
- Reduction of ionic contaminants



Putting It All Together

85°C/85% RH at Vr

Example of EIA7343-28 100uF 16V ESR = 50 mΩ



All Right

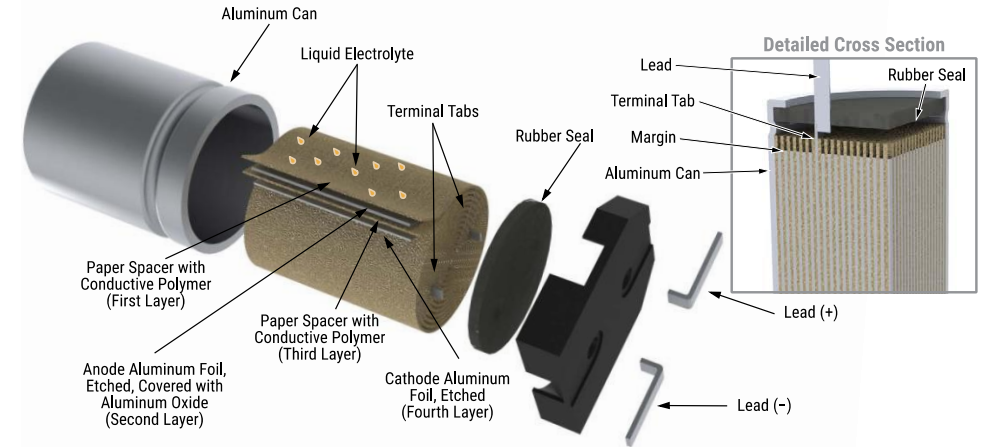
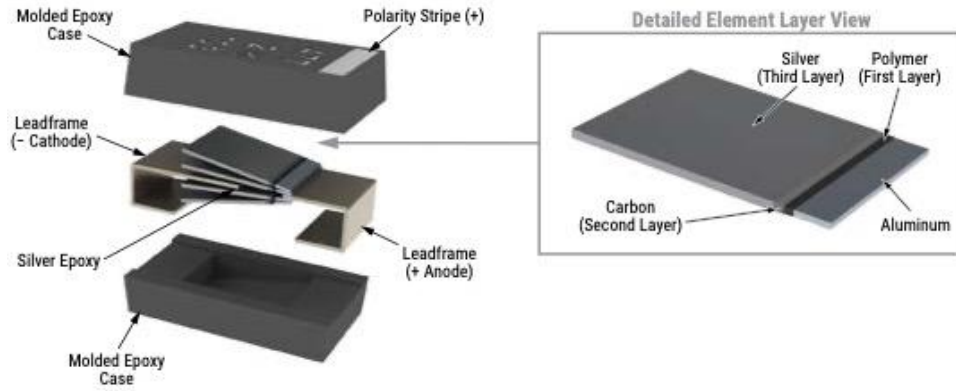


Tantalum-Polymer Capacitors for Harsh Environments

Series	EIA Case Sizes	Voltage Range (V)	Cap Range (μ F)	Lowest ESR (m Ω)	Temperature Rating ($^{\circ}$ C)	85 $^{\circ}$ C/85%RH Endurance (h)	AEC-Q200
T591	3528-21 7343-20 7343-31 7343-43	2.5-75	1.5-680	6	105 or 125 2000h	500	No
T597 (Face Down)	2012-10 3216-12	2.5-10	22-100	9	125 1000h	1000	Yes
T598	3528-21 7343-20 7343-31 7343-43	2.5-75	1.5-680	100	125 2000h	1000	Yes
T599	3528-21 7343-20 7343-31 7343-43	2.5-50	10-150	25	150 2000h	1000	Yes



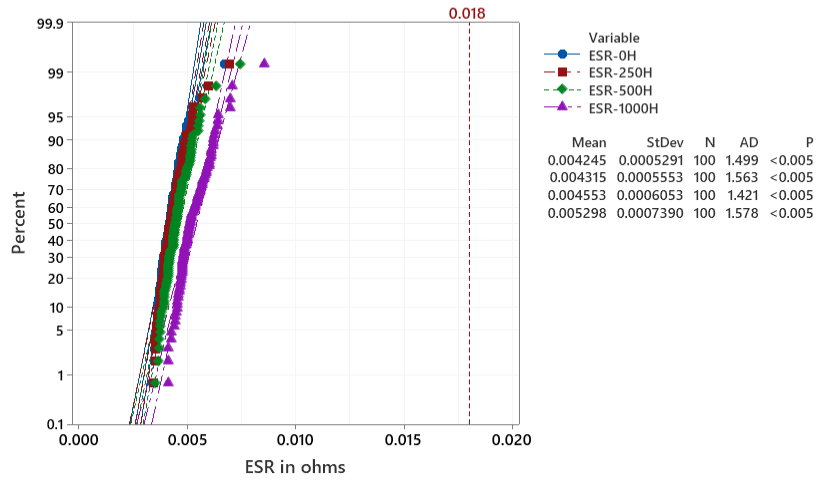
Aluminum-Polymer Construction and Performance



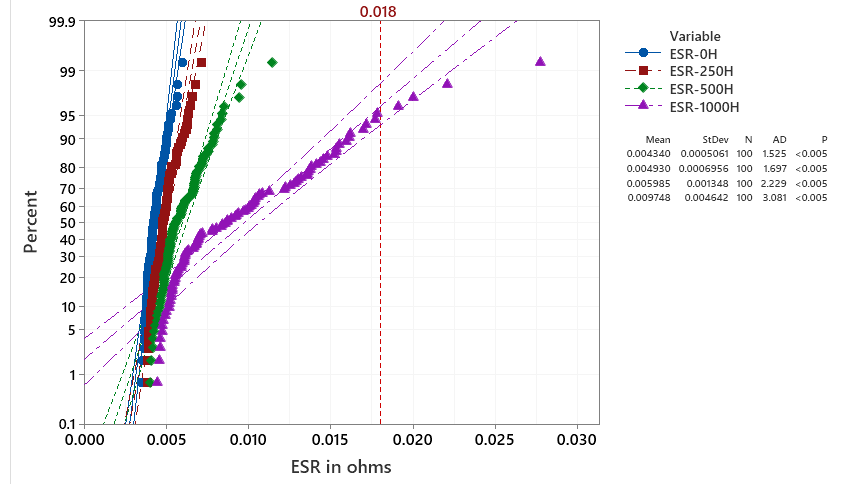
A700 60°C/90% 1000Hrs ESR

A700 85°C/85% 1000Hrs ESR

60C90% Load
Normal - 95% CI

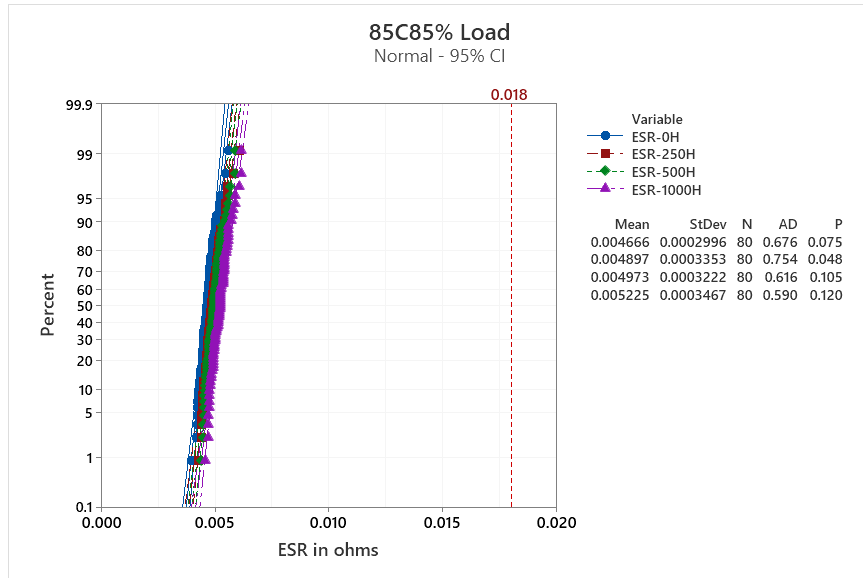


85C85% Load
Normal - 95% CI



Aluminum-Polymer Capacitors for Harsh Environments

A798 85°C/85% 1000Hrs ESR

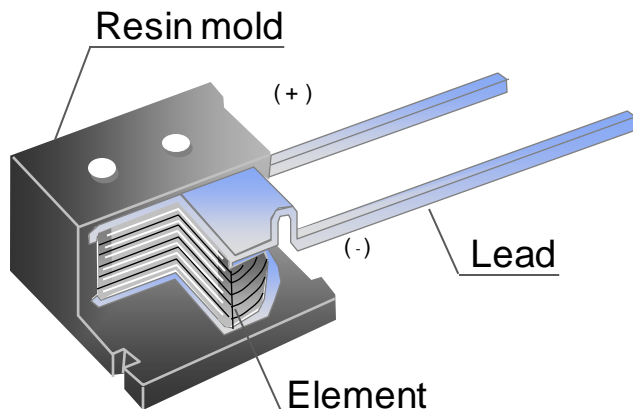
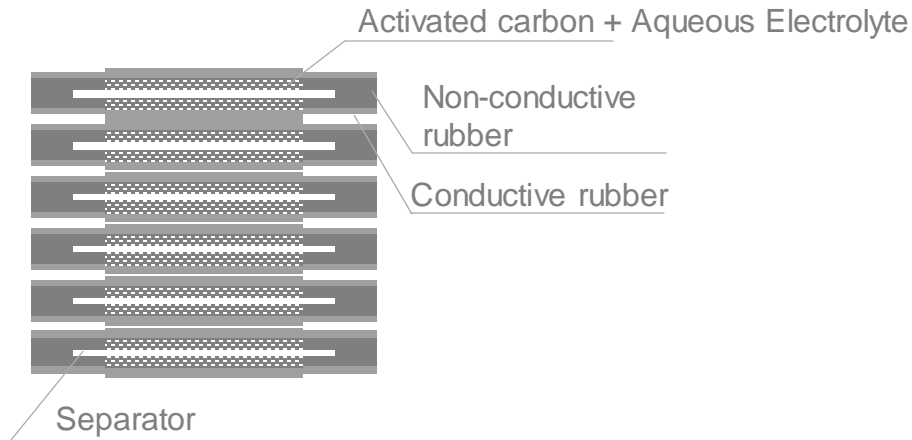




Series	Type	Voltage Range (V)	Cap Range (µF)	Lowest ESR (mΩ)	Temperature Rating (°C)	Humidity Endurance	AEC-Q200
A768	V-Chip Polymer	16-80	18-1000	17	125 2000h	60°C/95%RH 1000h	Yes
A780	V-Chip Hybrid	25-63	56-680	20	125 4000h	85°C/85%RH 2500h	Yes
A798	H-Chip Polymer	2-2.5	470	9	125 1000h	85°C/85%RH 1000h	No



Supercapacitors for Harsh Environments

85°C, 85°C/85%RH 1000h

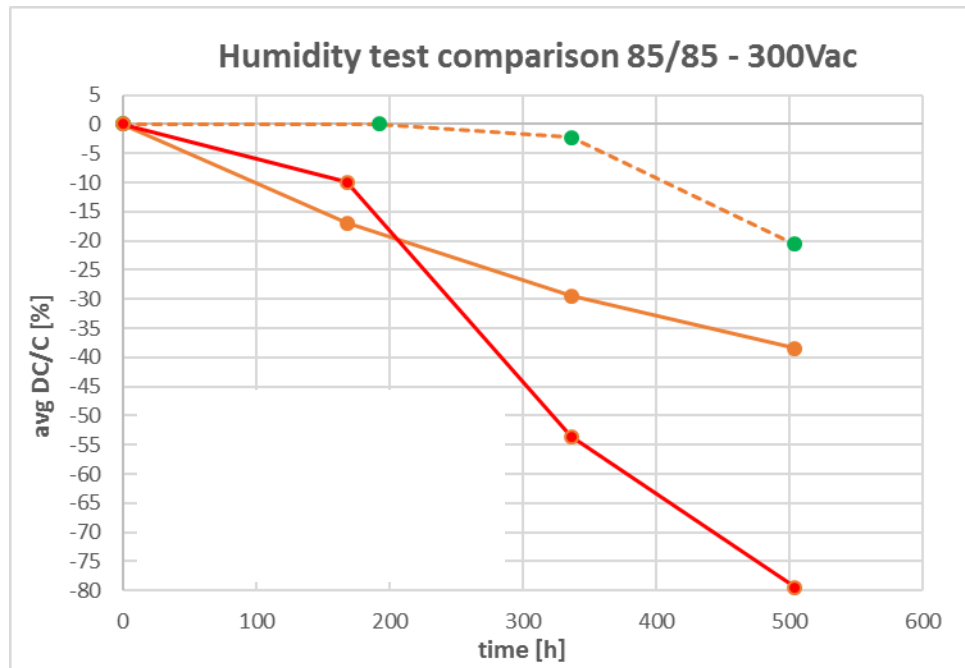


Part Number	Voltage (Vdc)	Capacitance (F)	ESR (Ω @ 1kHz)	Lkg Current (mA @ 30min)
FU0H105ZF 	5.5	1.0	10	1.5
FMD0H334ZF 	5.5	0.33	25	0.5



Film Capacitors For Harsh Environments

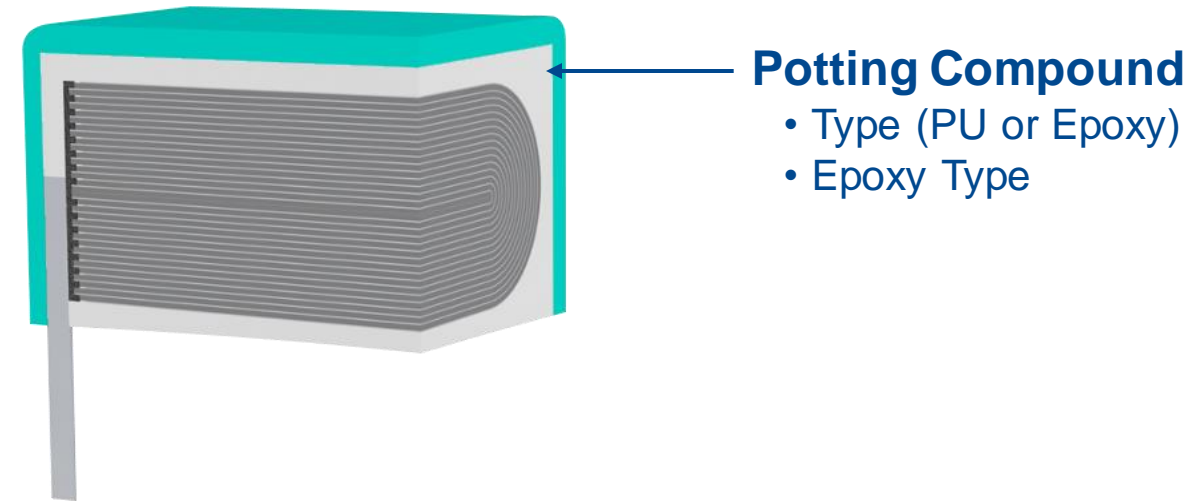
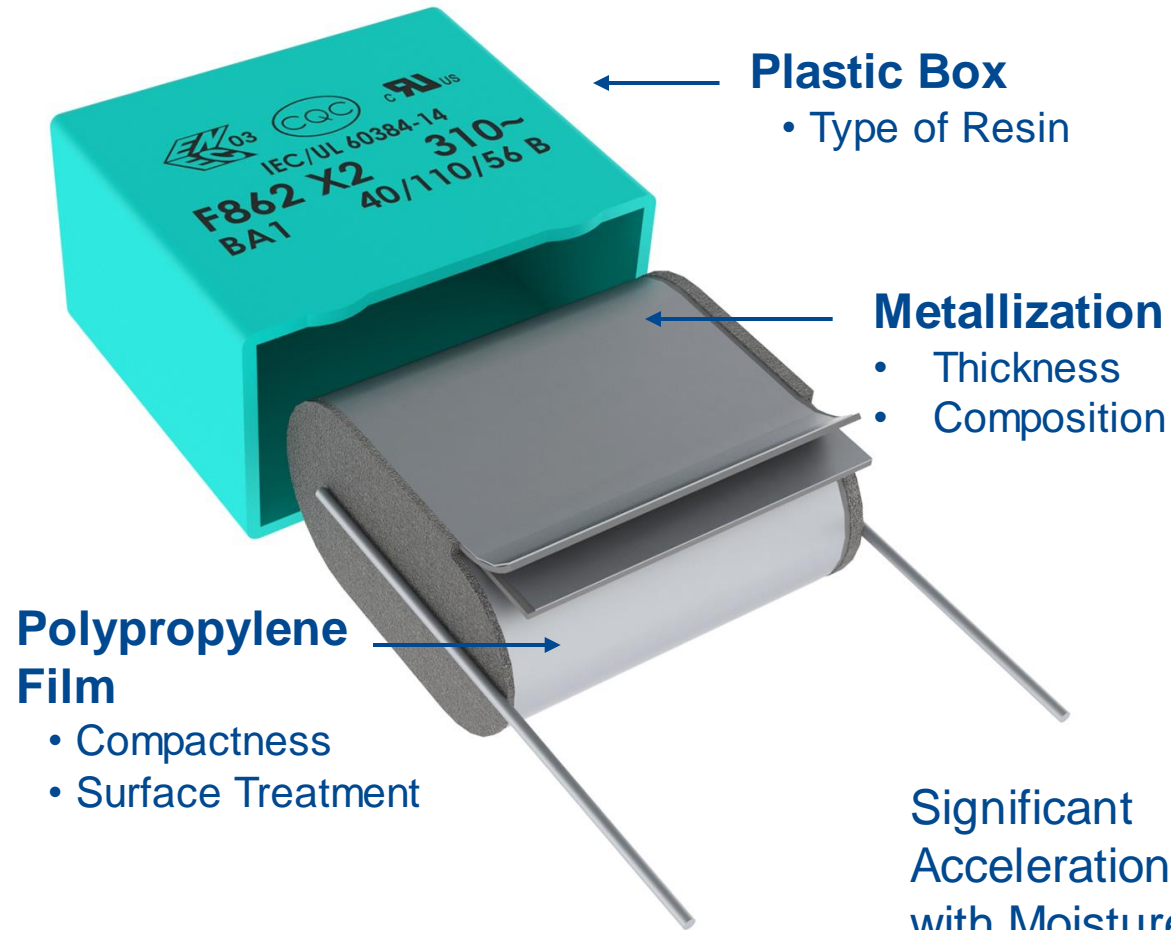
Film X2 Suppressor Capacitor Baseline—No Humidity Protection



Film capacitors show a degradation of capacitance with humidity exposure.



Film Capacitors for Harsh Environments



Capacitance Degradation Mechanisms

Significant Acceleration with Moisture

- Chemical Corrosion of Metallization
- Electrochemical Corrosion of Metallization
- Corona Effect



What is THB?

Temperature Humidity Bias (Rated Voltage)

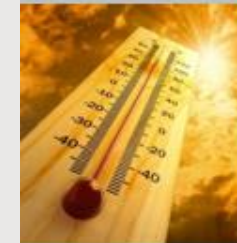
Grade	Test Condition A	Test Condition B
I	40°C/93%RH 21 days	85°C/85%RH 168 hours
II	40°C/93%RH 56 days	85°C/85%RH 500 hours
III	60°C/93%RH 56 days	85°C/85%RH 1000 hours

Requirements

Capacitance	$ \Delta C \leq 10\%$ 0.024 for $C \leq 1\mu\text{F}$
DF	0.015 for $C > 1\mu\text{F}$
IR	>50% of applicable limits



International
Electrotechnical
Commission
60384-14 Am.1
Ed.4 Fixed
capacitors



High
Temperature



High
Humidity



Extended
Reliability

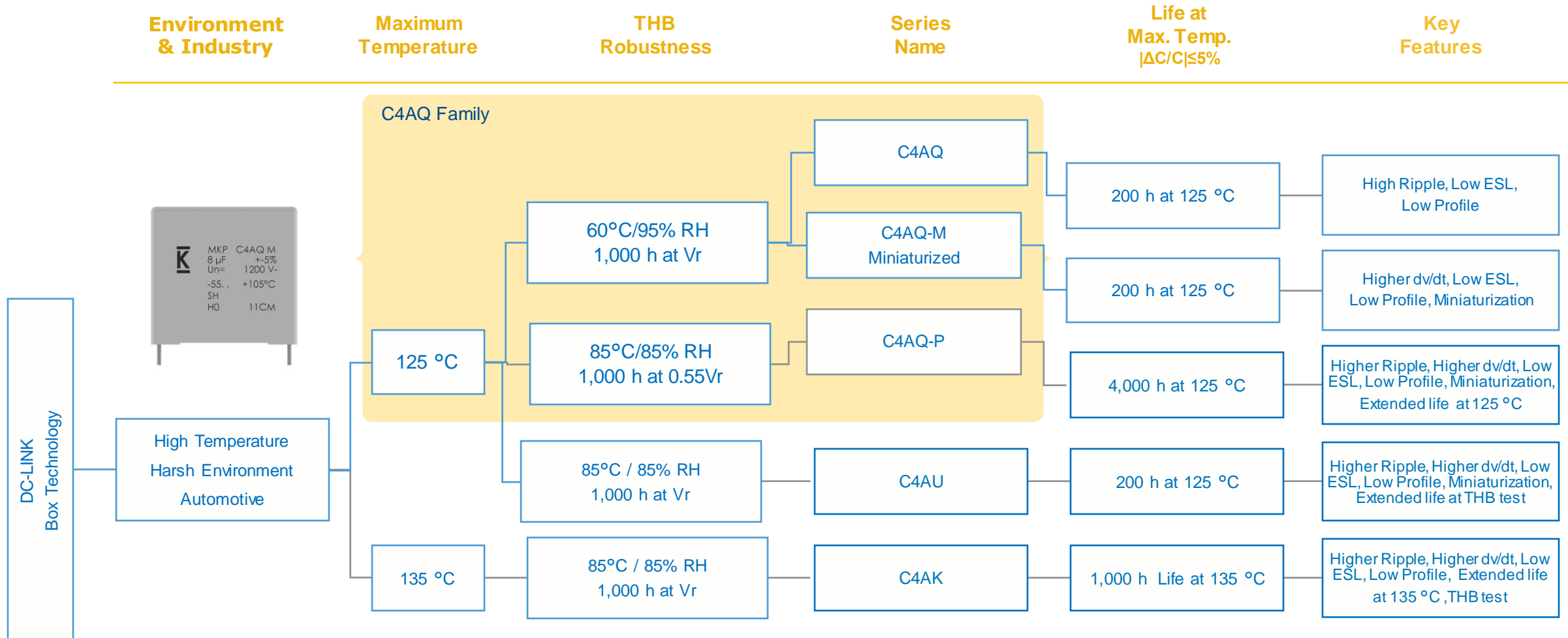
Film Suppressor (Safety Rated) Capacitors for Harsh Environments

Class	Series	Temp (°C)	Vac (V)	THB Grade	Remarks
X2	R46	110 125	275 310	IA	High temperature
	R46M	110	275	IA	Consumer Miniaturized
	F861	110	310	IA	Industrial applications
	R51	110	310	IB	Industrial Applications
	F862 V054	110	310	IIB	Automotive, Harsh Environment
	F863	110	310	IIB	Automotive, Harsh Environment
	R52	110	310	IIB	Automotive, Harsh Environment, Miniaturized
	R53	110	310	IIIB	Automotive, High T, Harsh Environment
	R47	110	440 520	IA	Automotive
	PHE844	105	480	IA	Industrial applications

Class	Series	Temp (°C)	Vac (V)	THB Grade	Remarks
X1	R49	110	330	IA	Industrial applications
	R47	110	440	IA	Industrial applications
	PHE845	105	760	IA	Industrial applications
	R41	110	300	IA	Industrial, Automotive
Y2	R41T	125	300	IIIB	Automotive, High T, Harsh Environment



DC-Link Film Capacitors for Harsh Environments



Film ^

Series

F862 V054 v

Pitch

15 v

Voltage

310 v

Film Available ^

- 100 nF - F862BK10413102 V054
- 150 nF - F862BK15413102 V054
- 220 nF - F862BP22413102 V054
- 330 nF - F862BS33413102 V054
- 390 nF - F862BS39413102 V054
- 470 nF - F862BY47413102 V054
- 560 nF - F862BZ56413102 V054

K-LEM: Life Expectancy Model v1.0 **BETA**

Profile	Vac (V)	Amb. (°C)	Rel. Humid. (%)	Working Time (%)	Life per Profile
Profile 1	240	50	20	50	75,000 hrs
Profile 2	240	50	20	25	37,500 hrs
Profile 3	240	50	20	25	37,500 hrs

[Add Profile](#) [Remove Last Profile](#)

Operating Lifetime Expectancy [$\Delta C/C=-20\%$]: 150,000 hrs -- 17.6 yrs

note: Maximum Rated Lifetime is limited to 150,000 hours.

Selected Part

Part Number	Series	Lead Spacing (mm)	Cap.	Vac (V)	Max. Amb. Temp. (°C)
F862BP22413102 V054	F862 V054	15	220 nF	310	110

Mission Profile 3 Input

Temperature, Relative Humidity and Voltage

Harsh Environment

Tool suitable for all the THB Film Series

Output

Life-Time Expectancy

Help the customer in design phase to select the KEMET series and part numbers



Thank you for your interest.



Philip Lessner

Philip.Lessner@yageo.com

+1-864-350-3563

Capacitor Industry Session

