Multiple Capacitor Dielectrics Support Wide Band Gap Solutions

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APEC 2022 Capacitor Industry Session

March 24, 2022

Wide Band Gap Semiconductors

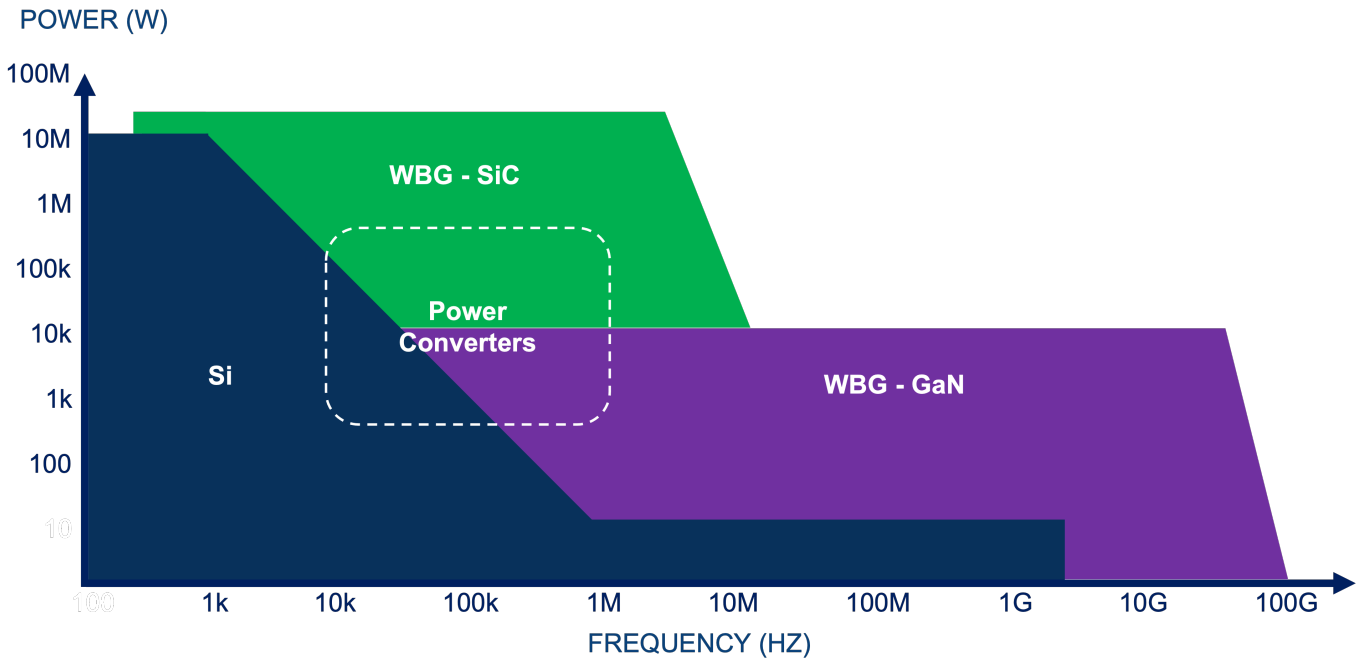
What Are They?

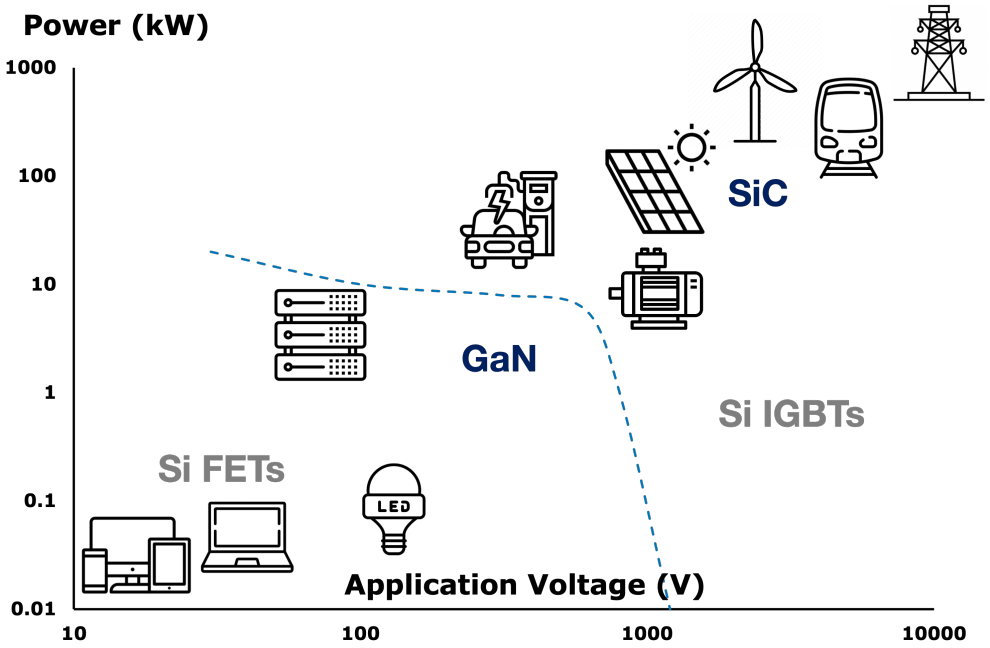
Semiconductor Material	Bandgap Energy (eV)	
Germanium (Ge)	0.7	
Silicon (Si)	1.1	
Silicon Carbide (SiC)	3.3	**Wide Band Gap**
Gallium Nitride (GaN)	3.4	

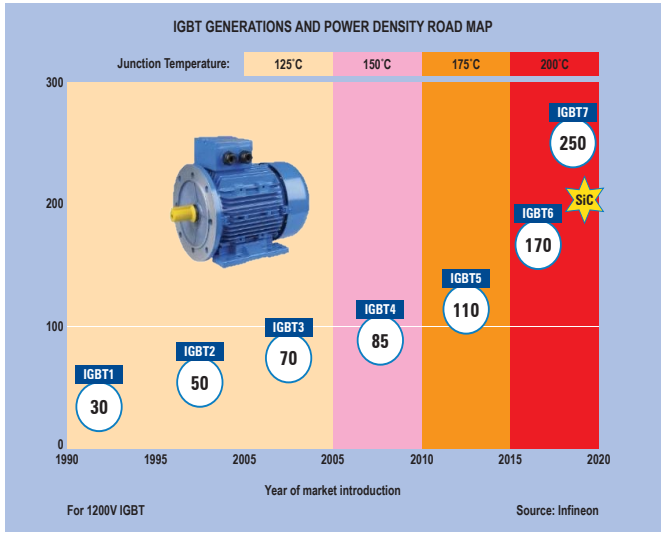
Why Use Them?

- Higher Efficiency Power Conversion
- Smaller Size Systems
  - Frequency ↑ (Smaller passives)
  - Temperature ↑
- Higher Voltage

Performance Characteristics of WBG Semiconductors







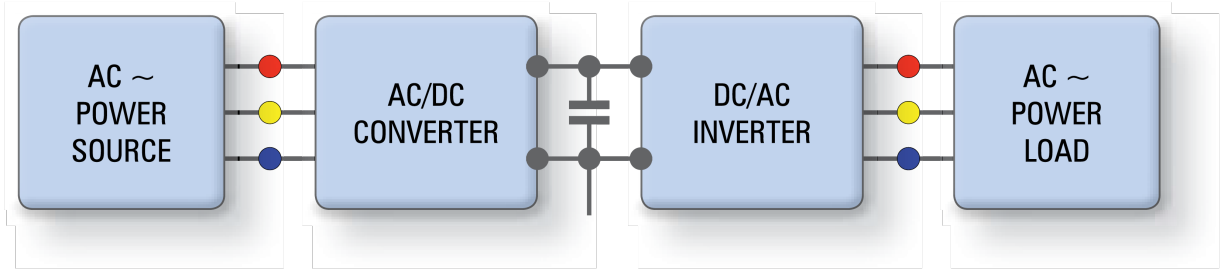
THE BIG 3 FOR WBG

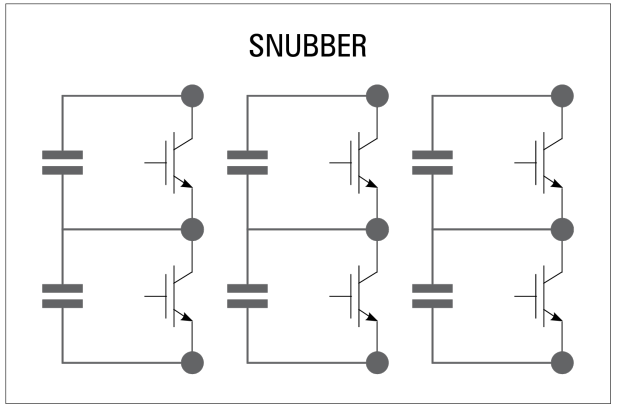
Higher Frequency

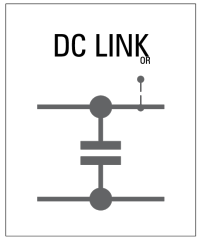
Higher Voltage

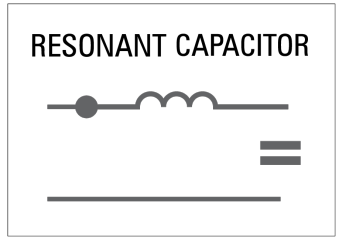
Higher Temperature

Capacitor Requirements







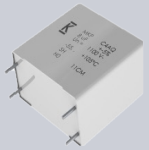
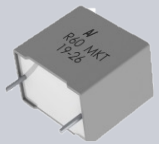
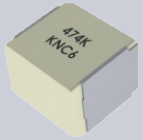
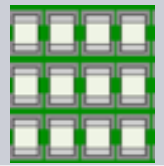
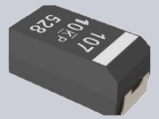


Capacitor Requirements	Wide Bandgap	
	DC-LINK	Snubber
Capacitance Density	●	○
Capacitance Stability vs Temperature	○	○
Capacitance Stability vs Voltage	○	○
Low ESR	●	●
Low Inductance	●	●
High DC Voltages	●	●
High AC Voltages	●	●
High AC Current	●	●
High Temperature Operation (>125C)	●	●
High Frequency Operation (>100kHz)	●	●

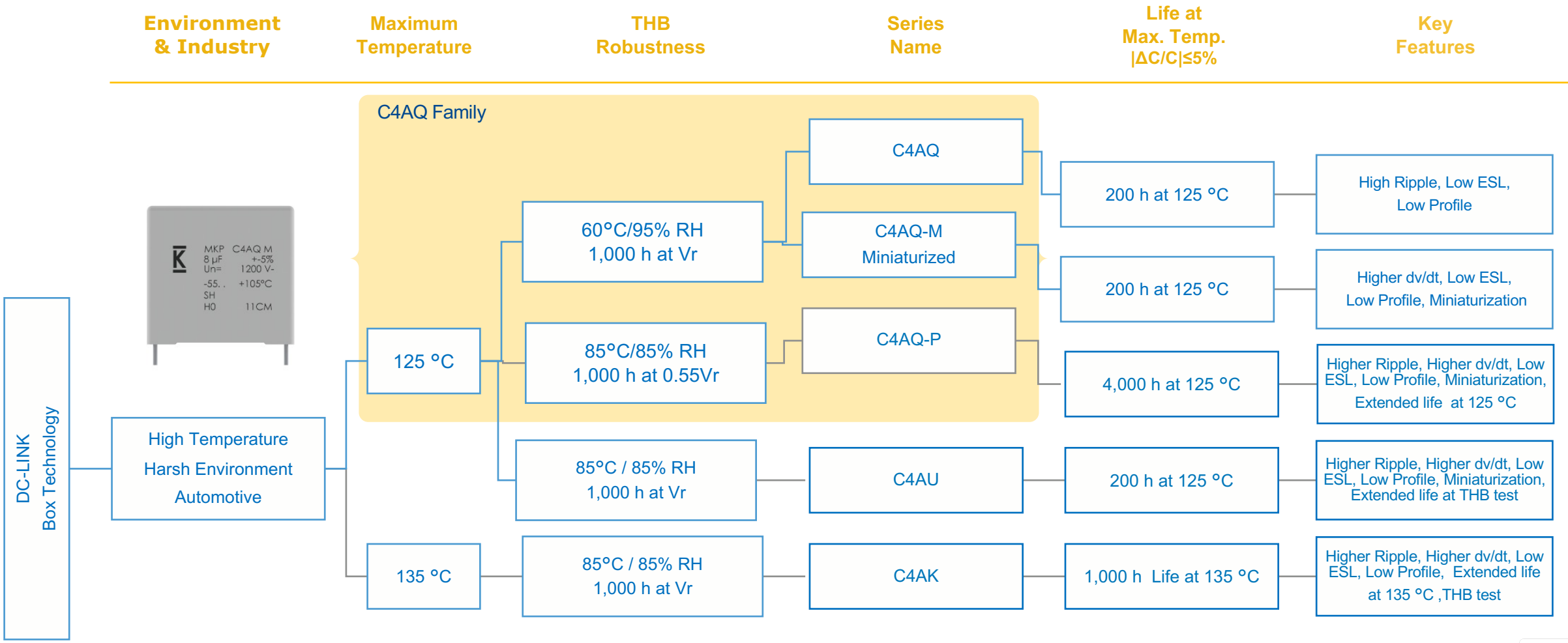
● - Critical Characteristic

○ - Important Characteristic, but not Critical

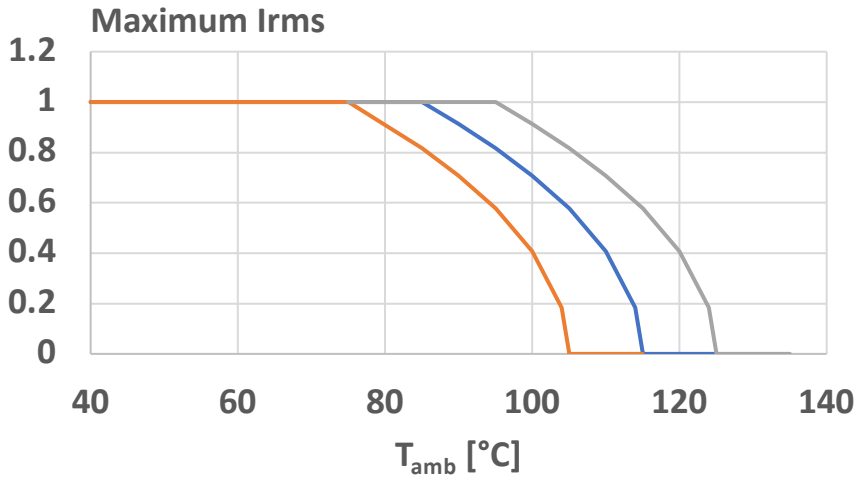
DC-Link Capacitor Choices

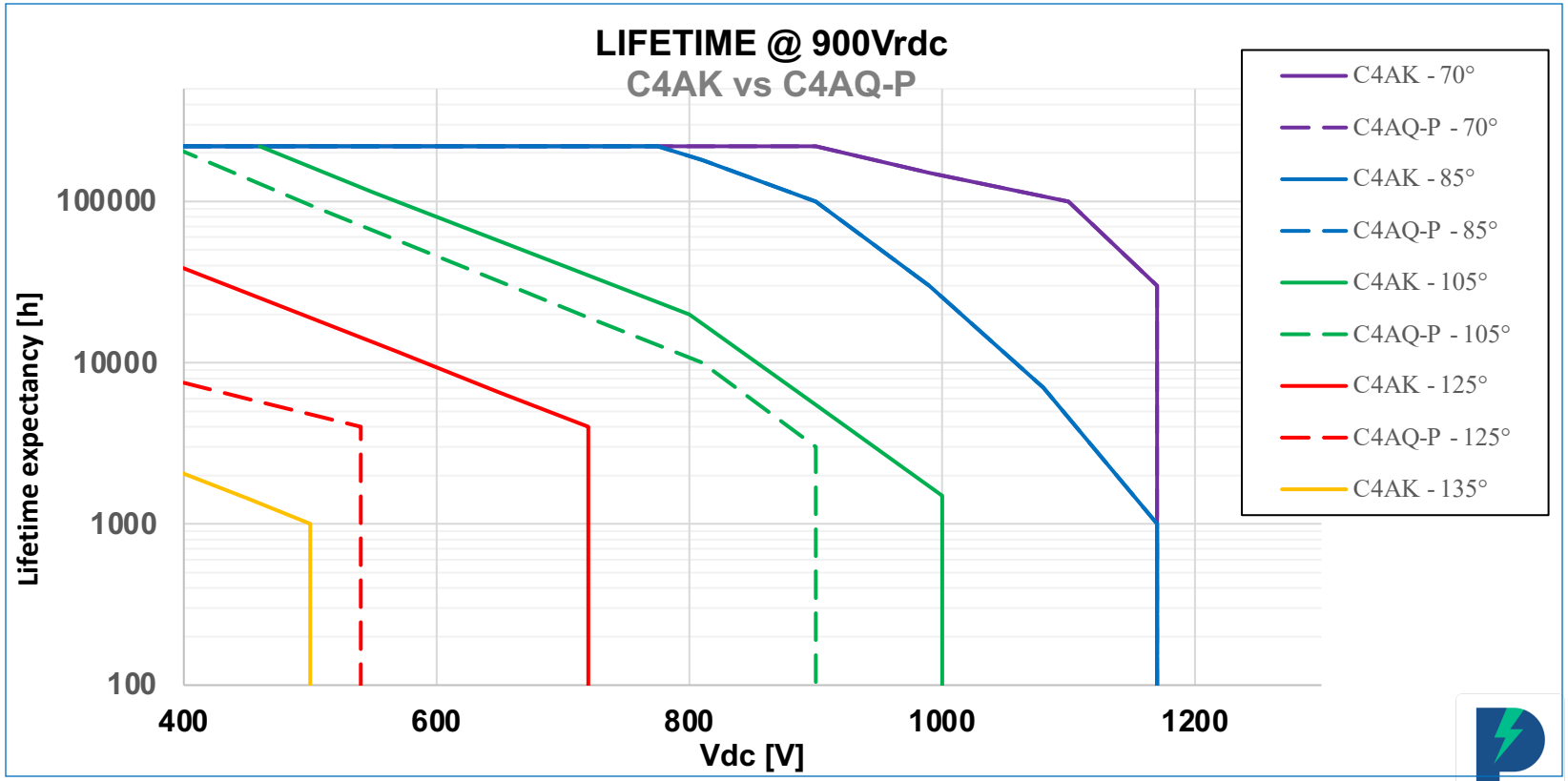
Rated Voltage: Application	Electrolytics					Film			MLCCs		Tantalum
	Axials / Hybrid	Snap-Ins	Screw term.	Radial	Polymer / Hybrid	PP	PET	SMD	X7R Bank	KC Link / C0G	KO Caps
											
Up to 100V: Small scale industrial / automotive drives	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓
100Vdc – 500Vdc: Industrial Drives, eComp, Buffer for industrial ECUs	✓	✓	✓	✓	✓*	✓	✓	✓	✓	✓	✗
500Vdc – 900Vdc: OBC, Power Train	✗	✗	✗	✗	✗	✓	✗	✗	✗	✓ WBG	✗
600Vdc – 1500Vdc: Solar and wind converters	✗	✗	✗	✗	✗	✓	✗	✗	✗	✓ WBG	✗
48V - 52V Powertrain	✓	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗

DC-Link Film Capacitors



Ripple Current and Lifetime

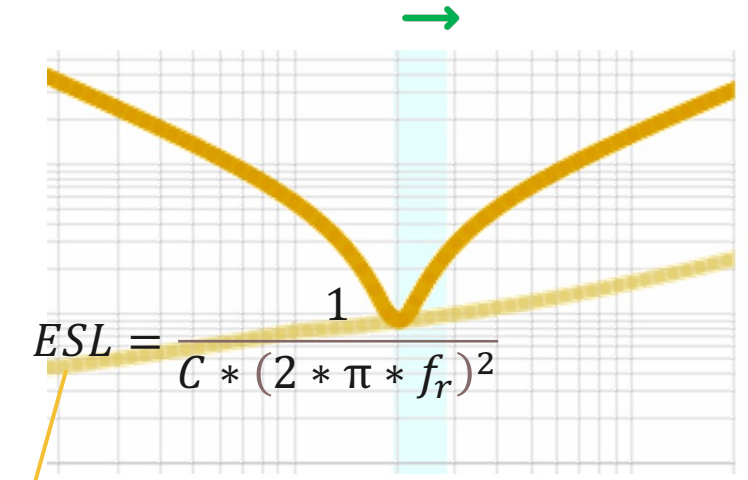




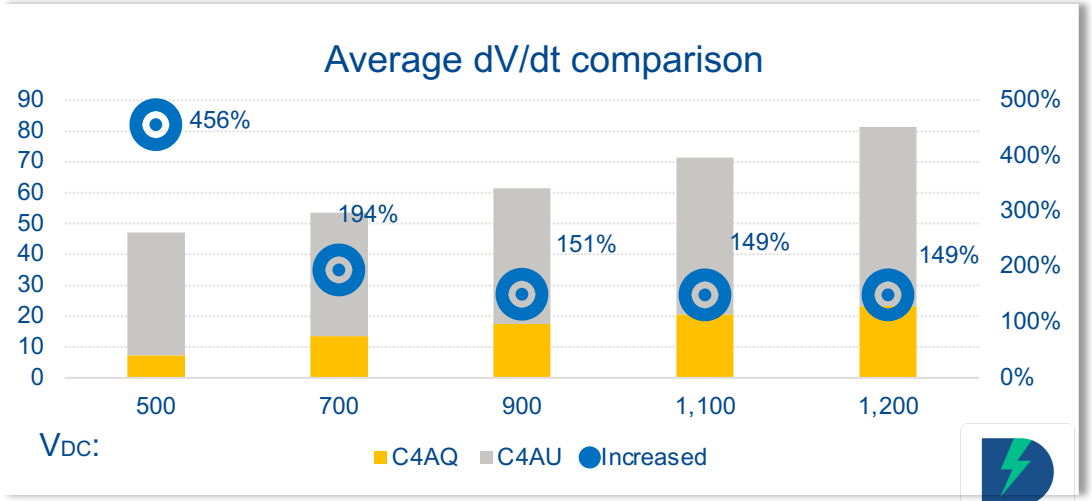
Resonance Frequency and dV/dt Performance

C4AQ Series

Cap Value (μF)	VDC	Dimensions (mm)					Wire Ø	ESL old	ESL new	f Res
		B	H	L	P	P1	mm	nH	nH	kHZ
U_{NDC} @70°C = 500Vdc; U_{OP85} @85°C = 450Vdc; U_{OP105} @105°C = 350Vdc										
5.6	500	11	20	31.5	27.5	\	0.8	25	17	516
10	500	13	25	31.5	27.5	\	0.8	25	22	339
12.5	500	14	28	31.5	27.5	\	0.8	26	24	291
15	500	19	29	31.5	27.5	\	0.8	26	25	260
25	500	22	37	31.5	27.5	\	0.8	28	28	190
40	500	20	40	42	37.5	10.2	1.2	30	12	230
50	500	28	37	42	37.5	10.2	1.2	30	10	225
70	500	30	45	42	37.5	20.3	1.2	30	13	167
90	500	35	50	42	37.5	20.3	1.2	35	14	142
100	500	30	45	57.5	52.5	20.3	1.2	35	13	140
130	500	35	50	57.5	52.5	20.3	1.2	35	15	114
170	500	45	56	57.5	52.5	20.3	1.2	41	17	94
210	500	45	65	57.5	52.5	20.3	1.2	45	19	80

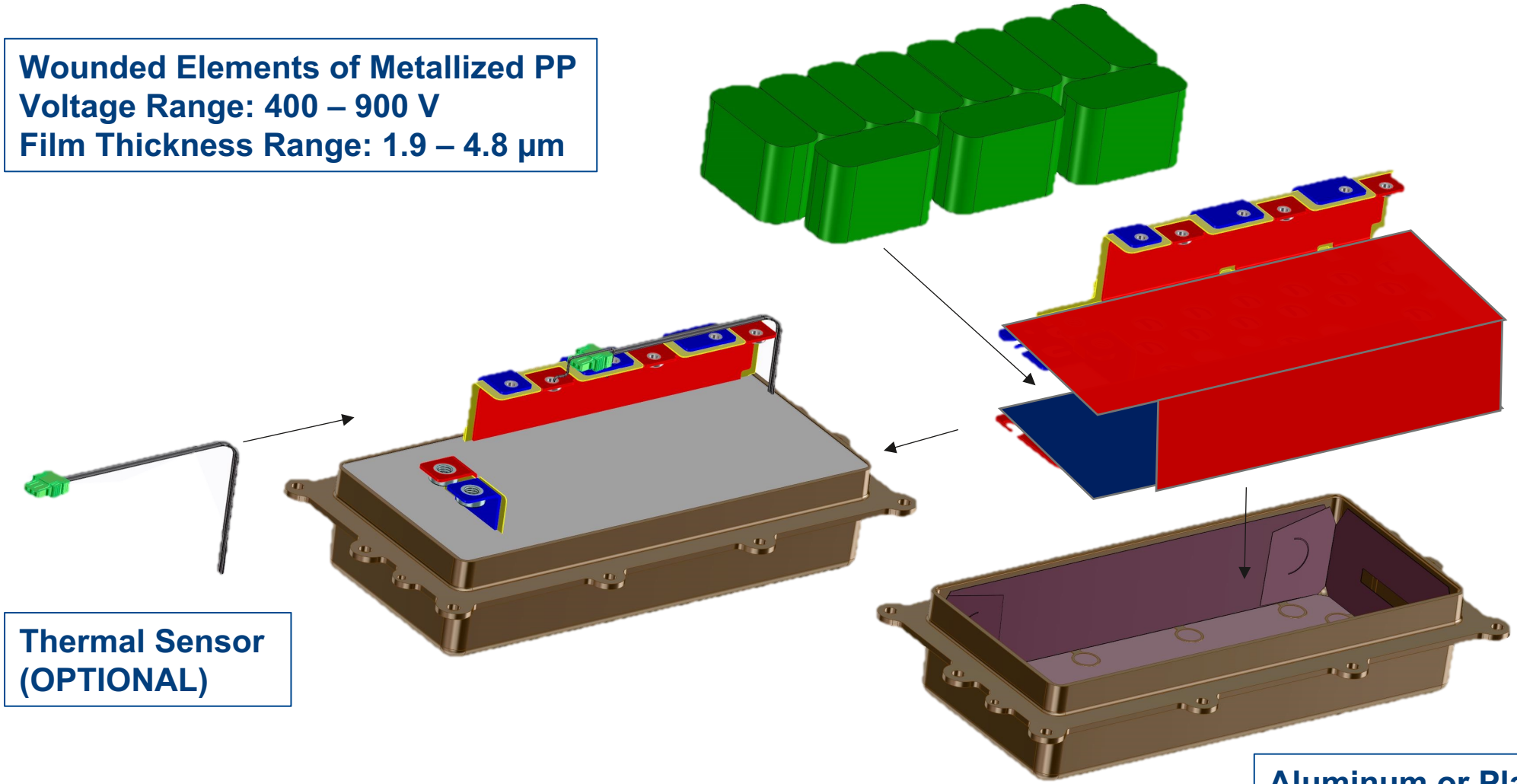


- f_r: (SRF) Frequency at the lowest Z value
- ESL measured near the resonance frequency
- C measured at 1 kHz



Custom Film Brick Capacitors

Wounded Elements of Metallized PP
Voltage Range: 400 – 900 V
Film Thickness Range: 1.9 – 4.8 µm



Busbar and Terminals in Sandwich Design for the Minimization of ESL

The Copper can be Naked or Ni-plated/passivated, and Insulation in PET. (*)

Thermal Sensor (OPTIONAL)

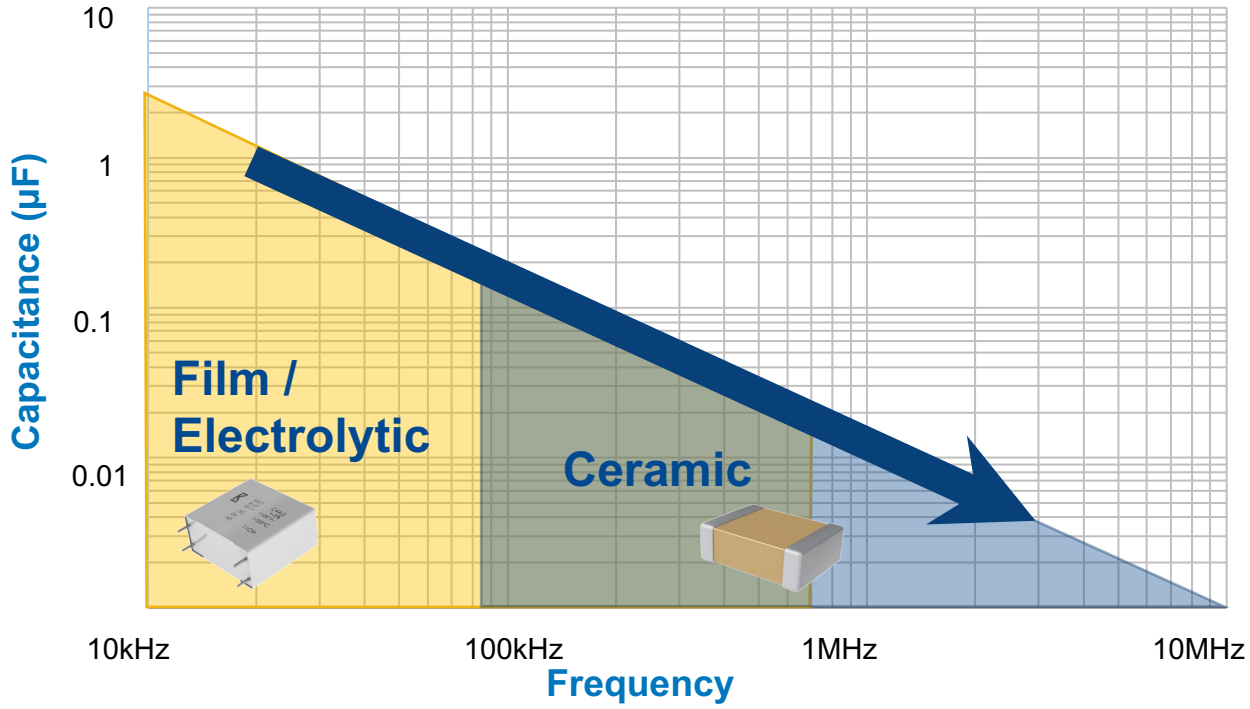
Aluminum or Plastic (PST) Case

Snubber and Resonant Film Capacitors

Metallization	Series	Max V (V)	Min C (pF)	Max C (µF)	Max Hot Spot T (°C)	Self Healing	Max dV/dt (V/µs)	85/85 THB
Single Metallized	R75	2000	220	33	105	Best	9500	
	R75H	2000	1000	33	125	Best	9500	Yes
Double Metallized	R76	2000	100	12	110	Good	11000	
	R76H	2000	470	12	125	Good	11000	Yes
	R76K	850	4700	0.27	135	Good	4000	Yes
Film/Foil	R73	2000	100	2.2	105	No	54000	

Effect of Frequency on Capacitance Requirements

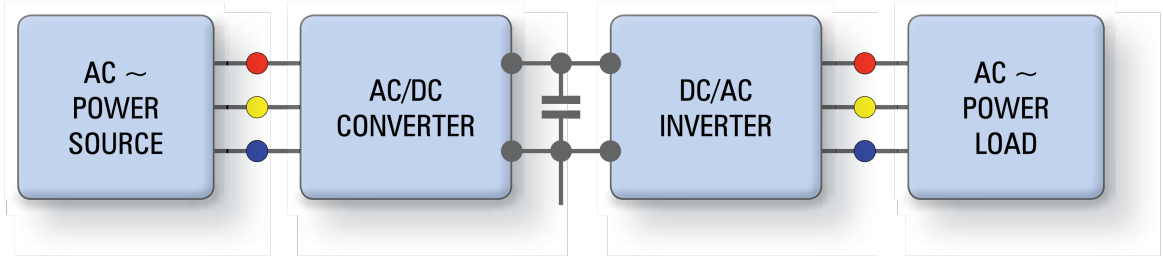
$$C = \frac{P_{load}}{V_{ripple}\left(V_{max} - \frac{V_{ripple}}{2}\right) 2\pi f_{rectifier}}$$

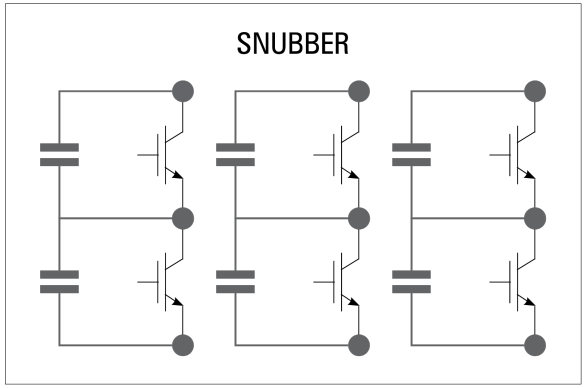


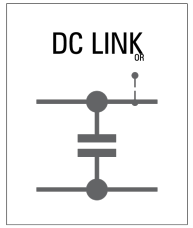
Source: Modified from Prof. R. Kennel, Technical University Munich, Germany

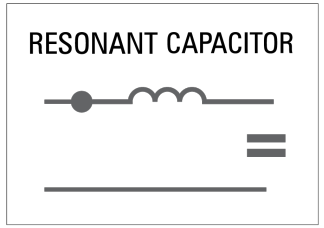
Ceramic Capacitors

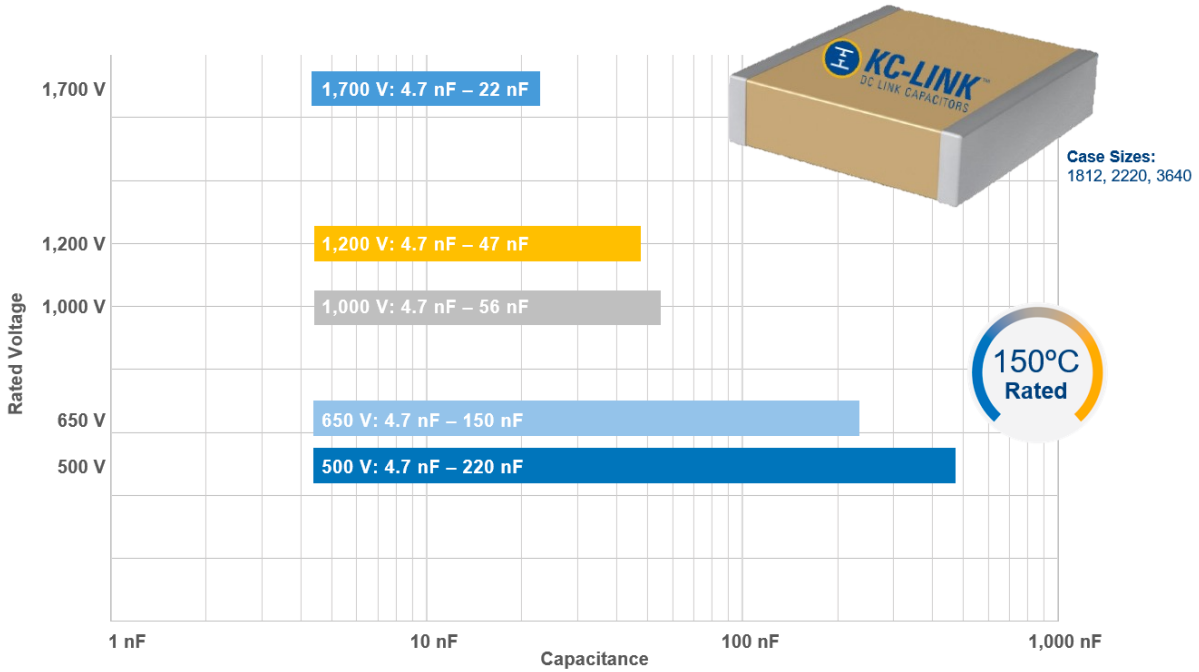
KC-LINK
DC LINK CAPACITORS







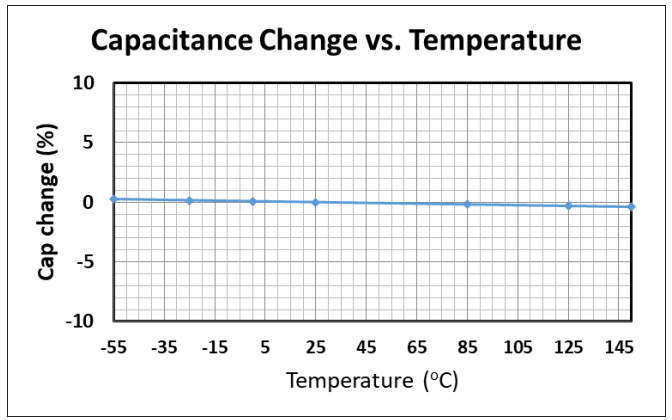




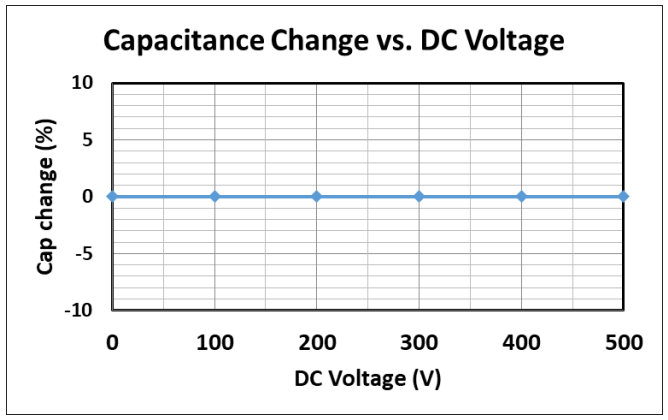
Features

3640,
0.22uF,
500V

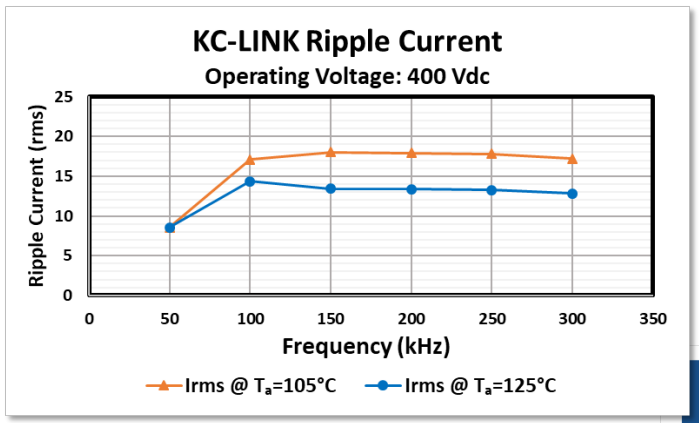
Temperature Stable Capacitance



Voltage Stable Capacitance

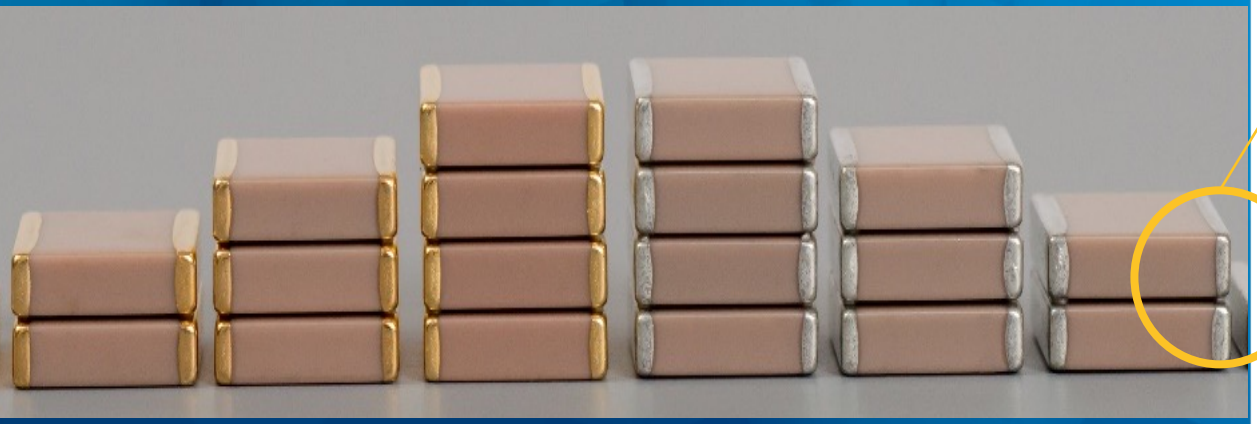


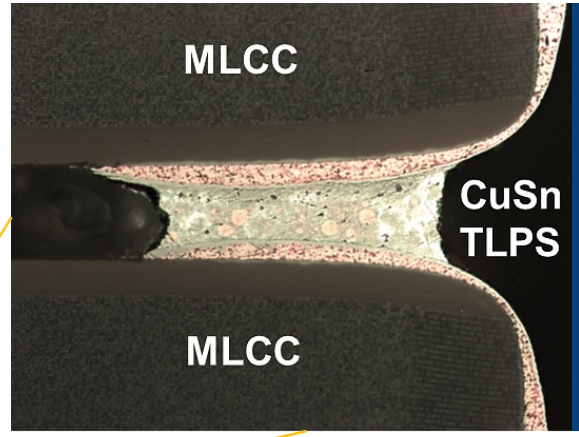
High Ripple Current



What is KEMET KONNEKT™ High Density Packaging ?

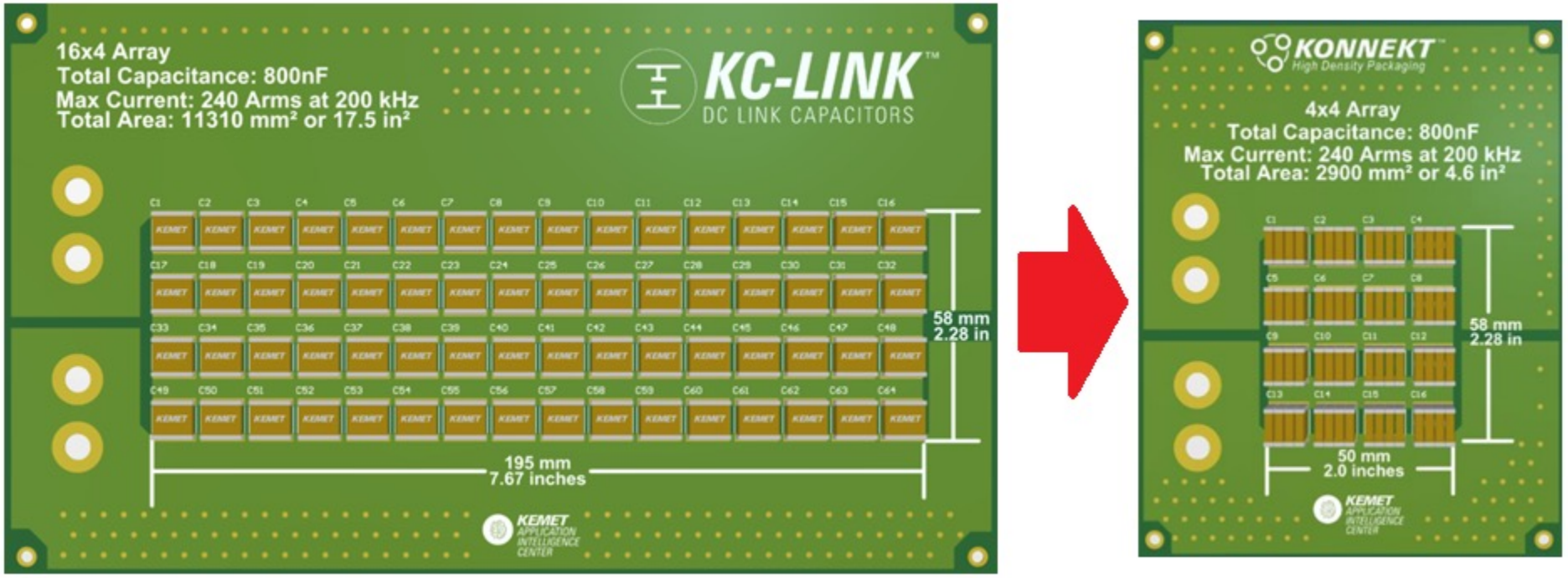
- KEMET KONNEKT™ is a high density packaging technology that allows components to be bonded together without leads
- Multilayer Ceramic Capacitors (MLCCs) packaged in this way are surface mountable using normal pick-and-place and SAC reflow processing



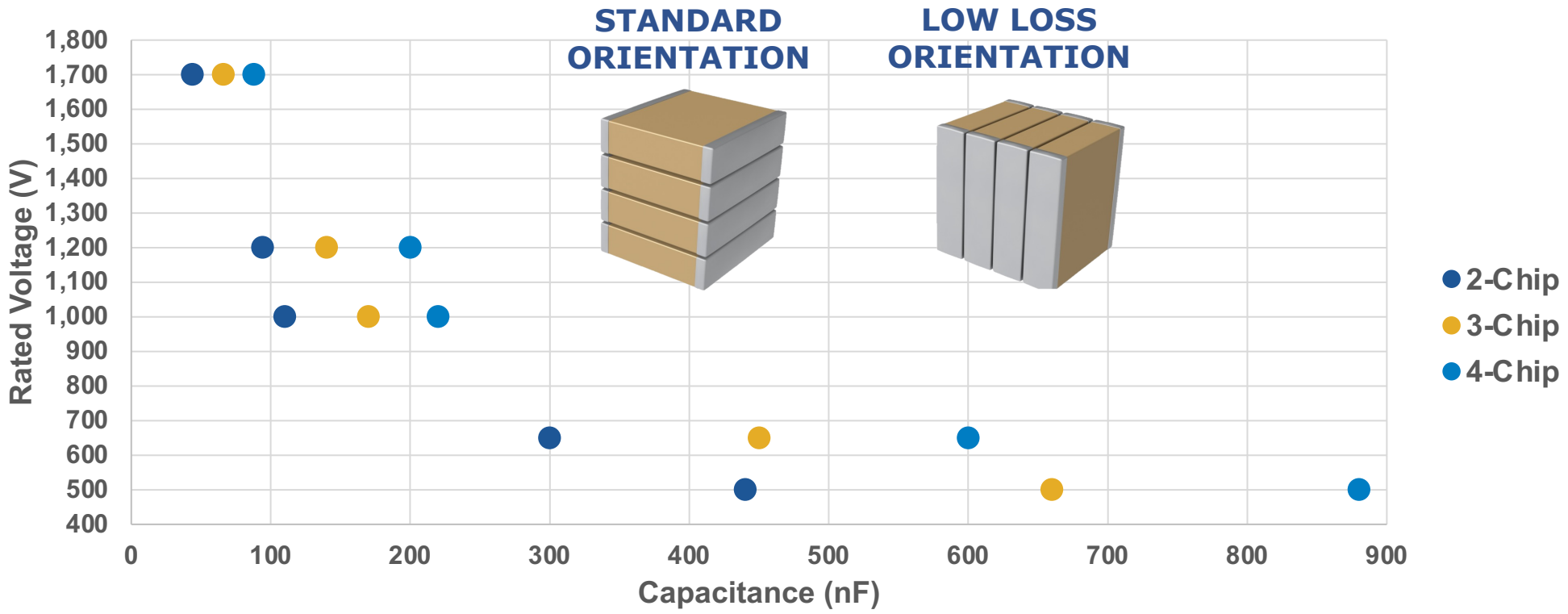


Bonds component terminations together using innovative Transient Liquid Phase Sintering (TLPS) technology

KEMET KONNEKT™ Saves Board Space



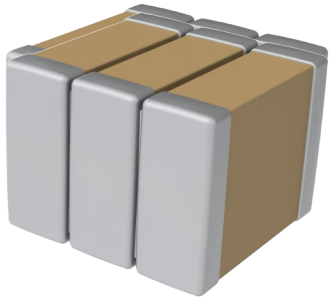
KC-LINK DC LINK CAPACITORS with KEMET KONNEKT™ High Density Packaging

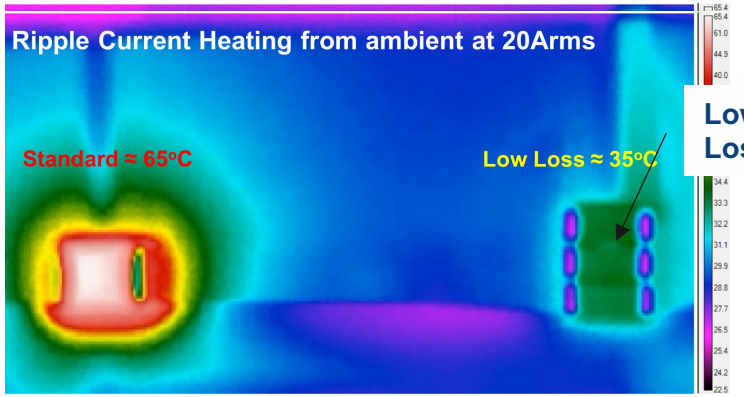


Product Design and Performance

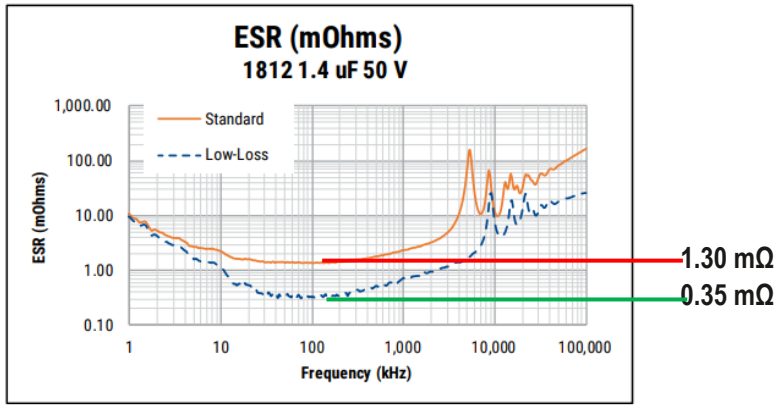
STANDARD ORIENTATION

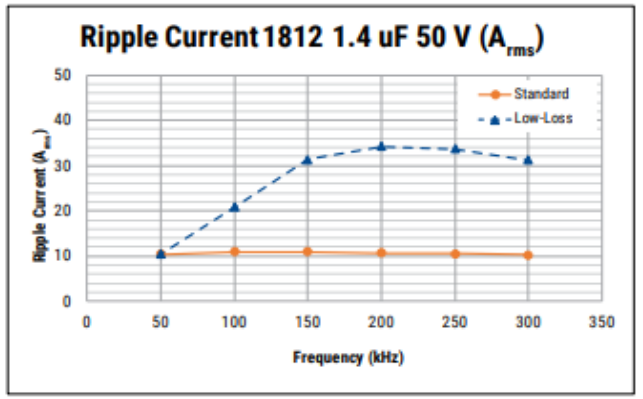
LOW LOSS ORIENTATION





Lower i²R Losses





Benefits of Low-Loss Orientation vs Standard Orientation:

- Lower ESR
- Lower Thermal Resistance
- Lower Inductance
- Higher Ripple Current

ESL	
Standard	1.6 nH
Low-Loss	0.4 nH

KONNEKT™
High Density Packaging

Summary

- Wide Band Gap Solutions are driving the need for components to operate at:
  - Higher frequency
  - Higher temperature
  - Higher voltage
- Film capacitors with advanced dielectrics are capable of operation to 135°C
  - Standard box configurations and custom brick configurations are available
- Higher frequency operation allows less capacitance to be used which opens the possibility of using MLCCs
  - Class 1 MLCCs with temperature ratings to 150°C and voltage ratings to 1700V are available
  - They can be stacked using KONNEKT™ technology for greater capacitance

Thank you for your interest.

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