
High-Capacitance
CERAMICS
Low-ESR
TANTALUMS
KEMET
High-Frequency
ALUMINUMS
High-Performance Solutions
Quality • Logistics • Support

KEMET Global Locations

● Direct Sales Offices ● Manufacturing Facilities ● Hubs

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Solutions for Your Changing World

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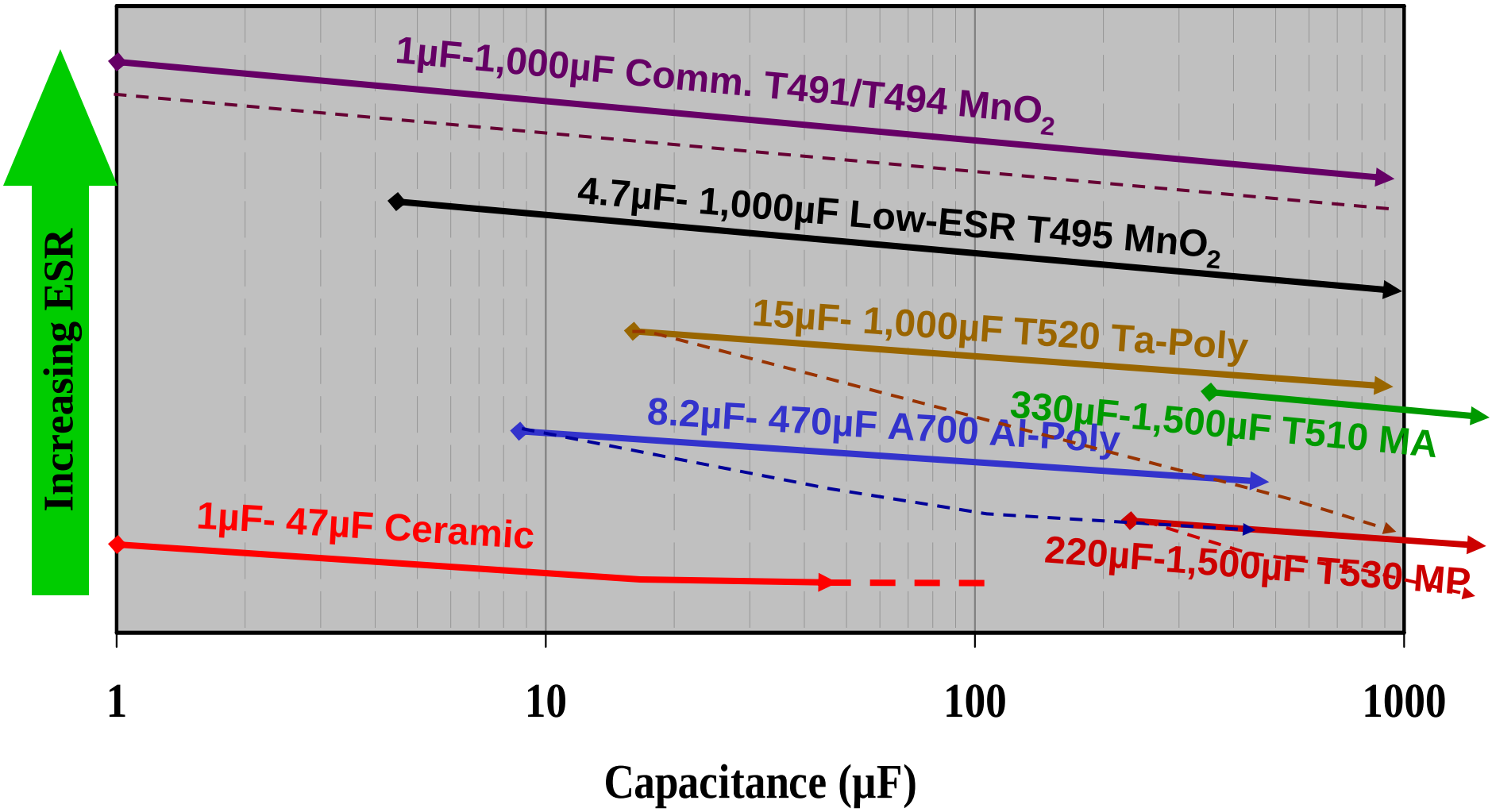
Technology Roadmaps
March, 2007

Capacitance & ESR



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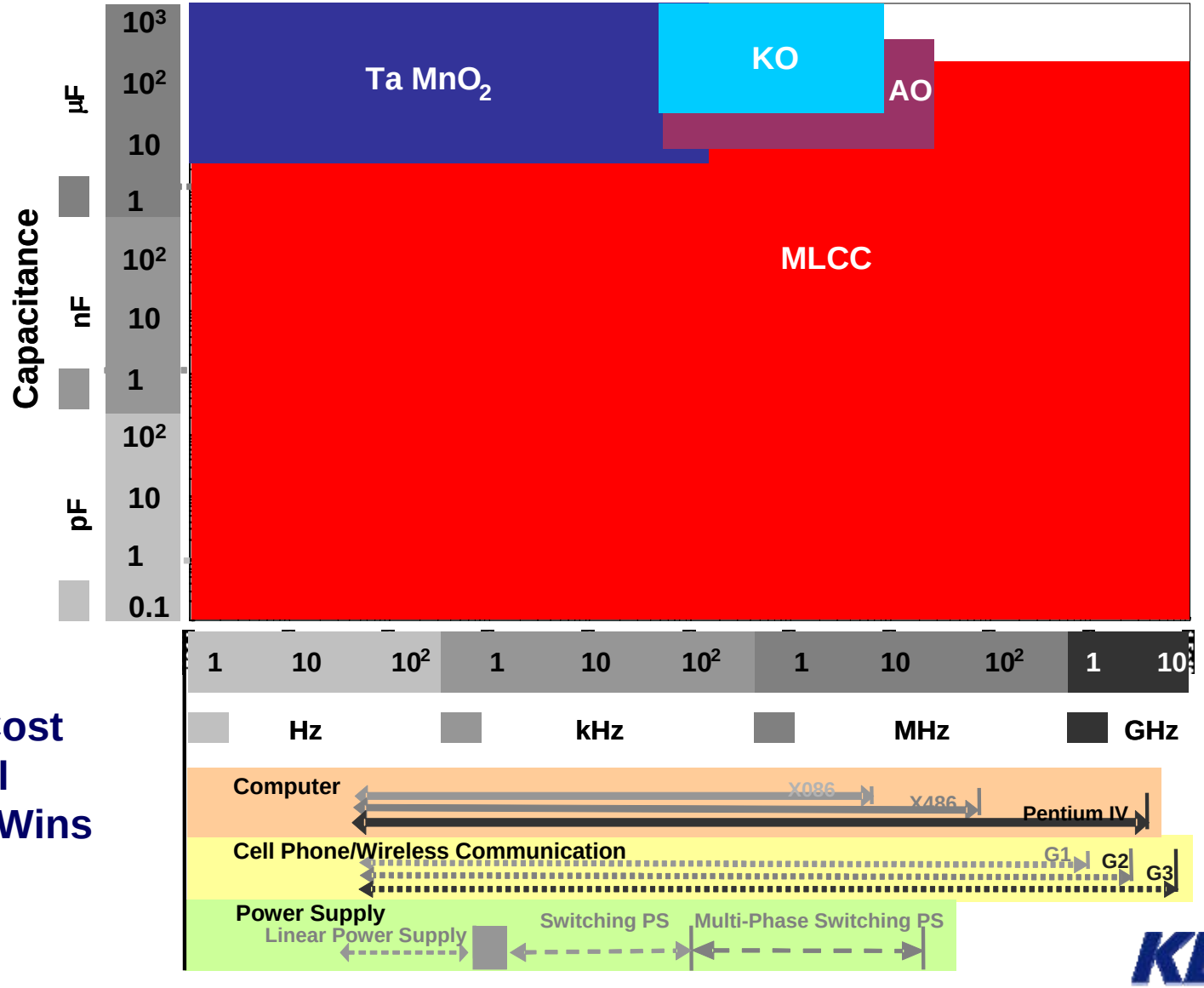
Capacitor Applications Space



Lowest Cost Technical Solution Wins

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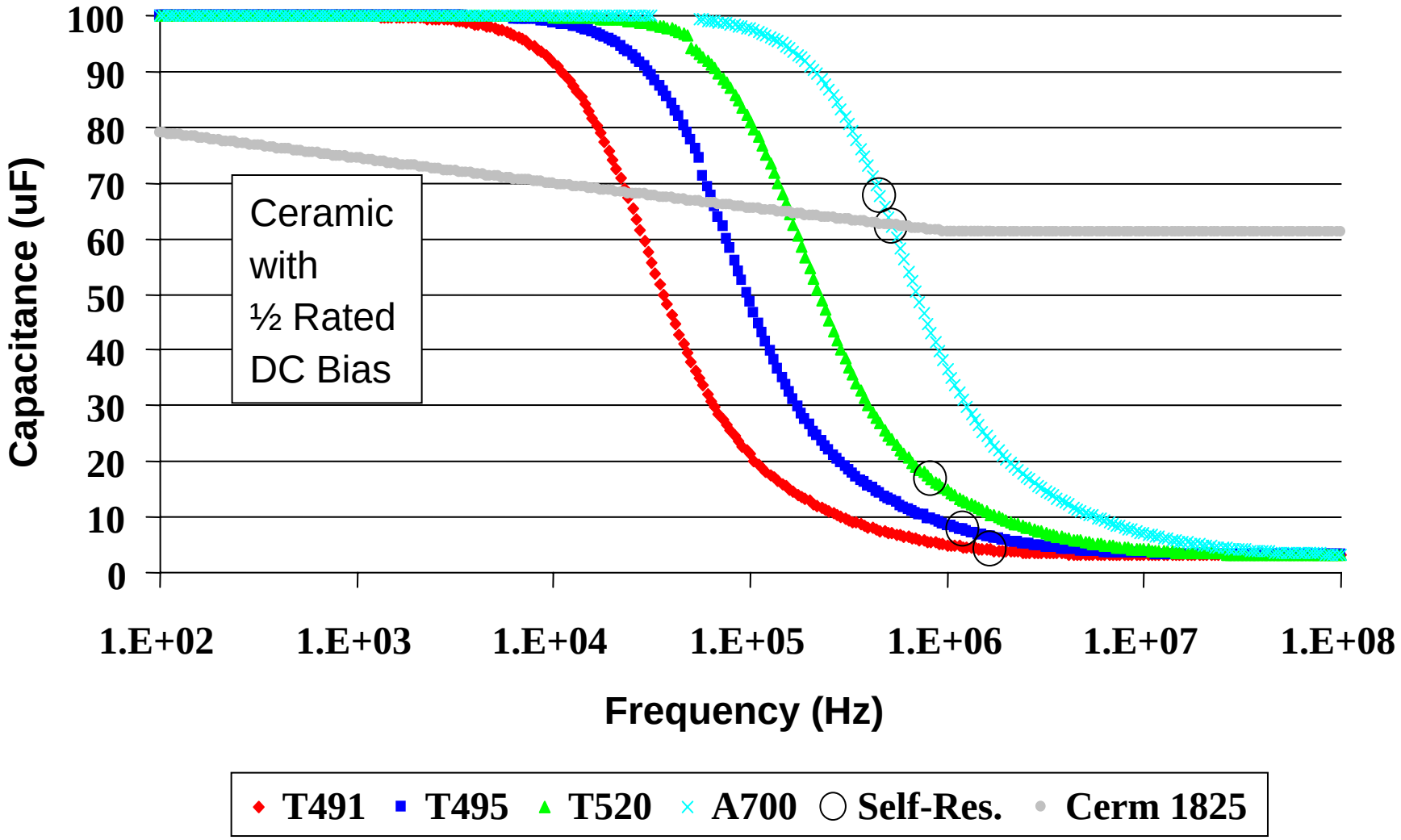
‘D’ Case – 100 uF Capacitance vs. Frequency



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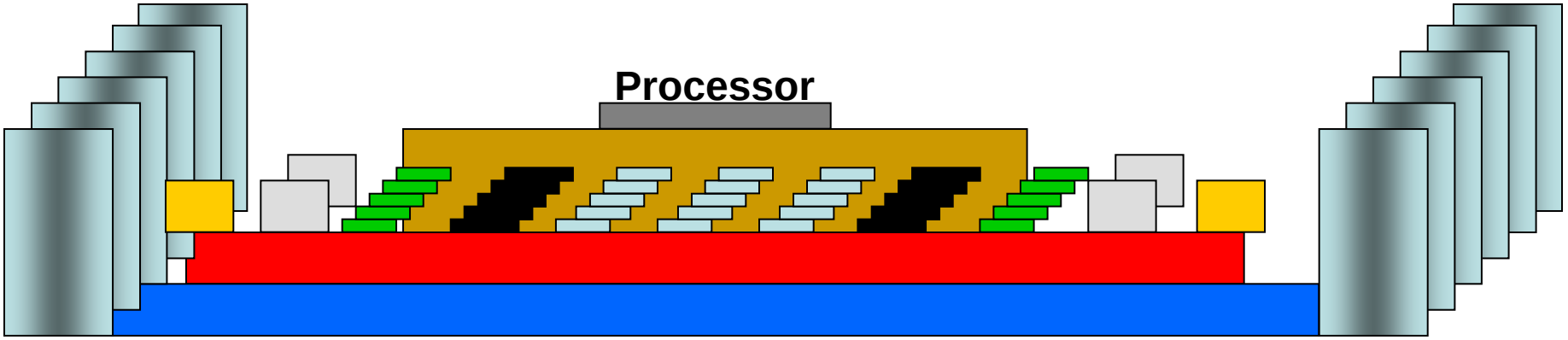
Typical Capacitor Distribution



IDC Ceram

Low-L Ceram

Std. Ceram

Al Poly

Ta MnO_2/Poly

Al Wet

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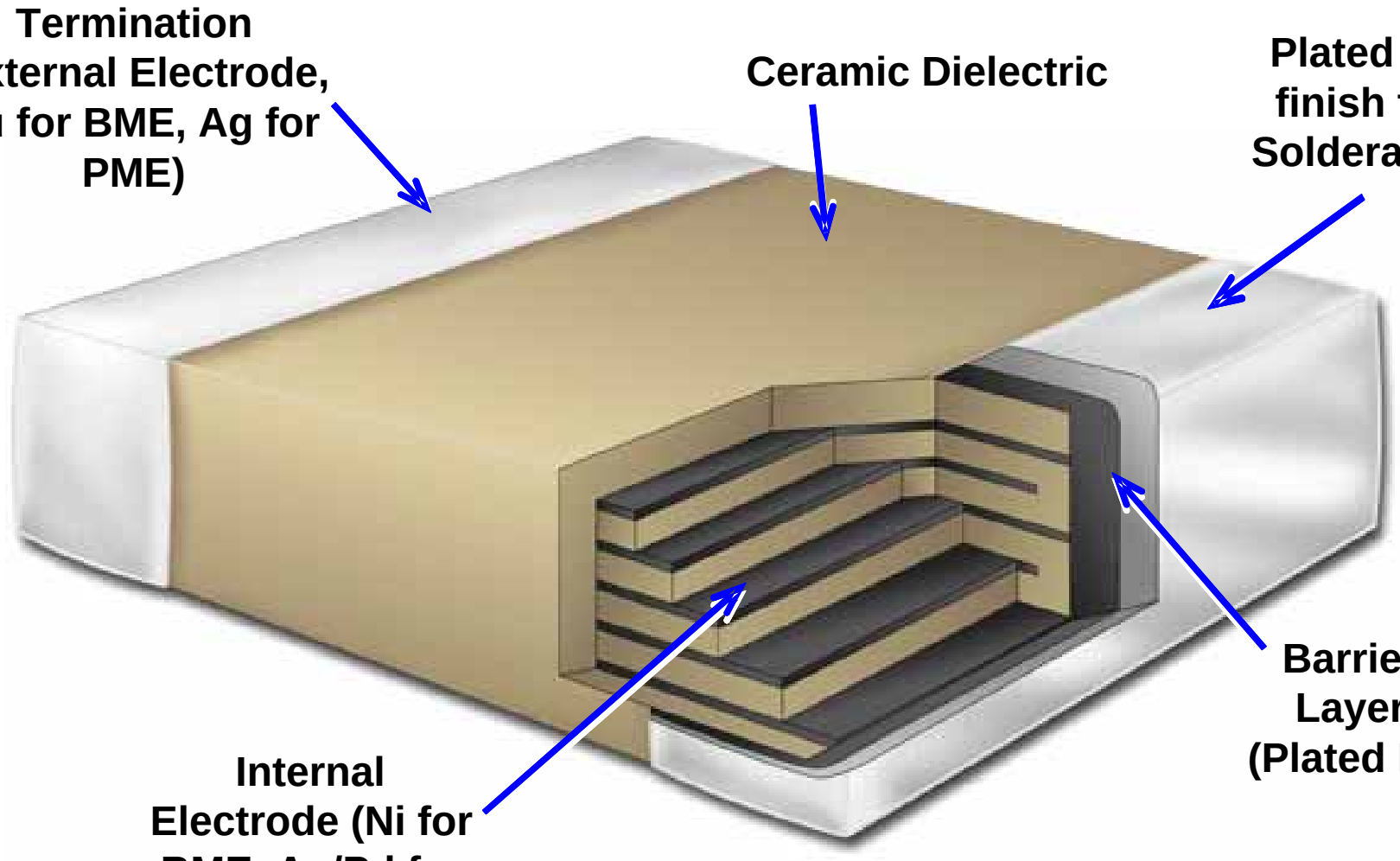
Ceramic Portfolio

Multilayer Ceramic Capacitor (MLCC)



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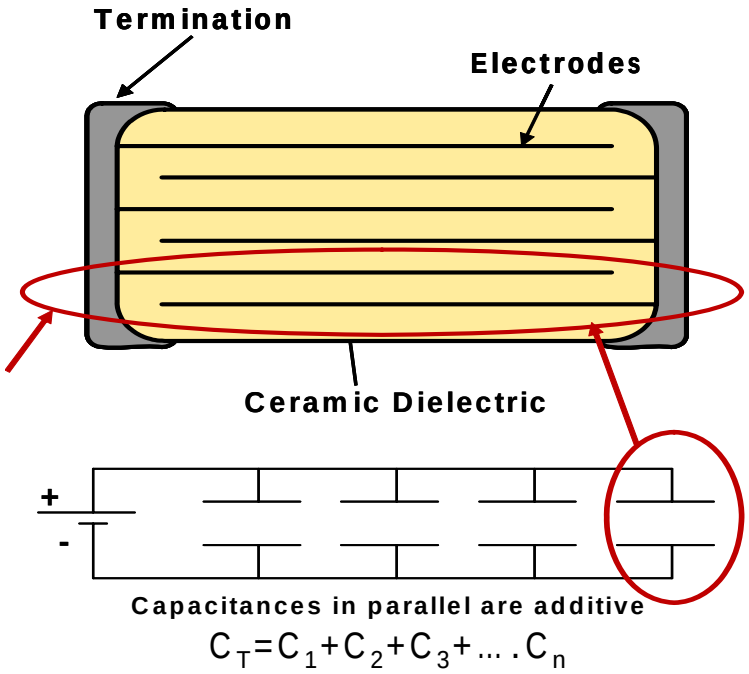
Capacitance

Capacitance and Volumetric Efficiency Equations



$$C = \frac{e_o K A n}{t}, \qquad VE = \frac{C}{V} \sim \frac{e_o K}{t^2}$$

C = Capacitance
VE=Volumetric Efficiency
V=volume
e_o=8.854x10^{-12} F/m
K = Dielectric Constant
A = Overlap Area per active
n = Number of actives
t = Ceramic Thickness

- Keys to improving volumetric efficiency (VE) is reducing dielectric thickness (t), maximizing the number of actives (n), maximizing dielectric constant (K), and using as much of the available chip as possible (margins, coverlayer, end termination thickness)

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EIA Designation for Class 1 Temperature Characteristics

+25°C

Significant Figure of Temperature Coefficient		Multiplier added to Temperature Coefficient		Tolerance of Temperature Coefficient	
PPM/°C	Symbol	Multiplier	Symbol	PPM/°C	Symbol
0.0	C	-1	0	± 30	G
0.3	B	-10	1	± 60	H
0.9	A	-100	2	± 120	J
1.0	M	-1,000	3	± 250	K
1.5	P	-10,000	4	± 500	L
2.2	R	+1	5	± 1000	M
3.3	S	+10	6	± 2500	N
4.7	T	+100	7		
7.5	U	+1,000	8		
		+10,000	9		

C0G?

NP0?

NP0 not shown - old designation style

+85°C

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EIA Designation for Class 2 & 3 Temperature Characteristics

Low Temperature		High Temperature		Maximum Capacitance Change	
°C	Symbol	°C	Symbol	°C	Symbol
10	Z	45	2	±1.0%	A
-30	Y	65	4	±1.5%	B
-55	X	85	5	±2.2%	C
		105	6	±3.3%	D
		125	7	±4.7%	E
		150	8	±7.5%	F
		200	9	±10.0%	P
				±15.0%	R
				± 22.0%	*S*
				+22%,-33%	*T*
				+22%,-56%	*U*
				+22%,-82%	*V*

X7R?

Z5U?

Y5V?

X5P?

X8R?

X8S?

Class 3

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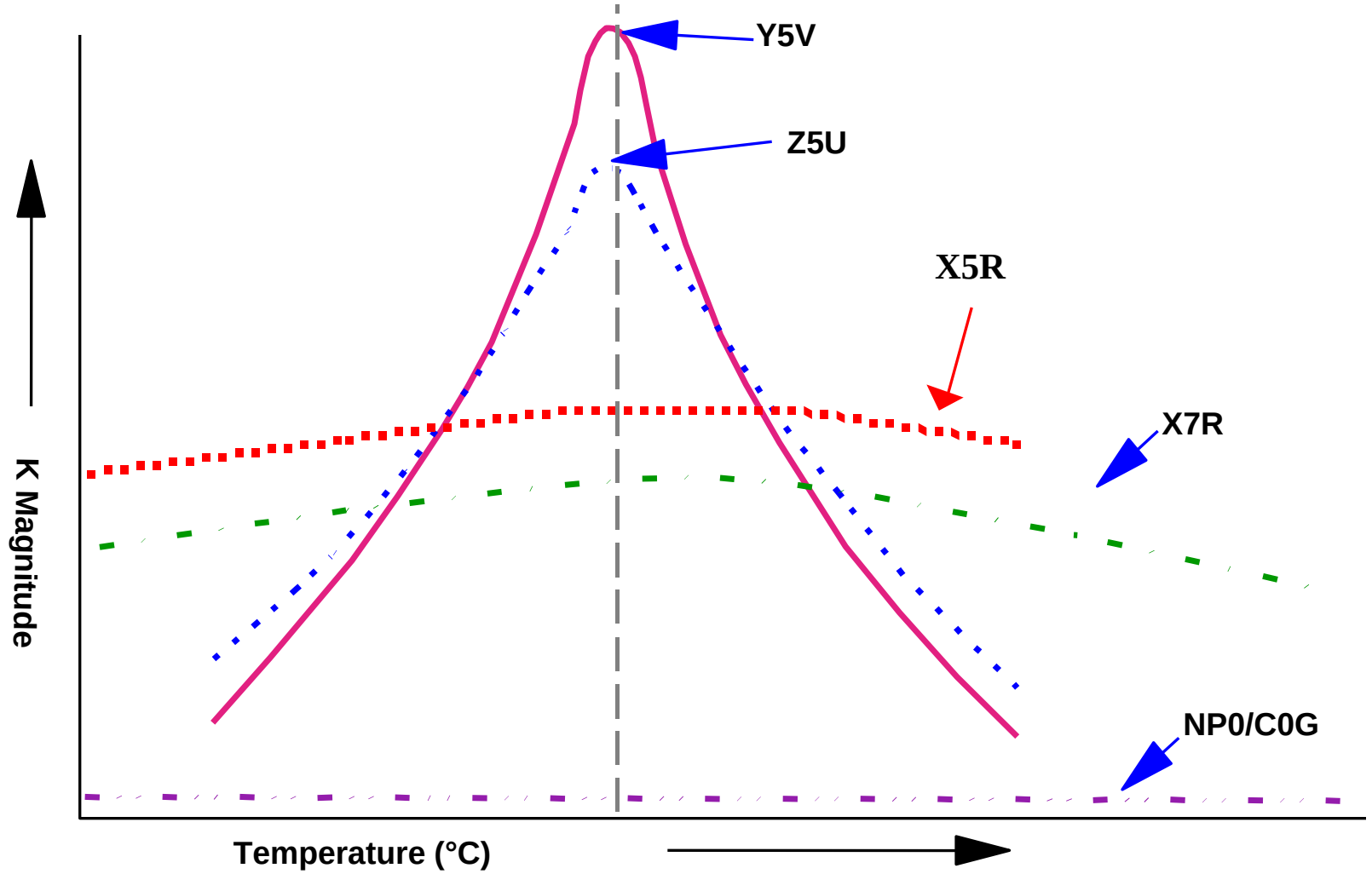
Relative Ceramic Temperature Effects



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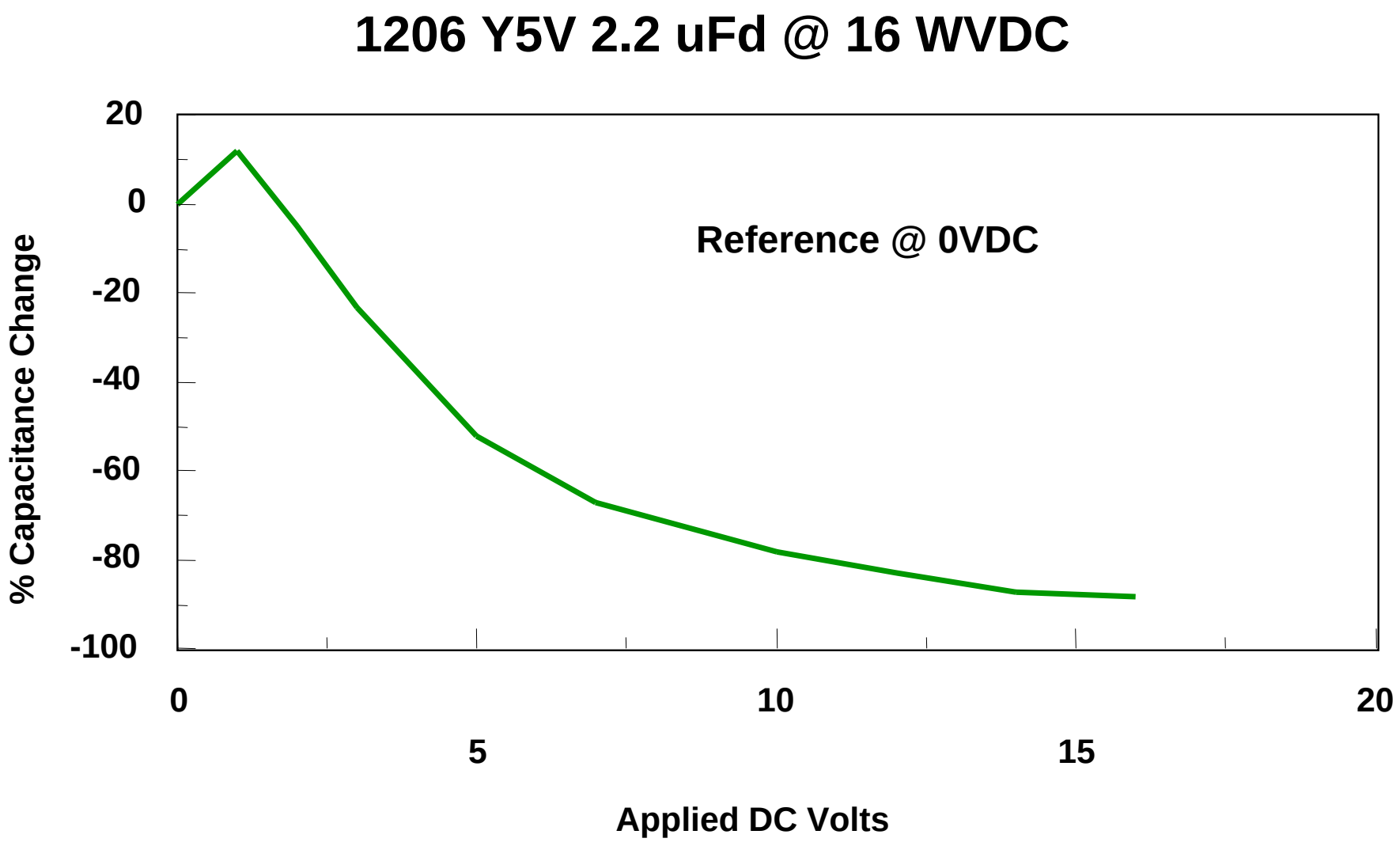
Voltage Coefficient of High K



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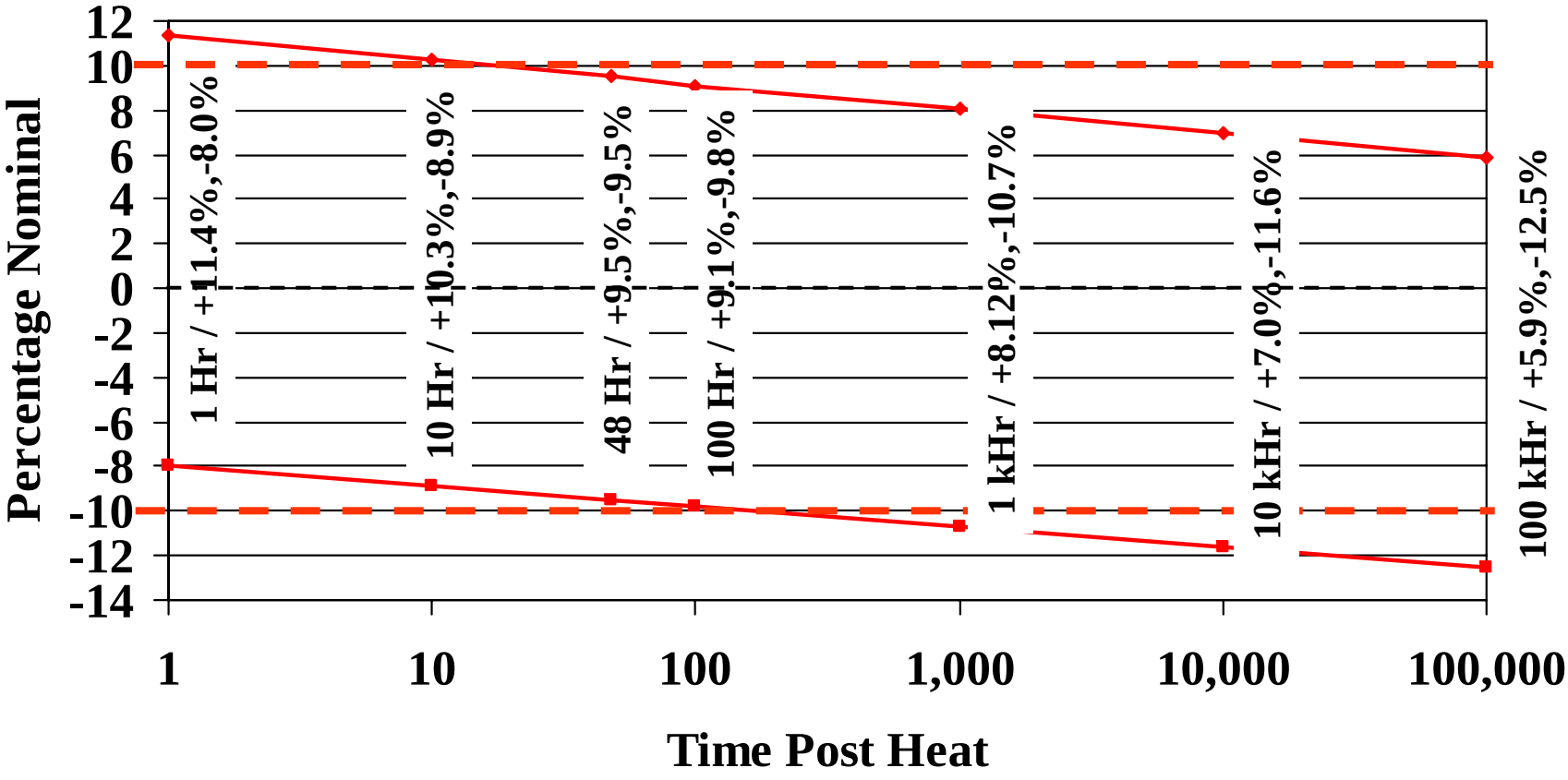
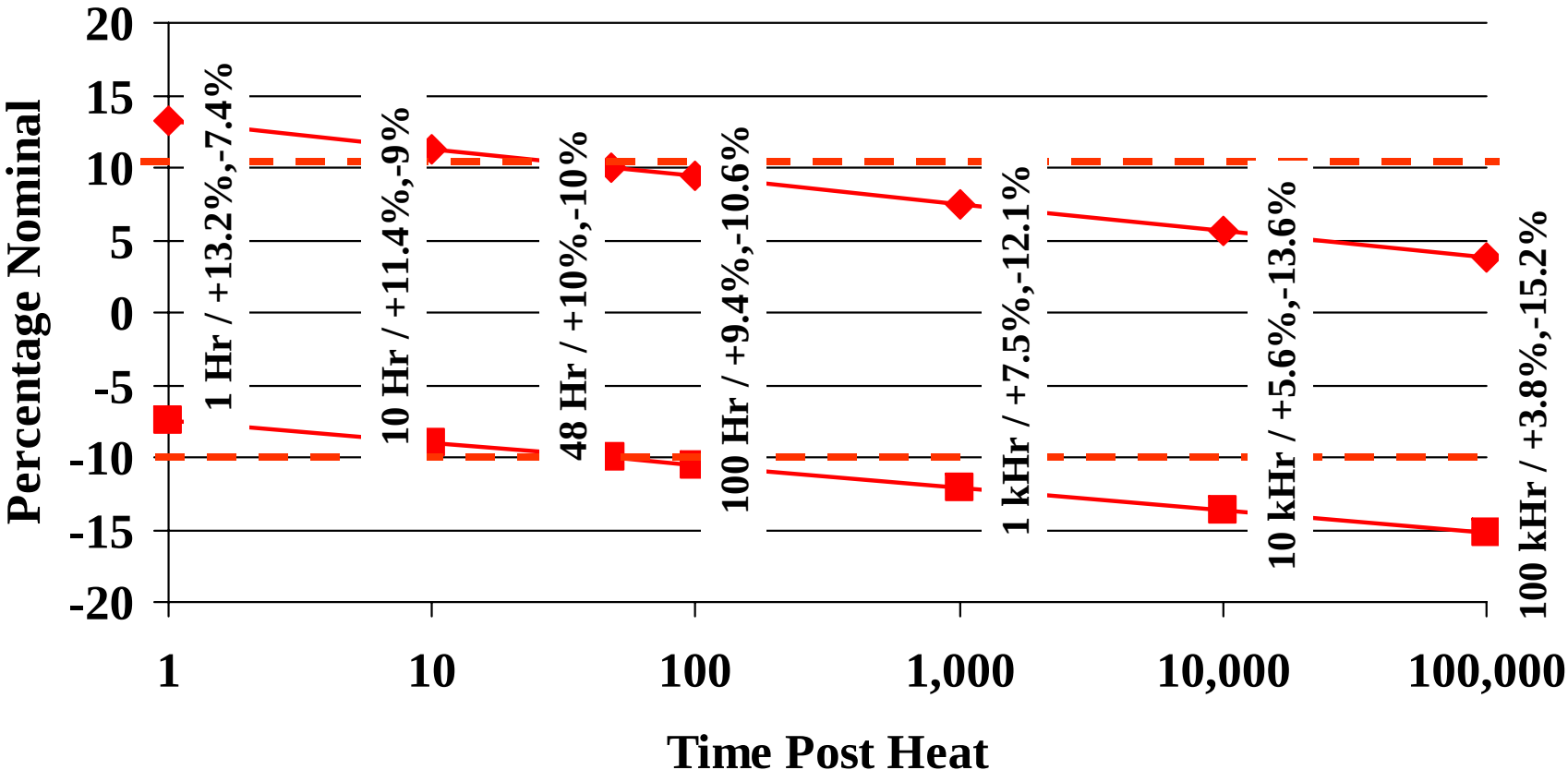
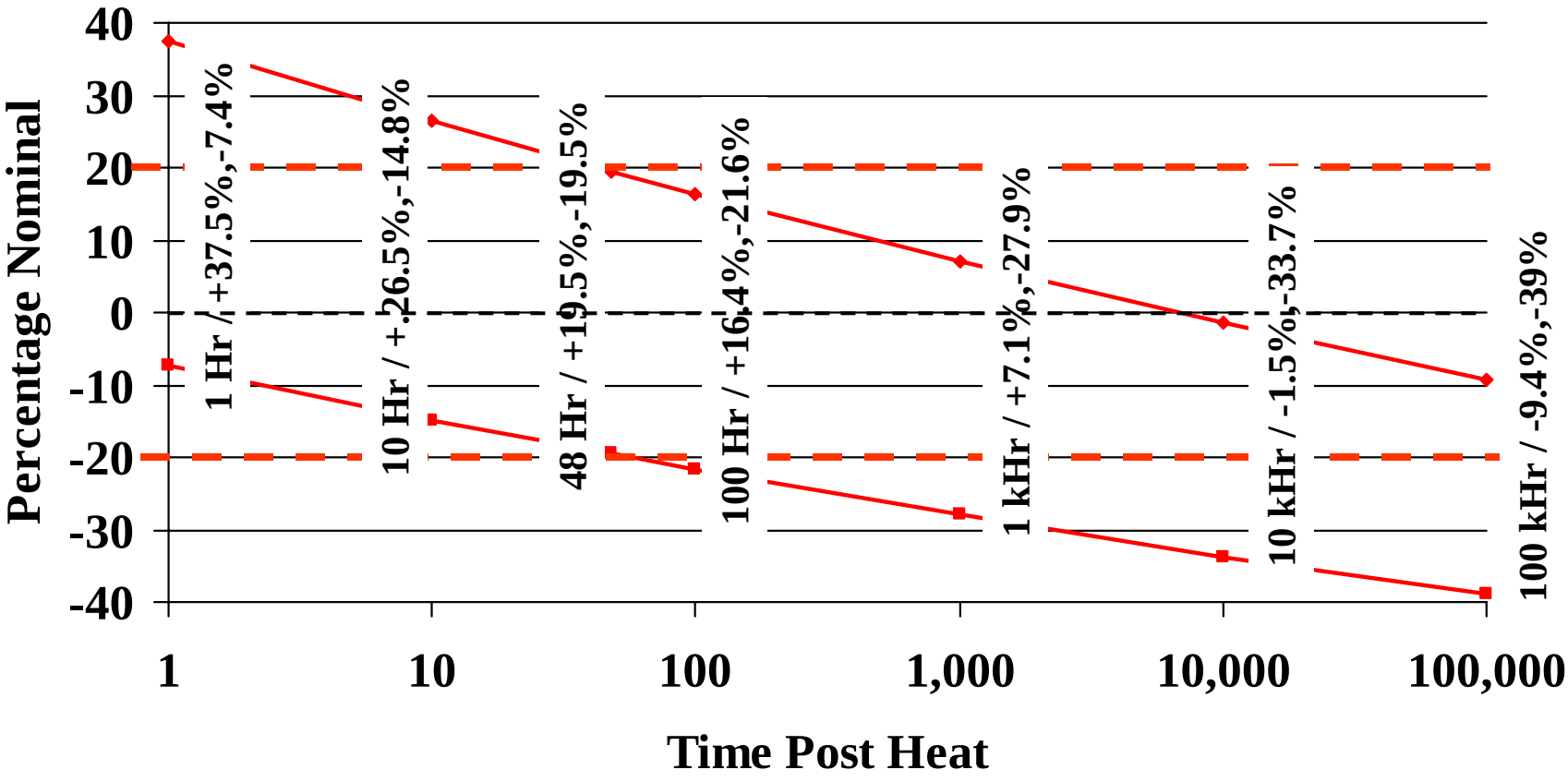
X7R Aging Rate of 1%/Dec-Hr



X5R Aging Rate of 1.7%/Dec-Hr



Y5V Aging Rate of 8%/Dec-Hr



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Surface Mount Portfolio

High CV MLCC			
Dielectric	**Size**	**Capacitance**	**Voltage**
X5R	0402 - 1812	1.0µF - 100.0µF	4v - 25v
X7R	0402 - 2220	1.0µF - 10.0µF	6.3v - 50v
Y5V	0402 - 1812	1.0µF - 22.0µF	4v - 50v

Low CV MLCC			
Dielectric	**Size**	**Capacitance**	**Voltage**
C0G	0201 - 2225	0.5pF - 0.033µF	10v - 200v
X7R	0201 - 2225	150pF - 1.0µF	6.3v - 200v
X5R	0201 - 1812	0.01µF - 1.0µF	6.3v - 50v
Y5V	0402 - 1210	0.022µF - 1.0µF	6.3v - 50v

Automotive MLCC			
Dielectric	**Size**	**Capacitance**	**Voltage**
C0G	0402 - 1210	100pF - 0.068µF	25v - 200v
X7R	0402 - 2225	0.01µF - 10µF	10v - 200v
X8R	Under Development		

Flex Crack Mitigation MLCC			
Dielectric	**Technology**	**Capacitance**	**Voltage**
X7R	Floating Electrode	0.15µF - 0.22µF	16v - 200v
X7R	Open Mode	0.015µF - 6.8µF	16v - 200v
C0G	Open Mode	270pF - 0.027µF	25v - 200v
X5R, X7R	Flex Term	Under Development	

COTS & Sn/Pb "L" Termination			
Dielectric	**Size**	**Capacitance**	**Voltage**
C0G	0402 - 2225	0.5pF - 0.033µF	10v - 200v
X7R	0402 - 2225	150pF - 10µF	6.3v - 200v

Low Profile (<1mm) MLCC			
Dielectric	**Size**	**Capacitance**	**Voltage**
X5R	0805	4.7µF, 10µF	6.3v

Capacitor Arrays				
Dielectric	**Size**	**Configuration**	**Capacitance**	**Voltage**
C0G	1206	4 in 1	10pF - 470pF	10v - 200v
X7R	1206	4 in 1	330pF - 0.1µF	10v - 200v

High Voltage MLCC			
Dielectric	**Size**	**Capacitance**	**Voltage**
C0G	0805 - 2225	1.0pF - 10,000pF	500v - 3kV
X7R	0805 - 2225	10pF - 0.22µF	500v - 3kV
C0G	1515 - 6560	12pF - 0.1µF	500v - 5kV
X7R	1515 - 6560	270pF - 2.2µF	500v - 5kV

High Voltage Tip & Ring MLCC			
Dielectric	**Size**	**Capacitance**	**Voltage**
X7R	0805 - 2225	0.022µF - 1.2µF	250v

Military Chips (MIL-PRF-55681, MIL-PRF-123, GR90			
Dielectric	**Size**	**Capacitance**	**Voltage**
P, X	0805 - 2225	10pF - 1.0µF	50v, 100v, 200v

Mil- and Mil-Equivalent Stacks (MIL-PRF-49470)			
Dielectric	**Size**	**Capacitance**	**Voltage**
X7R	Case 1-6	0.15µF - 270µF	50v, 100v, 200v, 500v

Inductors					
Application	**Construction**	**Series**	**Comments**	**Sizes**	**Inductance**
Filtering on Signal Line	Wire Wound	LBM	High Q, high ind.	0806	1.0 - 100 µH
	Multi-layer	LK	High Q, low ind	0402 - 1206	0.047 - 33 µH
Noise Reduction on Power Supply Line	Wire Wound	LB		0805 - 1207	1.0 - 1000 µH
		LBC	High Current	0805 - 1007	1.0 - 680 µH
		LBMF	Bottom surface electrode	0603	1.0 - 47 µH
	Multi-layer	CK		0603, 0805	0.10 - 10 µH
Power Inductor for switching regulator	Wire Wound	CBL	Low Profile, high current	0805	1.0 - 47 µH
		CBMF	Bottom surf. electrode	0603	1.0 - 47 µH
		CB	Low Rdc	0805 - 1007	1.0 - 1000 µH
		CBC	High Current	0805 - 1210	1.0 - 100 µH
		NR		1210 - 4040	1.0 - 220 µH
	Multi-layer	CKP	Low Profile, Low Rdc	1008, 1206	1.0 - 4.7 µH
Application	**Construction**	**Series**	**Comments**	**Sizes**	**Impedence**
EMI Suppression (Ferrite Beads)	Wire Wound	FBMJ		0603 - 1806	8 - 100 Ohms
		FBMH	High Current / Impedence	0603 - 1812	30 - 2000 Ohms
	Multi-layer	BKP	For Power lines	0402 - 0805	33 - 390 Ohms
		BK		0201 - 0805	10 - 2500 Ohms

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Thru Hole Portfolio

Standard Voltage			
Dielectric	**Lead Type**	**Capacitance**	**Voltage**
C0G	Axial	1.0pF - 0.015µF	50v, 100v, 200v
X7R	Axial	10pF - 0.68µF	50v, 100v, 200v
Z5U	Axial	1000pF - 2.2µF	50v, 100v, 200v
C0G	Radial	1.0pF - 0.12µF	50v, 100v, 200v
X7R	Radial	10pF - 4.7µF	50v, 100v, 200v
Z5U	Radial	1000pF - 6.8µF	50v, 100v, 200v

High Voltage			
Dielectric	**Lead Type**	**Capacitance**	**Voltage**
C0G	Radial	12pF - 0.33µF	Up to 10kV
X7R	Radial	220pF - 5.6µF	Up to 10kV

Single Layer Disc			
Dielectric	**Lead Type**	**Capacitance**	**Voltage**
C0G	Disc	1.2pF - 236pF	3kV - 20kV
X7R	Disc	10pF - 7400pF	3kV - 50kV

Disc Stack			
Dielectric	**Lead Type**	**Capacitance**	**Voltage**
C0G	Disc	1.2pF - 141pF	5kV - 20kV
X7R	Disc	37pF - 4400pF	5kV - 20kV
X5U	Disc	80pF - 10.4nF	5kV - 20kV

High Temperature (Radial & Axial)			
Dielectric	**Temp.**	**Capacitance**	**Voltage**
C0G	125°, 200°, 260°C	1.0pF - 0.12µF	50v, 100v, 200v
X7R	125°, 200°, 260°C	100pF - 3.3µF	50v, 100v, 200v

High Temperature (200°C) + High Voltage			
Dielectric	**Lead Type**	**Capacitance**	**Voltage**
C0G	Radial	390pF - 0.015µF	500v - 4kV
X7R	Radial	1400pF - 0.270µ	500v - 4kV

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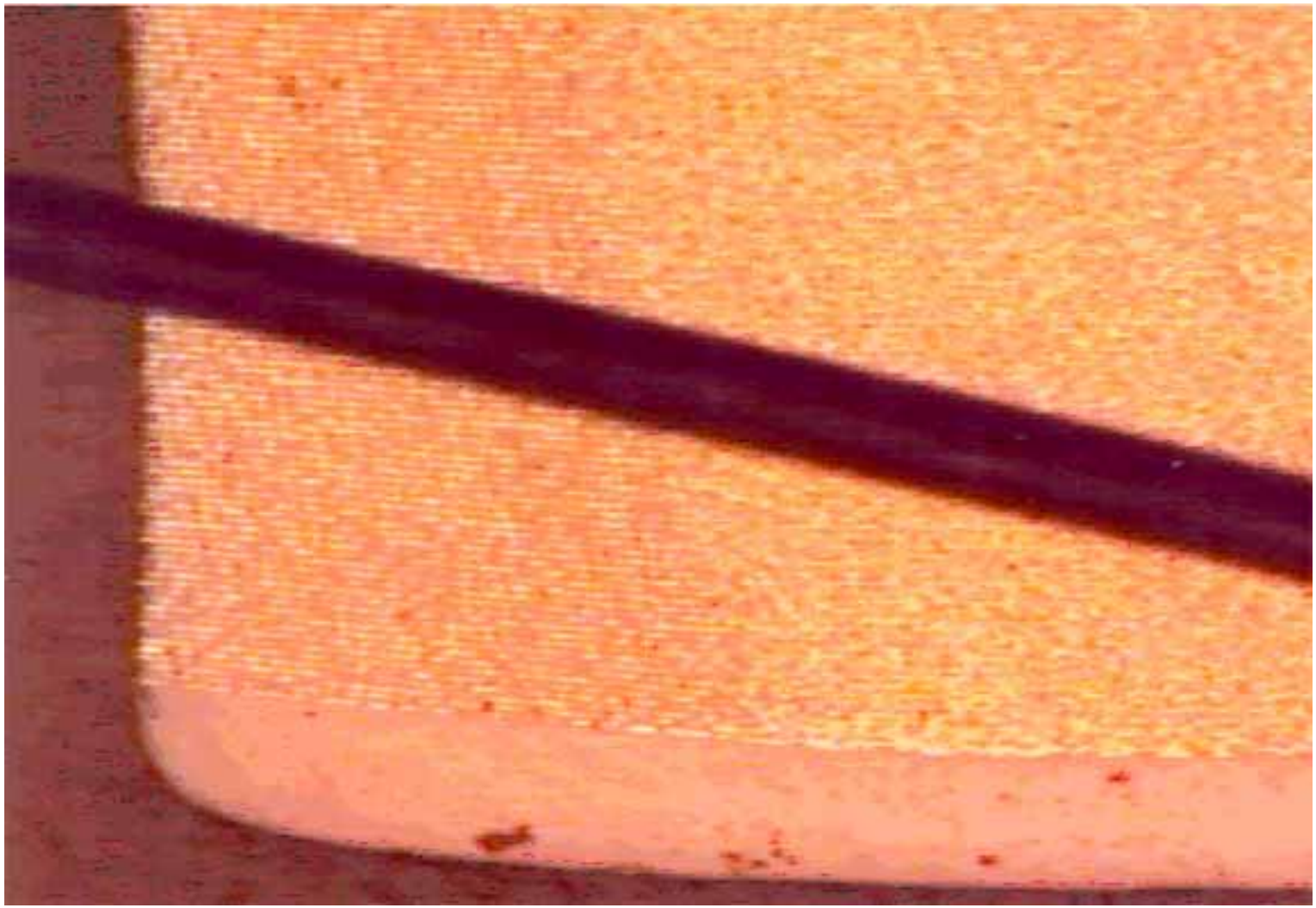
500 Active Layer 1210 and A Human Hair



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X5R, X7R & C0G Capacitance Extension Roadmaps

X5R Roadmap 0201 – 0805 Sizes

EIA Case Size		0201					0402							0603							0805						
Cap	Code	4	6.3	10	16	25	4	6.3	10	16	25	35	50	4	6.3	10	16	25	35	50	4	6.3	10	16	25	35	50
100	101																										
1,000	102																										
10,000	103				New!																						
15,000	153																										
22,000	223																										
33,000	333																										
47,000	473																										
68,000	683																										
100,000	104		New!																								
150,000	154																										
220,000	224																										
330,000	334																										
470,000	474																										
680,000	684																										
1,000,000	105								New!																		
1,500,000	155																										
2,200,000	225							M									New!										
3,300,000	335																										
4,700,000	475																										
6,800,000	685																										
10,000,000	106														M	CY08								New!			
22,000,000	226																					M					
47,000,000	476																				New!						
100,000,000	107																										

= Available
= Samples Available
= Within Capability
= Development

"M" indicates available only in M (± 20%) tolerance

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X5R Roadmap 1206 – 1812 Sizes

EIA Case Size		1206						1210						1812					
Cap	Code	6.3	10	16	25	35	50	6.3	10	16	25	35	50	6.3	10	16	25	35	50
100	101																		
1,000	102																		
10,000	103																		
15,000	153																		
22,000	223																		
33,000	333																		
47,000	473																		
68,000	683																		
100,000	104																		
150,000	154																		
220,000	224																		
330,000	334																		
470,000	474																		
680,000	684																		
1,000,000	105																		
1,500,000	155																		
2,200,000	225																		
3,300,000	335																		
4,700,000	475													New!	New!	New!	New!	New!	New!
6,800,000	685																		
10,000,000	106													New!	New!	New!	New!		
22,000,000	226																		
47,000,000	476							M											
100,000,000	107	New!						M											

= Available
= Samples Available
= Within Capability
= Development

"M" indicates available only in M (± 20%) tolerance

X7R Roadmap 0402 – 1206 Sizes

EIA Case Size		0402					0603							0805								1206							
Cap pF	Code	6.3	10	16	25	50	6.3	10	16	25	50	100	200	6.3	10	16	25	35	50	100	200	6.3	10	16	25	35	50	100	200
150	151																												
220	221																												
330	331																												
470	471																												
680	681																												
1,000	102																												
1,500	152																												
2,200	222																												
3,300	332																												
4,700	472																												
6,800	682																												
10,000	103																												
15,000	153																												
22,000	223																												
33,000	333																												
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680,000	684																												
1,000,000	105																												
1,500,000	155																												
2,200,000	225																												
3,300,000	335																												
4,700,000	475														CY07														
6,800,000	685																												
10,000,000	106													CY07															

= Available
= Samples Available
= Within Capability
= Development

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X7R Roadmap 1210 – 2225 Sizes

EIA Case Size		1210						1812				1825				2220				2225			
Cap pF	Code	10	16	25	50	100	200	25	50	100	200	25	50	100	200	25	50	100	200	25	50	100	200
2,200	222																						
3,300	332																						
4,700	472																						
6,800	682																						
10,000	103																						
15,000	153																						
22,000	223																						
33,000	333																						
47,000	473																						
68,000	683																						
100,000	104																						
150,000	154																						
220,000	224																						
330,000	334																						
470,000	474																						
680,000	684																						
1,000,000	105																						
1,500,000	155																						
2,200,000	225																						
3,300,000	335																						
4,700,000	475				New!			New!	New!														
6,800,000	685																						
10,000,000	106			New!				New!															
15,000,000	156																						
22,000,000	226																						
33,000,000	336																						
47,000,000	476																						

= Available
= Samples Available
= Within Capability
= Development

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C0G Roadmap 0201 – 1206 Sizes

EIA Case Size		0201			0402				0603						0805						1206					
Cap	Code	10	16	25	10	16	25	50	10	16	25	50	100	200	10	16	25	50	100	200	10	16	25	50	100	200
0.5 - 9.1	508 - 919																									
10.0	100	New!	New!	New!																						
12.0	120	New!	New!	New!																						
15.0	150	New!	New!	New!																						
18.0	180	New!	New!	New!																						
22.0	220	New!	New!	New!																						
27.0	270	New!	New!	New!																						
33.0	330	New!	New!	New!																						
39.0	390	New!	New!	New!																						
47.0	470	New!	New!	New!																						
56.0	560	New!	New!	New!																						
68.0	680	New!	New!	New!																						
82.0	820	New!	New!	New!																						
100.0	101	New!	New!	New!																						
120.0	121				New!	New!	New!	New!																		
150.0	151				New!	New!	New!	New!																		
180.0	181				New!	New!	New!	New!																		
220.0	221				New!	New!	New!	New!																		
270.0	271				New!	New!	New!	New!																		
330.0	331				New!	New!	New!	New!																		
390.0	391																									
470.0	471																									
560.0	561																									
680.0	681																									
820.0	821																									
1000.0	102						Q207																			
1200.0	122																									
1500.0	152																									
1800.0	182																									
2200.0	222										Q207															
2700.0	272																									
3300.0	332										Q207															
3900.0	392																									
4700.0	472										Q207						Q207									
5600.0	562																									
6800.0	682																									
8200.0	822																									
10,000.0	103										Q207						Q207									
18,000.0	183																									
22,000.0	223																Q207						Q207			
33,000.0	333																Q207									
47,000.0	473																						Q207			
68,000.0	683																									
100,000.0	104																						Q207			

= Available
= Samples Available
= Within Capability
= Development

C0G Roadmap 1210 – 2225 Sizes

EIA Case Size		1210				1812				1825				2220				2225			
Cap	Code	25	50	100	200	25	50	100	200	25	50	100	200	25	50	100	200	25	50	100	200
10 - 100.0	100 - 101																				
120.0	121																				
150.0	131																				
180.0	181																				
220.0	221																				
270.0	271																				
330.0	331																				
390.0	391																				
470.0	471																				
560.0	561																				
680.0	681																				
820.0	821																				
1,000.0	102																				
1,200.0	122																				
1,500.0	152																				
1,800.0	182																				
2,200.0	222																				
2,700.0	272																				
3,300.0	332																				
3,900.0	392																				
4,700.0	472																				
5,600.0	562																				
6,800.0	682																				
8,200.0	822																				
10,000.0	103																				
12,000.0	123																				
15,000.0	153																				
18,000.0	183																				
22,000.0	223	Q207																			
27,000.0	273																				
33,000.0	333																				
47,000.0	473	Q207																			
68,000.0	683																				
100,000.0	104	Q207																			
220,000.0	224	Q207																			

= Available
= Samples Available
= Within Capability
= Development

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KEMET Advantage vs. Film Cap

	KEMET HICV C0G		PEN* Film Cap
Will not smoke or burn?	✓	Yes	No
125°C Rated Temperature?	✓	Yes	No, <105°C
Low DF?	✓	Yes, < 0.1%	No, <1.0%
Non Moisture Sensitive?	✓	Yes	No, moisture pack
Approved for activating flux?	✓	Yes	No
Stable cap over temp range?	✓	Yes, 0±30 ppm	No, -20% to +5%
Pb-Free Soldering OK?	✓	Yes, up to 260°C	No, <240°C

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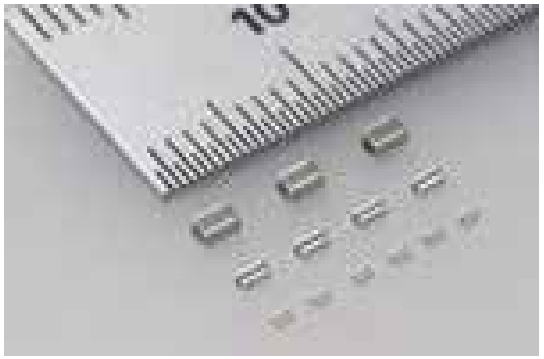
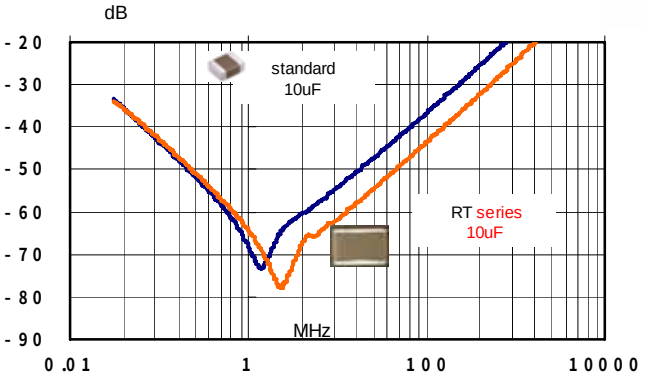
Low Inductance Products

Reverse Terminations - Low Inductance





Case Size			Voltage Ratings	
EIA	Metric	Dielectric	6.3	10
0204	1005	X7R	104	
		X5R		
0306	1608	X7R	105	
		X5R		
0508	2012	X7R		
		X5R	475 (Max T = 0.95mm)	
0612	3216	X7R		225 (Max T = 0.95mm)
		X5R		106 (Max T = 0.95mm)

Development Timeline based on Customer Input

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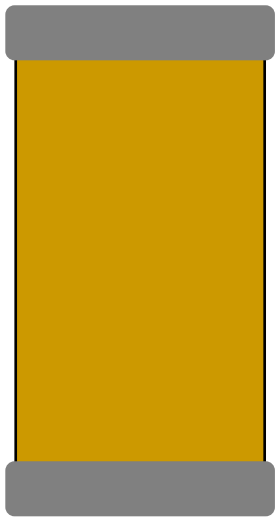
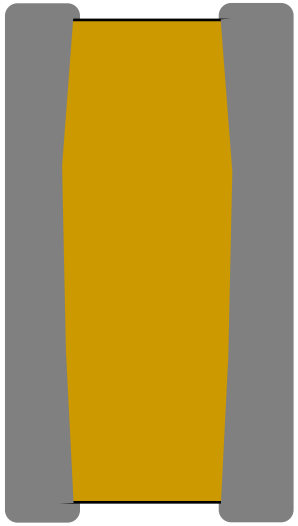
Low Inductance Progression

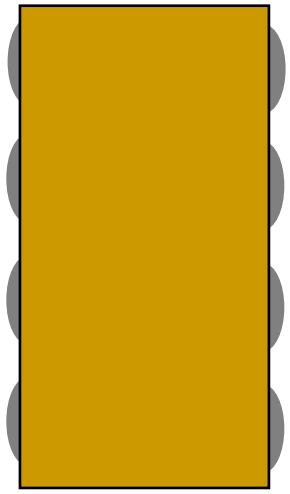
1206
1200+ pH



0612
400+ pH



0612
IDC
40+ pH



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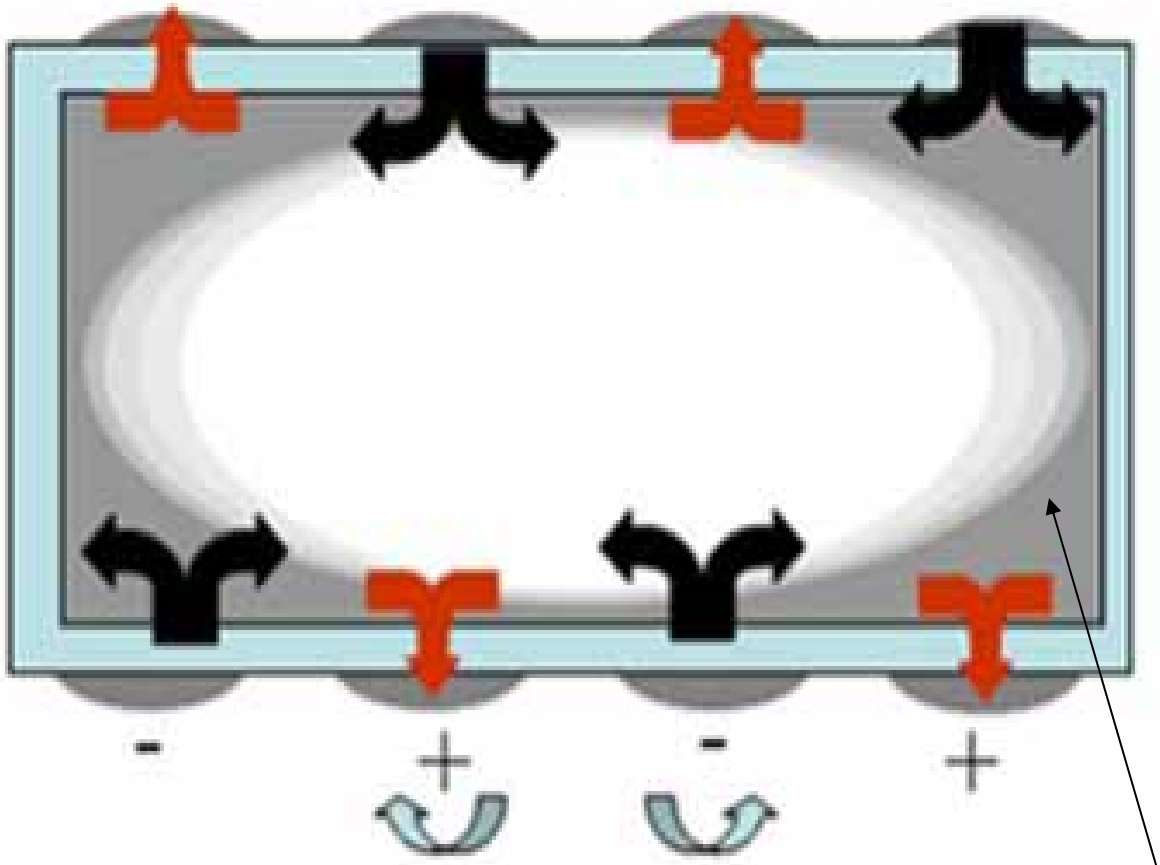
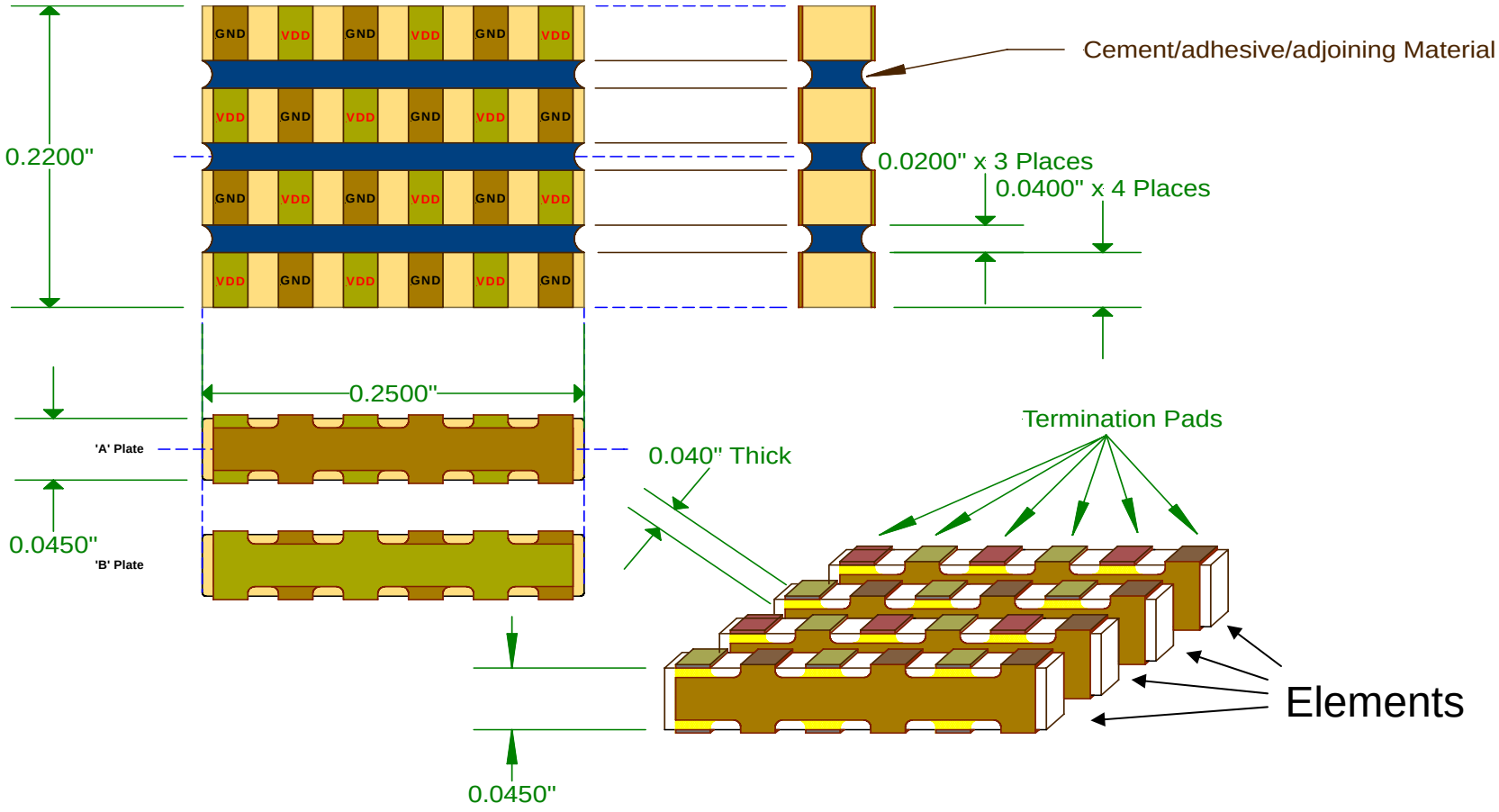
Interdigitated Capacitor (IDC)



Charge concentration per plate.

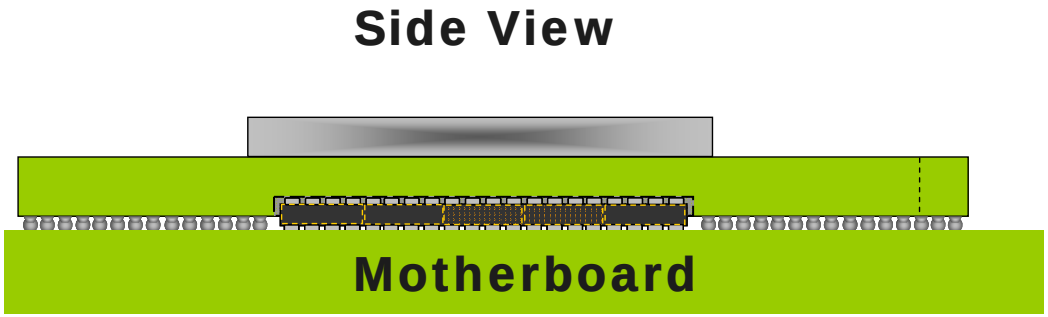
3D Decoupling- Multiple Unit

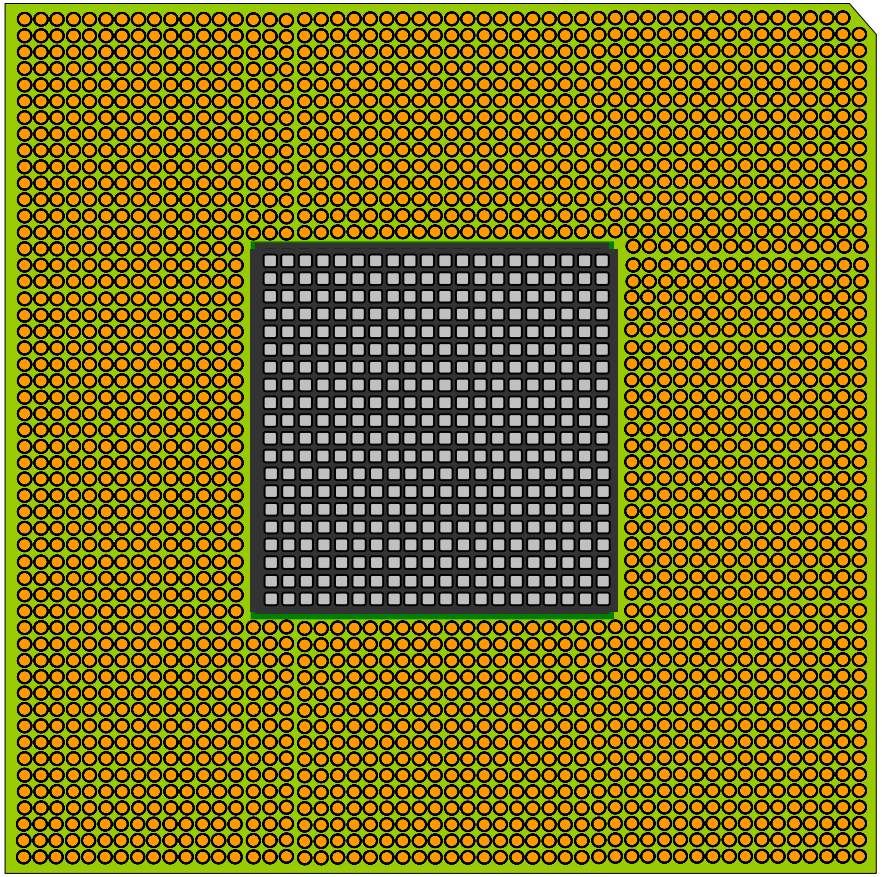
Matrix Layout



Matrix Termination 3D-Decoupling Capacitors

D-Pack™: Partial Interposer Design





Other Configurations Also Available

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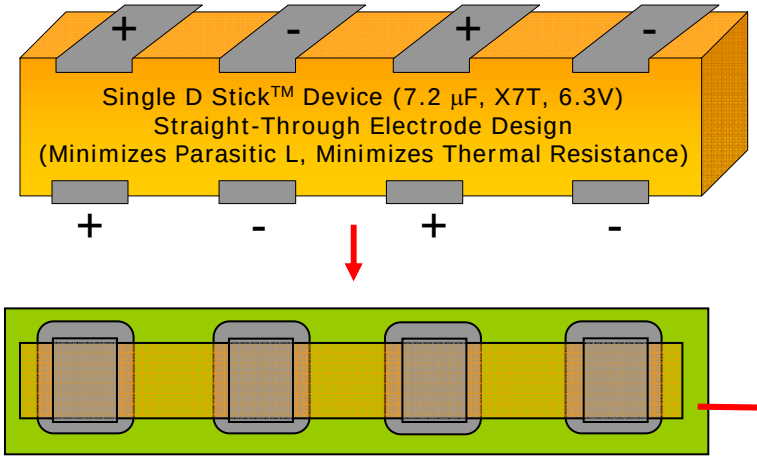
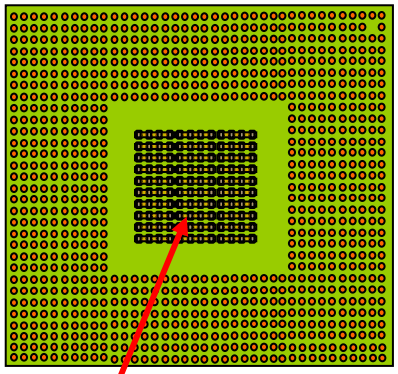
D-Stick™ 3D Decoupling Capacitors

Objective:

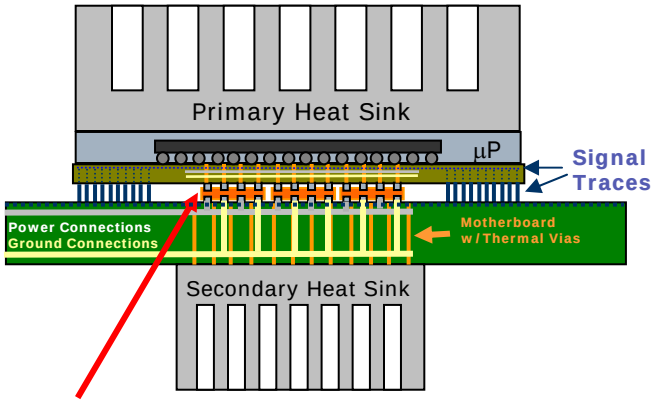
Replace Current μP Decoupling Capacitor Scheme (IDCs, Reverse Terms, MLCCs, etc.) with Extremely Low Inductance, High Thermal Transfer, Interposer Decoupling Capacitor System



Vertical Orientation Mounted Device (Top View)



~D Sticks are mounted on the underside of the μP Package (beneath the Si, as an interposer between the μP and the Motherboard)



D Sticks mounted as interposer. ESL and R_{Th} are Minimized, >>150uF/cm²

D-Sticks **are Mounted w/Vertical Orientation (Minimize ESL and R_{Th}) and Arranged in Gangs (ganged devices available as "*D-Packs*")**

- >150 μF/cm²
- D-Sticks/D-Packs Between the μP Package and the Motherboard
- Projected to Enables Increased Clock Speed (Inductance Projected <~4 pH/cm²)
- Enables High Performance Thermal Management
- Patented (US 7,068,490)
- Full Decoupling Solution Should Enable Elimination of Other Decoupling Capacitors (Higher level)

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D-Stick Decoupling

- ✓ Eliminates pick-and-place steps
- ✓ Saves critical board space
- ✓ Saves critical package space
- ✓ Improves thermal management
- ✓ Increases clock speed
- ✓ Eliminates some higher level decoupling capacitors

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Flex Crack Solutions

Ceramic

Flex Cracks

- Manufacturing defects have been systematically eliminated (PPM level)
- Customer Complaints:
  - IR Failure due to Flex Cracks: #1 failure mode

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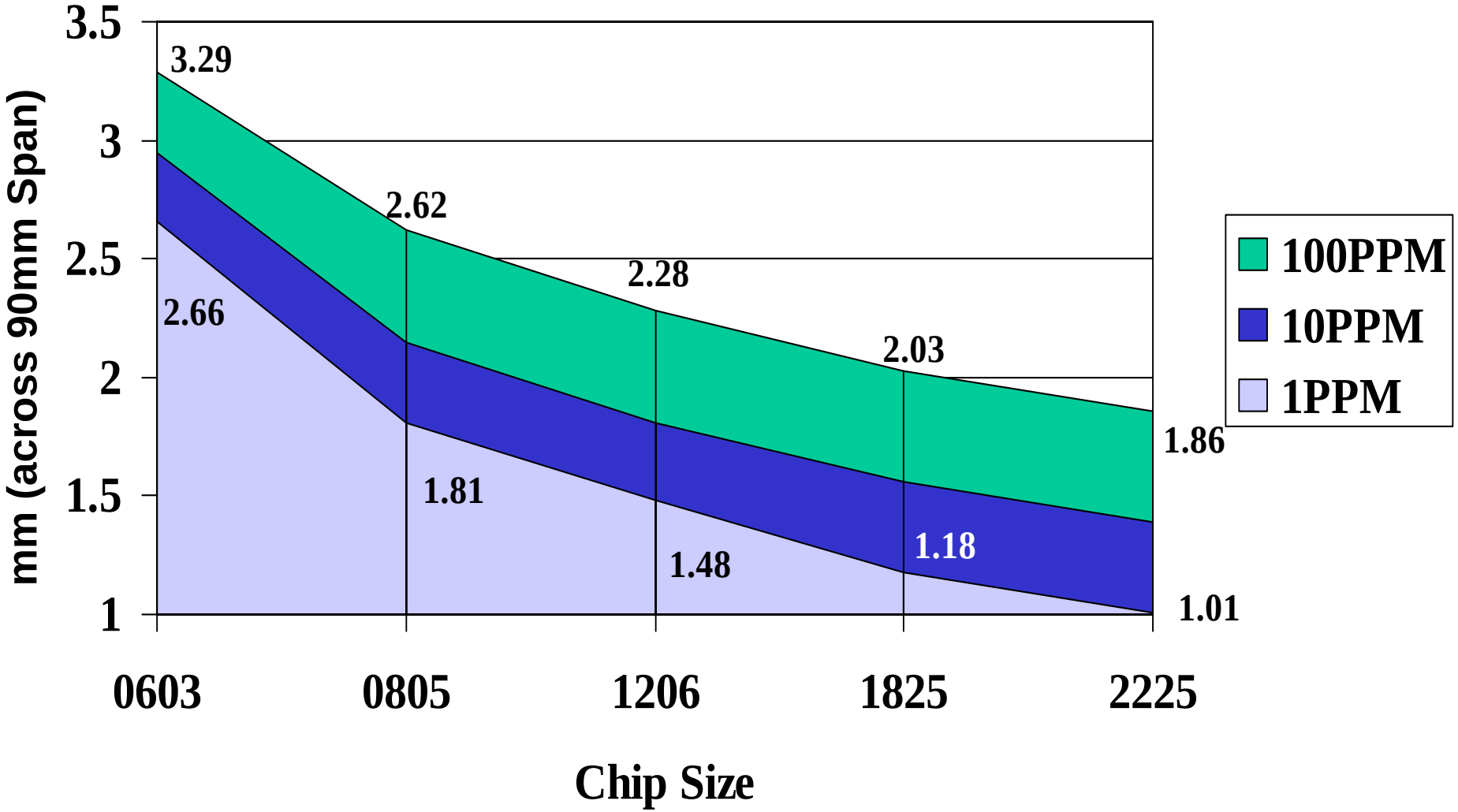
Flex Failures



Flex Crack Mitigation

- KEMET Technology at the forefront of Flex Crack Mitigation
- Different designs depending on requested capacitance value

Solution	Type	Status	Moves Out Point of Failure During Board Flex	Eliminates Catastrophic Failure Mode	Eliminates Flex Cracks
Soft Termination	MLCC	Samples Available Now	X		
Extended Termination	MLCC	Under Development	X		
Open Mode	MLCC	Available Now		X	
Floating Electrode	MLCC	Samples Available Now		X	
Ta SMD	Ta & AO	Available Now			X
Leaded	Ta & MLCC	Available Now			X
Clip-on Lead Frame	MLCC	Samples Available Now			X

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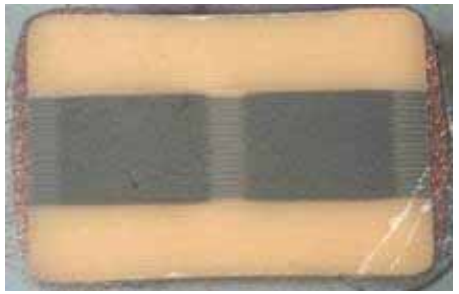
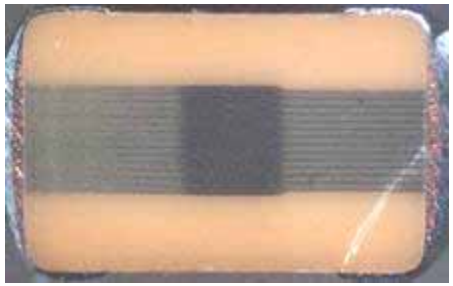
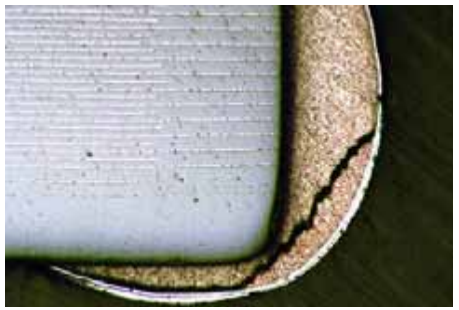
Flex Crack Mitigation

Technology	Target Values	Example
Floating Electrode C0805**S**104K5RAC	Low Capacitance	
Open Mode C0805**F**104K5RAC	Mid Capacitance	
Flexible Termination C0805**X**104K5RAC	High Capacitance	

Coming Soon: C0805Y0104K5RAC (Floating + Flex)

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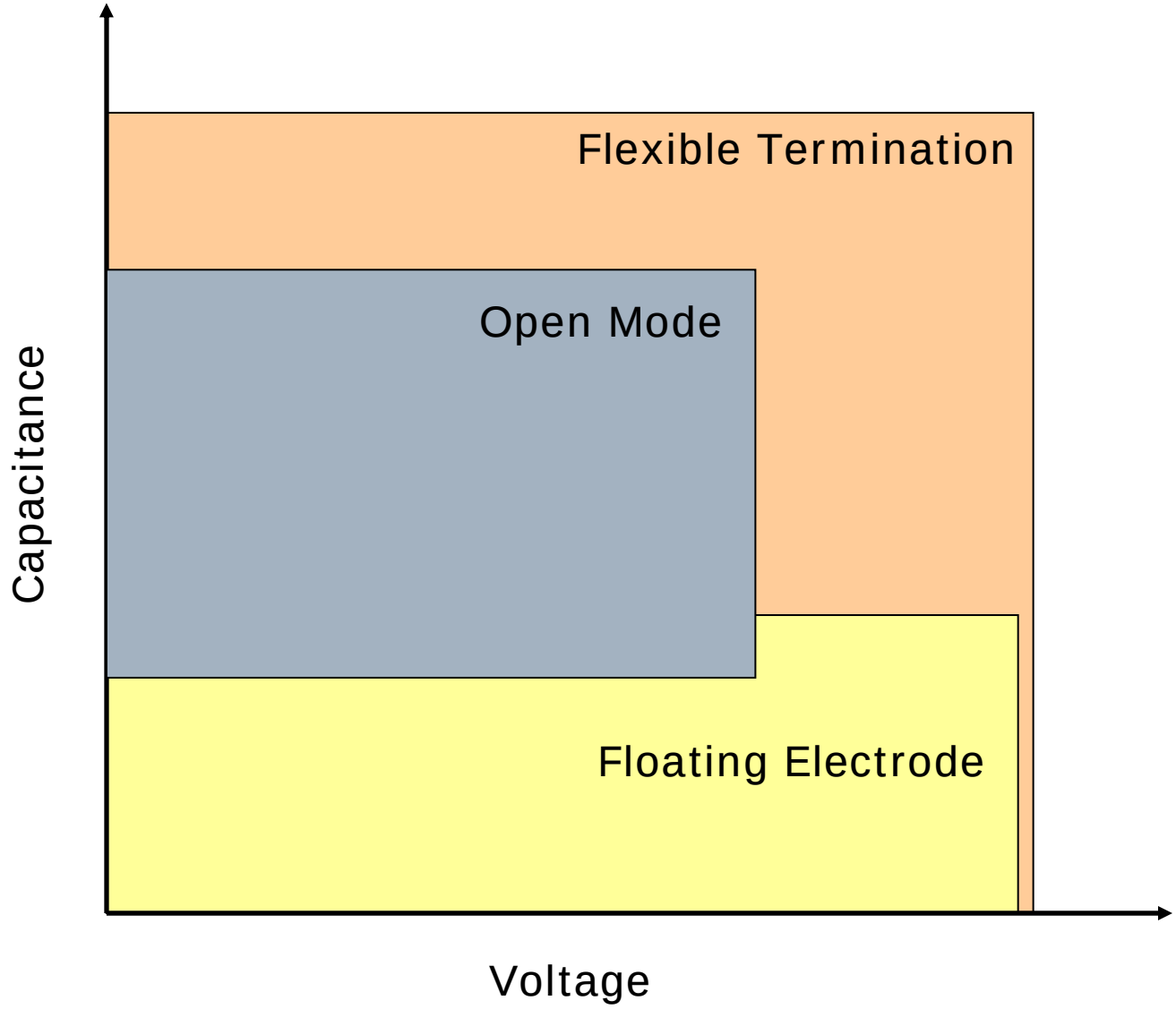
Flex Solutions



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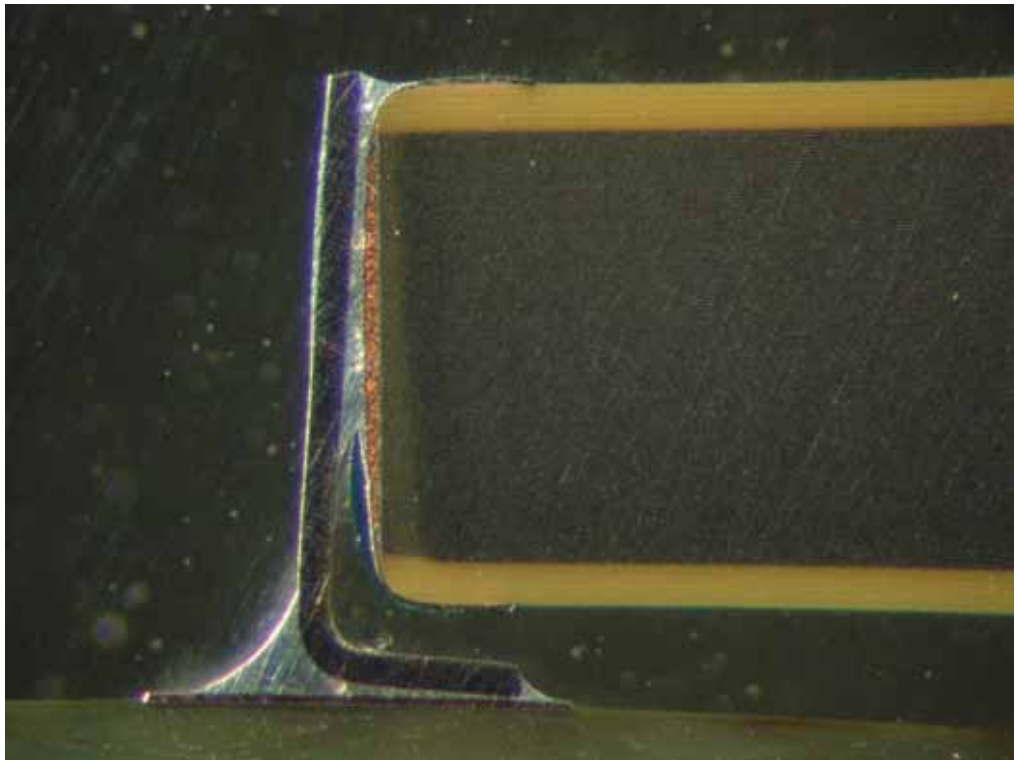
Clip-on Leadframe – Flex Robust

- No flex crack even after FR4 was flexed to 10mm!



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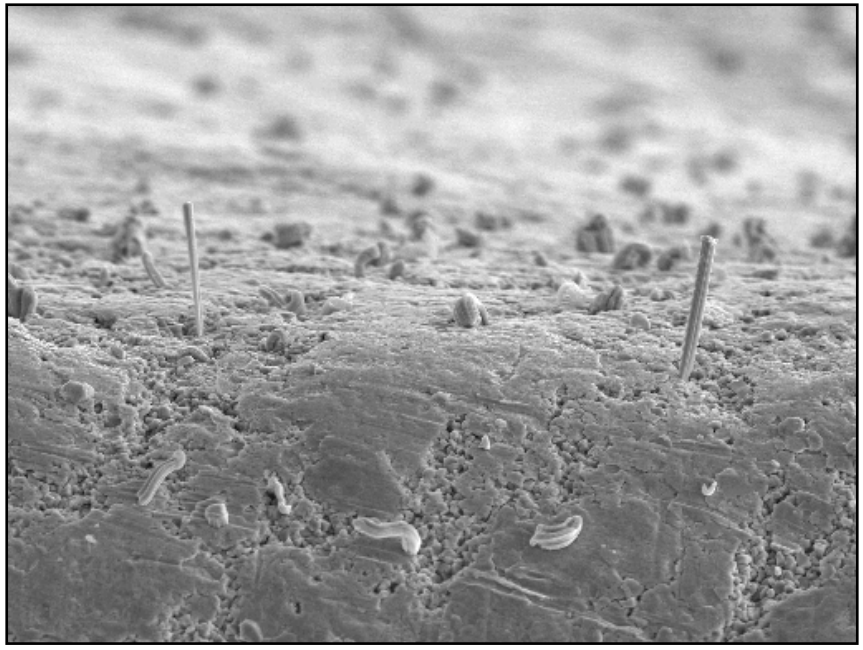
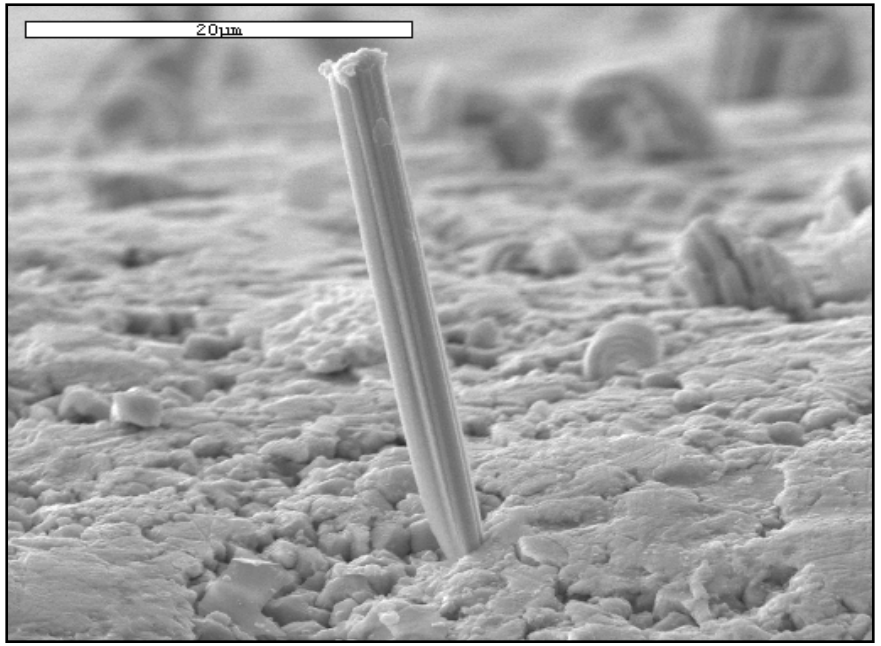
Sn/Pb "L" Terminations Released August 2005

Commercial SnPb

- Commercial SnPb Offering
  - Any Surface Mount chip currently offer can have a 90Sn/10Pb plating
  - Minimum 5% Lead content in termination.
  - Currently available in C0G & X7R dielectrics
  - Available for customers with concerns about Tin Whiskers





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High Voltage SMD MLCC

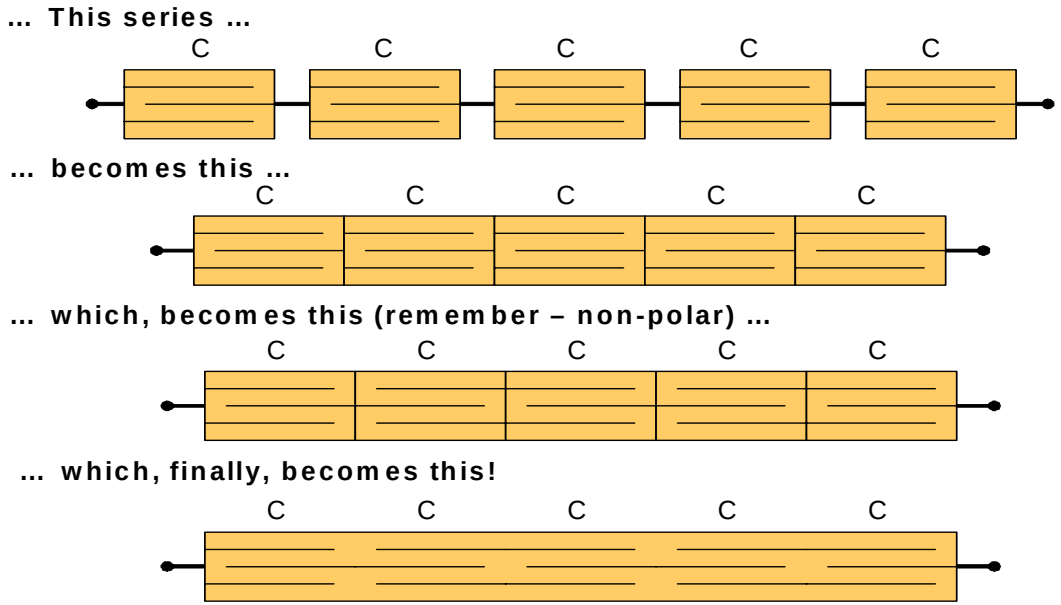
High Voltage Surface Mount MLCC Capacitors

What is a High Voltage SMD MLCC Capacitor?

Features

- Cascading electrode design which divides applied voltage
- Sn plated terminations

High Voltage Cascade Design . . .



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HV SMT X7R Roadmap, 0805 - 2225

EIA Case Size	Voltage Ratings							
	250V	500V	630V	1kV	1.5kV	2kV	2.5kV	3kV
0805	223	332		102				
1206	104	153	103	472	152	102		
1210	104	473	223	123	272	222		
1808		473		153	472	272	102	821
1812	474	683	473	223	682	391	122	102
1825	105	154		473	153	822	392	272
2220	105	154		473	153	822	392	272
2225	125	224		623	183	123	472	392

Available

Within Capability

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HV SMT X7R Roadmap, 1515 - 6560

EIA Case Size	X7R Voltage Ratings					
	500V	1kV	2kV	3kV	4kV	5kV
1515	683	223	392			
1812	563	183	272			
1825	184	473	822	272		
2020	184	683	822	392		
2225	224	683	153	472		
2520	224	823	183	562		
3333	474	224	273	123		
3530	564	274	333	153	682	
4040	824	394	473	183	822	
4540	125	474	683	333	103	682
5440	155	684	563	123	103	
5550	185	824	124	393	153	103
6560	225	105	184	823	273	153

Available

Within Capability

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HV SMT C0G Roadmap, 0805 - 2225

Case	Voltage Ratings					
EIA	500V	1kV	1.5kV	2kV	2.5kV	3kV
0805	181	101				
1206	102	561	181	121		
1210	332	182	681	471		
1808	272	152	561	331	331	121
1812	392	222	821	471	471	181
1825	822	472	182	122	102	391
2220	822	562	182	122	102	391
2225	103	752	242	152	122	561

Available

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HV SMT C0G Roadmap, 1515 - 6560

EIA Case Size	C0G Voltage Ratings					
	500V	1kV	2kV	3kV	4kV	5kV
1515	472	152	681	151		
1812	272	122	471	121		
1825	822	392	821	561		
2020	822	392	821	561		
2225	123	822	122	681		
2520	103	682	122	681		
3333	153	123	272	152	681	
3530	223	183	332	152	681	
4040	393	223	562	222	122	
4540	563	353	682	392	152	102
5440	823	333	822	332	222	
5550	683	473	103	682	222	222
6560	104	683	223	822	392	272

Available

Within Capability

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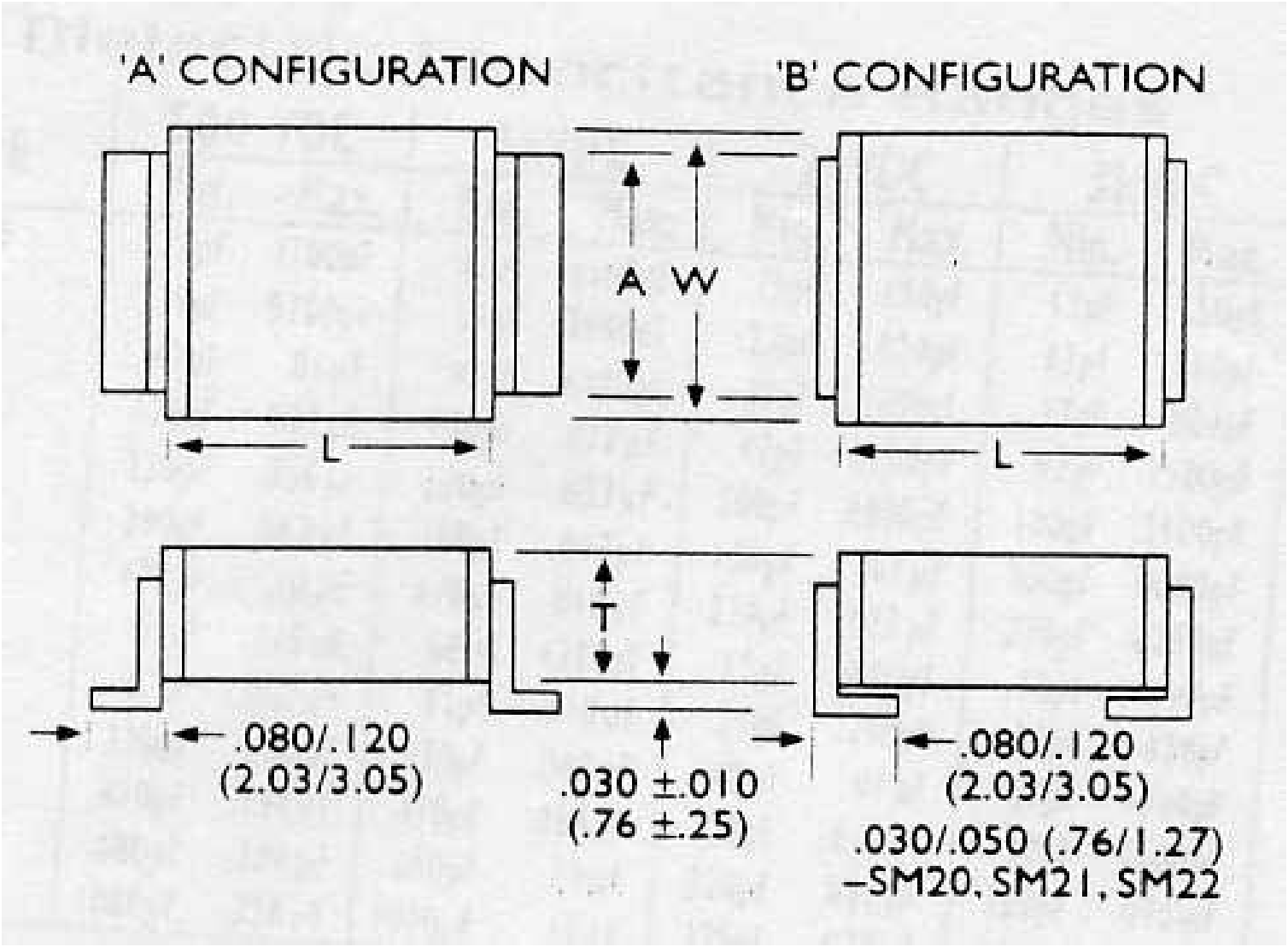
HV MLCC SMD J and L-Lead



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Tantalum & Aluminum Portfolio

Tantalum, Polymer & Aluminum Surface Mount Portfolio

	Series	Cathode	Description
Commercial	T491	MnO_2	Standard Tantalum Chip
	T494		Low ESR Standard Tantalum Chip
	T495		Low ESR, Surge Robust: Expanding with E-specs!
	T496		Fused DSCC Drawing 04053, Lower ESR Options
	T498/T499		150°C and 175°C Rating!
	T510		Low ESR, Multiple Anode Expanding with E-specs!
	T520	Polymer	Low ESR (to 6 mΩ), Rated to 105°C: Low ESR Leader!
	T525		125°C Rating DSCC Drawing 04051
	T526/T536		Fused, Fail-Open Under Development
	T528/T428	Polymer/ MnO_2	Face Down Termination, Low ESL
	T530	Polymer	Ultra Low ESR (to 5 mΩ), Multiple Anode DSCC Drawing 04052
	A700		Low ESR Aluminum (12.5V & 16V)
Specialty	T492	MnO_2	CWR11 New Termination Options QPL Expansion(Q2 '07)
	T409/T419/T429		CWR09/19/29 New Termination Options and 50V
	T493		Military COTS Grade – Ultra Low ESR Level
	T497		High Grade

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Standard and Low ESR Ta-MnO_2 Chips

T491/4/5 & T510

Product Offering (Tantalum - MnO_2)

- T491 Commercial Ta-MnO_2 SMD
- T492 Military (CWR11)
- T493 Military COTS
- T494 Lower ESR T-491
- T495 Low ESR Ta-MnO_2 (by design)
- T496 Fused Ta-MnO_2
- T499 High Temperature Ta-MnO_2 (+175°C)
- T510 Multiple-anode Ta-MnO_2

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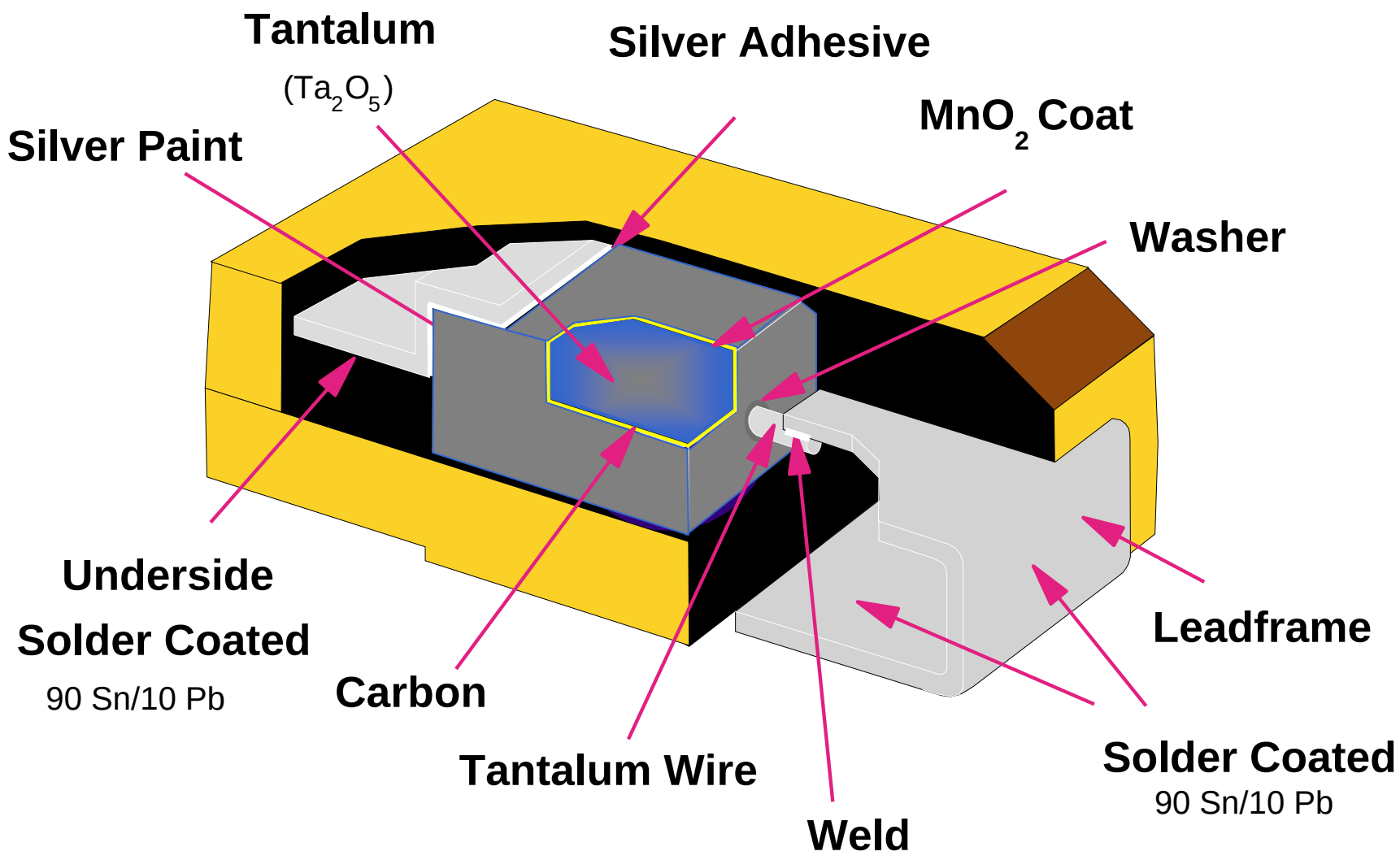
T491/T494/T495 Solid Tantalum



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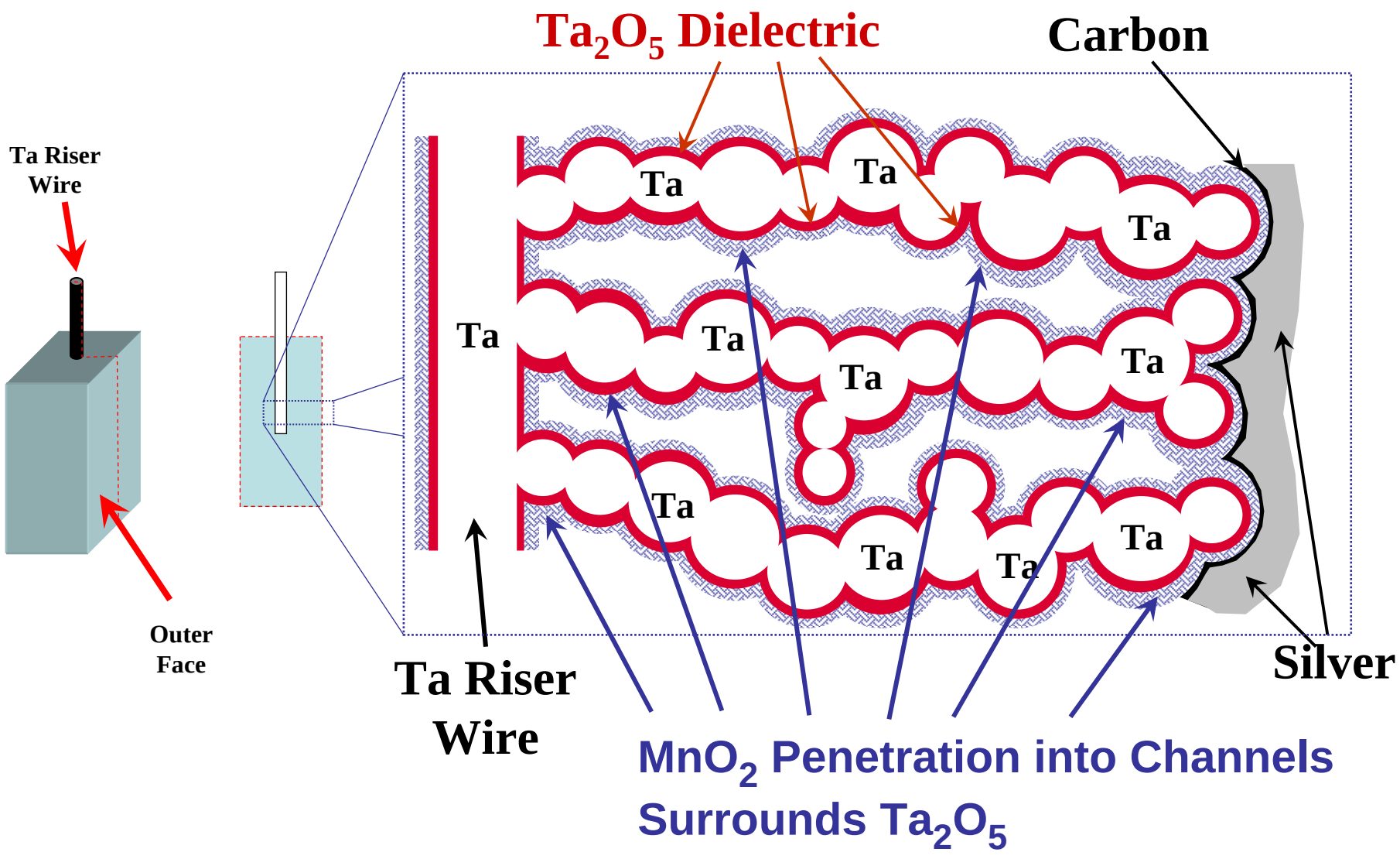
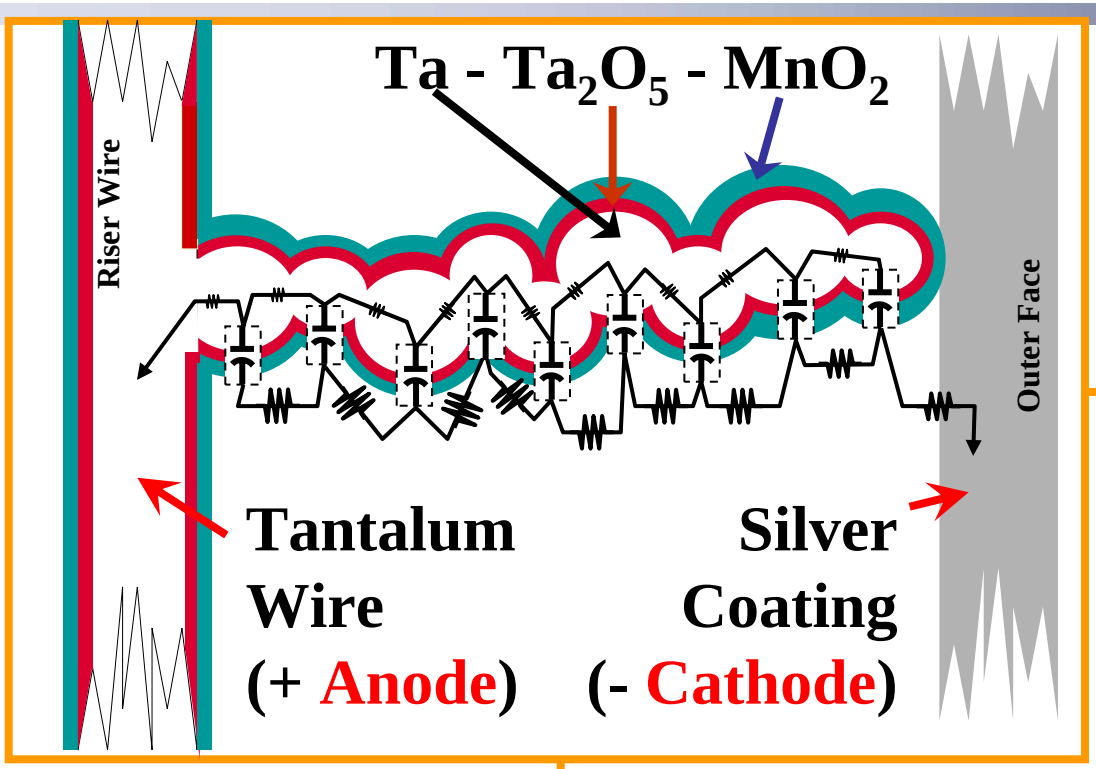
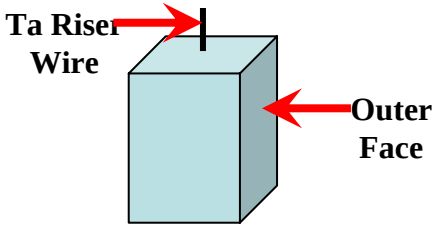
Tantalum Construction



Electrolytic RC-Ladder Structure



RC-Ladder Effects



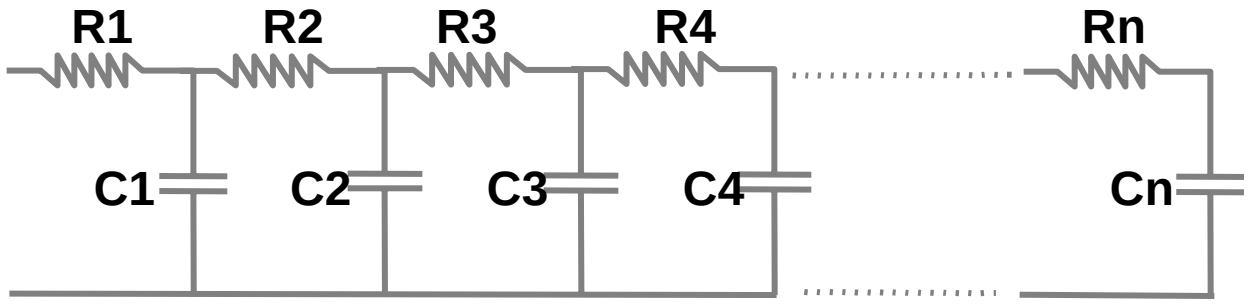
$tc1 = C1 \times R1$

$tc2 = C2 \times (R1+R2)$

$tc3 = C3 \times (R1+R2+R3)$

$tcn = Cn \times (R1+R2+R3...+Rn)$

RC-Ladder effects are factored by both capacitance and resistance.



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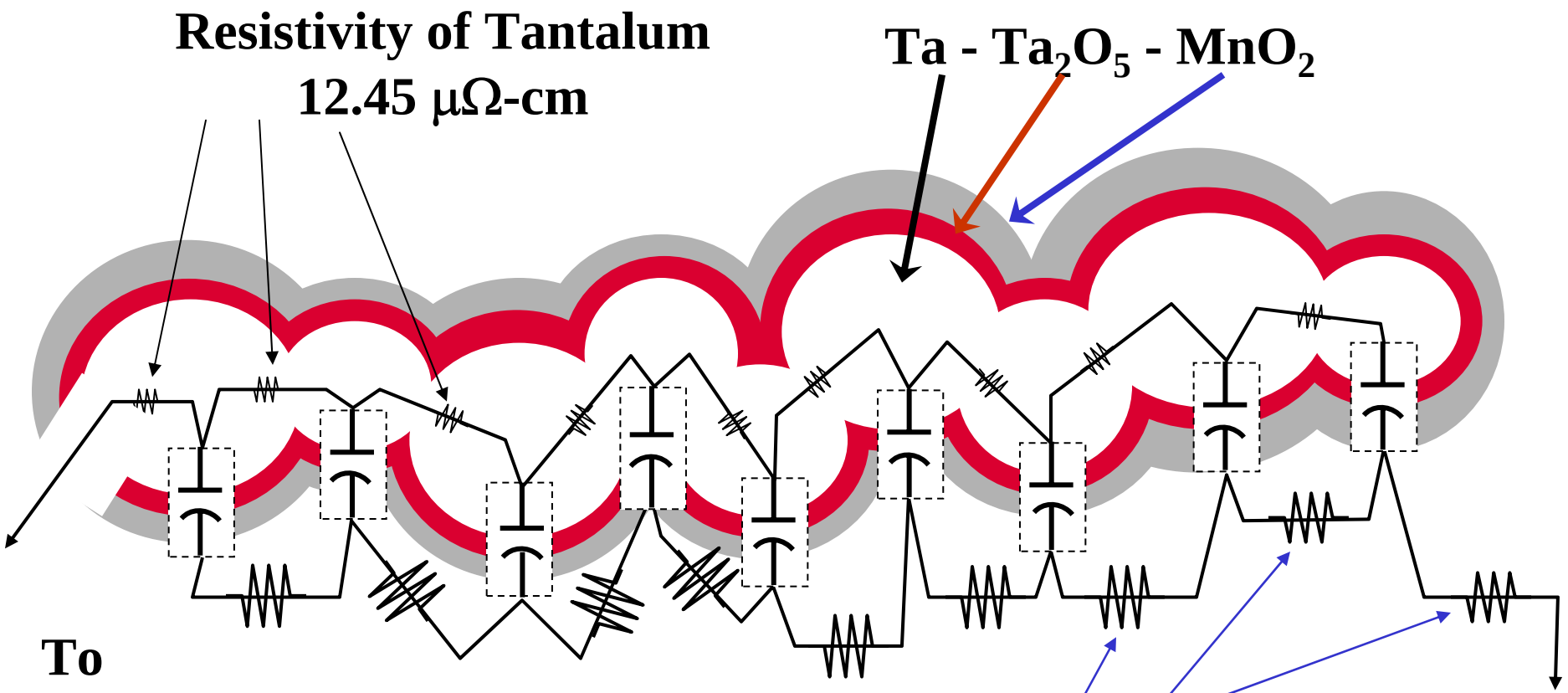
Distributed Capacitance



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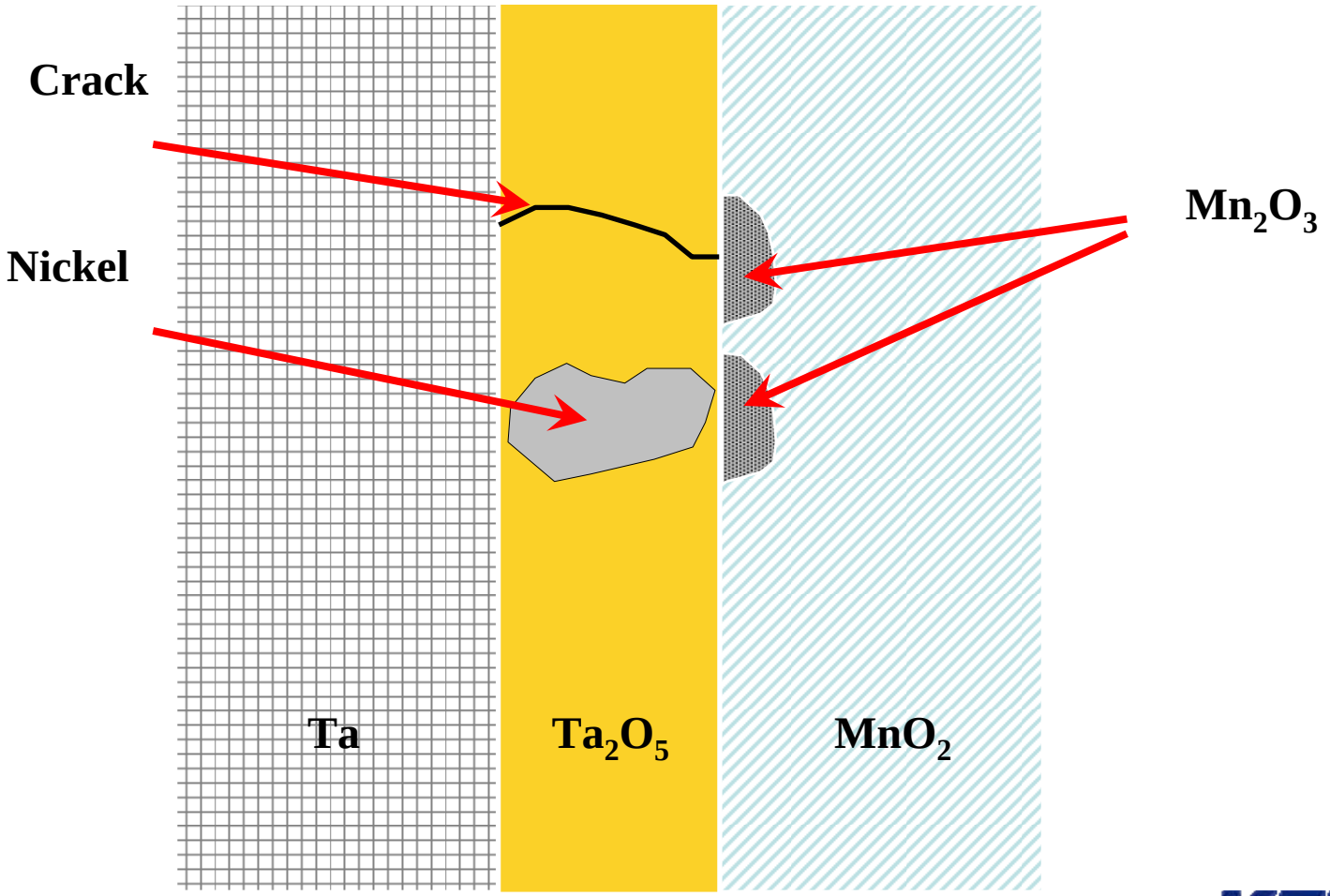
MnO_2 Self-Healing

Healing Effect of MnO_2 Layer



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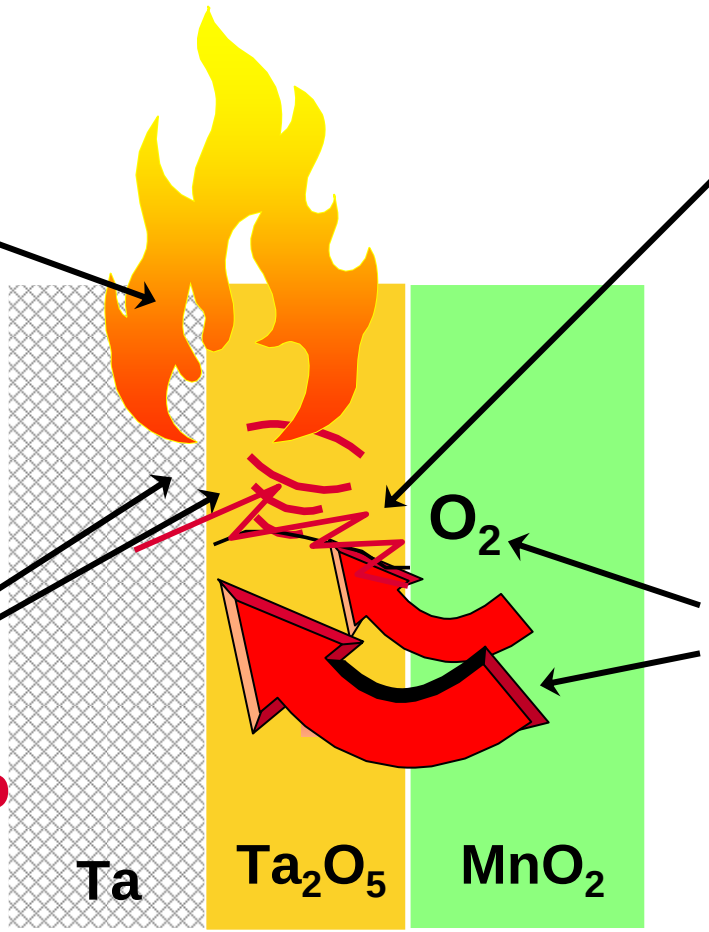
$TaMnO_2$ "Ignition"



1.

Crack initiates current & heat

2.

MnO_2 conversion starts - O_2 generated - Ta_2O_5 to crystalline

3.

Oxygen feeds heated Ta

4.

Ta + O_2 RAPIDLY combine = Ignition

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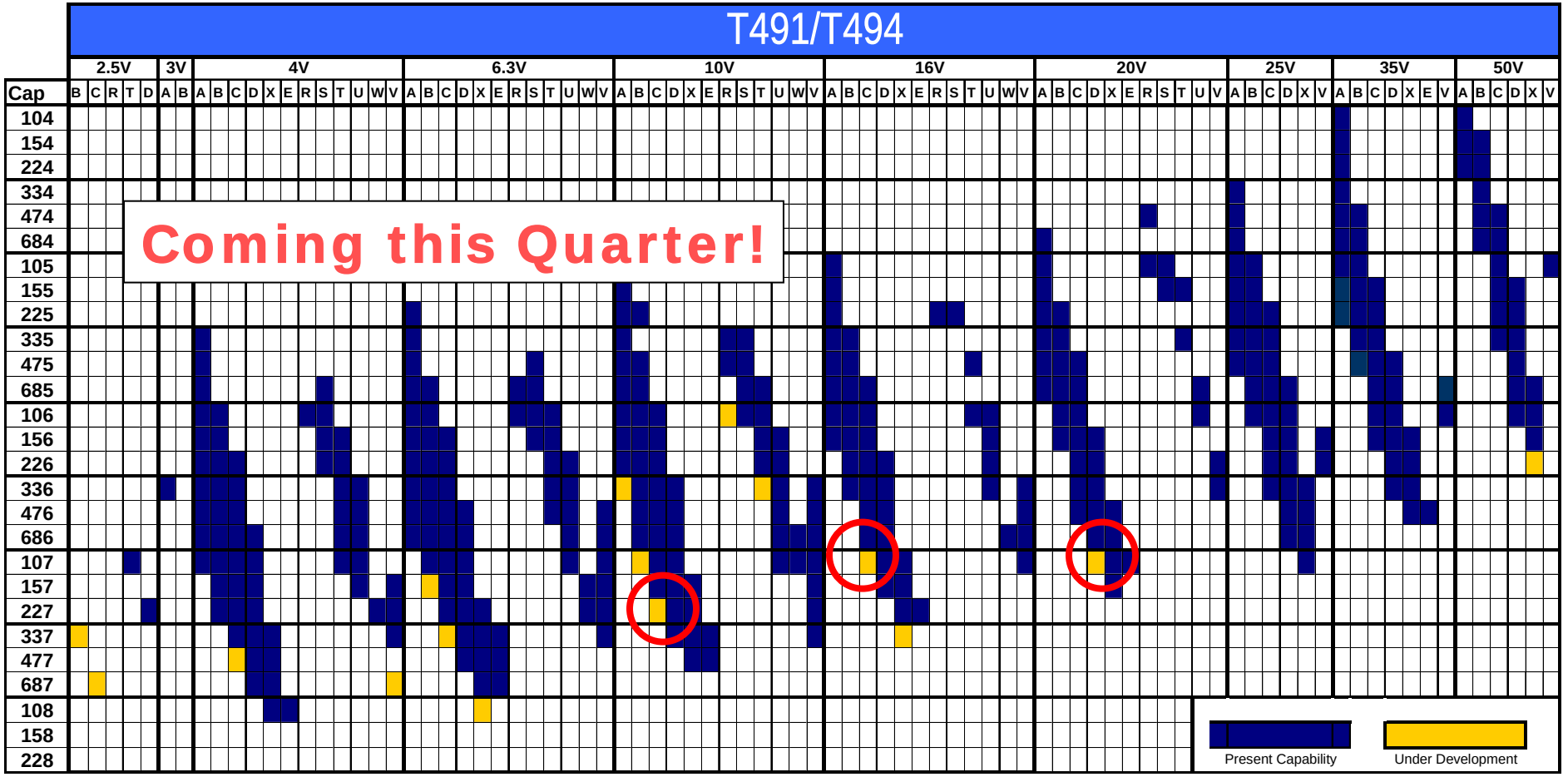
T491/4 Roadmap

- Ongoing Focus on CV Extension



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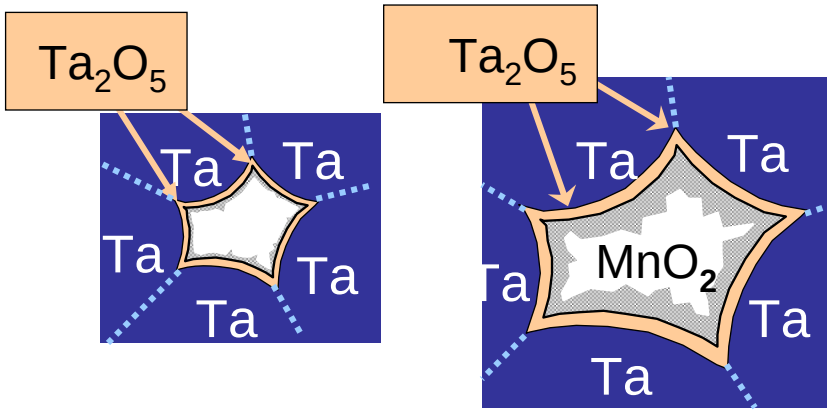
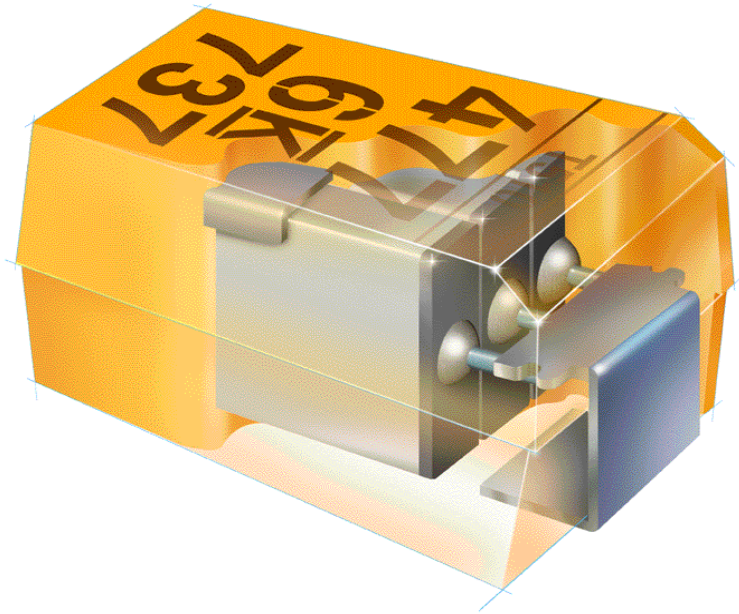
ESR Reduction in Tantalum …

Lower Capacitance Loss with Frequency



T495
Larger Pores
More MnO2
Lower ESR

T510
Multiple-pellets
Lower ESR



T495 Roadmap (2.5V – 10V)

- Roadmap Drivers
  - Lower ESR (35mohms)
  - Higher CV

T495 Surge Robust - Low ESR 2.5V - 10V

	2.5V					4V									6.3V										10V									
Cap	A	B	T	D	X	A	B	T	C	U	D	W	V	X	E	A	B	T	C	U	D	V	W	X	E	A	B	T	C	U	D	V	W	X	E
154																																			
224																																			
334																																			
474																																			
684																																			
105																																			
155																										5K0									
225	5K0					5K0										5K0										1K8									
335	3K0					3k0										3k0										2K0									
475	3K5					3K5										3K5										1K3	1K3								
685	2K0					2K0										2K0											900								
106	2K0					2K0										2K0	1K0	1K2								2K0	750	1K5	200						
156	2K0					1K5										2K0	700	1K0								1K8	500	1K2	375						
226	1K5					1K5			380							1K5	500	1K0	380							1K5	700		290						
336	1K0					1K0		1K2	300							1K0	500		300								450		300			100			
476						750		2K0	250								400		250			150					400		300	400	80	200			
686									150				150				350		150	400	175						600		200	300	70	70	200	150	
107		3K0	3K0				300		150								250		150	350	50	90							100		50	100	200	100	
157							900		200	350	100								200		50	40	250	100							50	100		85	
227				45					100		40	250							100		45	150	250	70							45	150		45	
337									300		30			100							40	150		45	60						100	150		35	40
477											100			30							100			30	55						150			45	
687																								60											
108					40									60	35										50										
158																																			
228																																			

Coming this Quarter!

KEMET CHARGED.

T495 Roadmap (16V – 50V)

T495 Surge Robust - Low ESR 16V - 50V

Coming this Quarter!

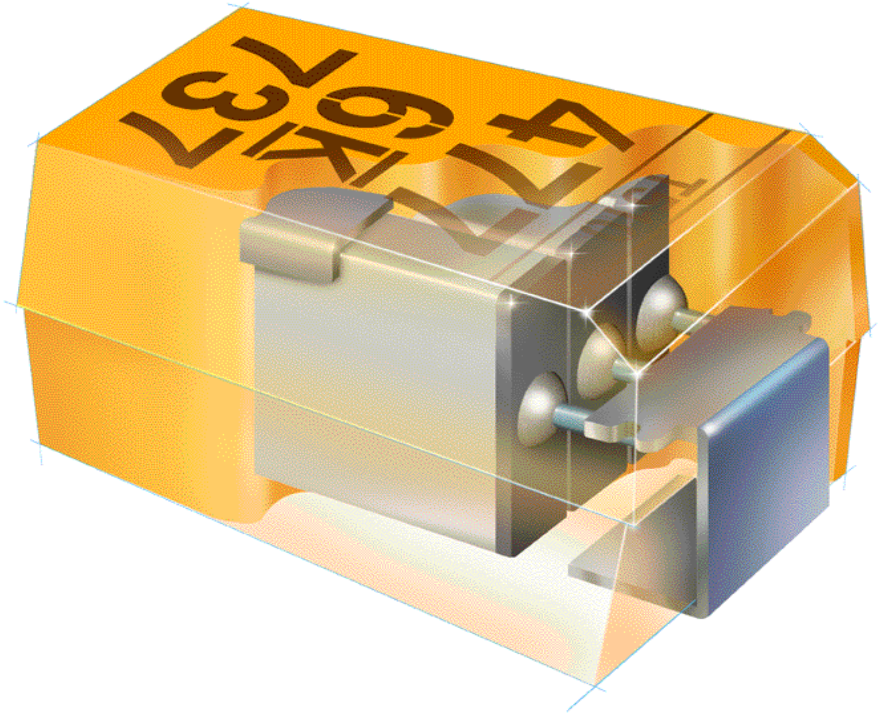
	16V									20V						
Cap	A	B	T	C	U	D	V	X	E	A	B	C	D	E	X	V
154																
224																
334																
474																
684										6K0						
105	5K0									5K0						
155	5K0									4K5						
225	2K5									3K0	1K5					
335	3K0	2K0								2K5	1K3					
475	2K0	700								1K8	750					
685	1K5	900		750								480				
106	2K5	500	800	450							800	400				
156	2K5	650									500	375	275			
226		700		250	500							200	180			400
336		350		225	400	150	250					200	100		200	400
476				300		80	250						75		65	
686				180		70	180	150					70		120	
107						100	60	80						85	150	
157						60		75								
227								100	75							
337																
477																
687																
108																
158																
228																

	25V					35V						50V		
Cap	A	B	C	D	X	A	B	C	D	V	X	C	D	X
154						15K								
224						13K								
334	10K					7K0								
474	4K5					7K0	1k5							
684	6K0					6K0	2K5							
105	5K0					3K0	1k5					1k3		
155	4K0	1K5				2K0	2K0					1K5		
225	3K5	1K2	1k3			1K5	1K5	750					600	
335	1K5	800	750				900	550					700	
475		800	530				1K0	450	300				275	300
685		700	400					350	150	600	300		275	300
106		750	300					400	120	600	175			260
156			300	230	200			350	225		200			200
226			280	200	225				200		125			
336				90	175				200		175			
476				120	80						185			
686					125									
107														
157														
227														
337														
477														
687														
108														
158														
228														

ESR (mOhms) — Present Capability

ESR (mOhms) — Under Development

T510 Multiple Anode Tantalum



Multiple Anodes for Lower ESR

% Anode Penetration vs. Thickness

High frequency loss of penetration

Approximately 80% of volume lost resulting in ~20% of Reference Cap

About 50% of volume lost, or 50% of 1/3 ~ 17% of Reference Cap

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Multiple Anode Penetration

Decreased high frequency loss of volume

Low Frequency Penetration

High Frequency Penetration

Three narrow anodes lose 1/2 of original, or result in ~ 50% of Reference Cap replacing single with only 20% of capacitance retained. (150% improvement)

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T510 Roadmap

T510 - Mult-Anode

	4V		6.3V		10V		16V		20V		25V		35V		50V	
Cap	X	E	X	E	X	E	X	E	X	E	X	E	X	E	X	E
335																
475																
685																
106															90	
156																
226													60			
336													50			
476													55	50		
686											45					
107									35			50				
157							30									
227							25									
337					35											
477			30													
687	30		23	12												
108	18	10														
158																
228																

Q2 '07

ESR (mOhms) — Present Capability

ESR (mOhms) — Under Development

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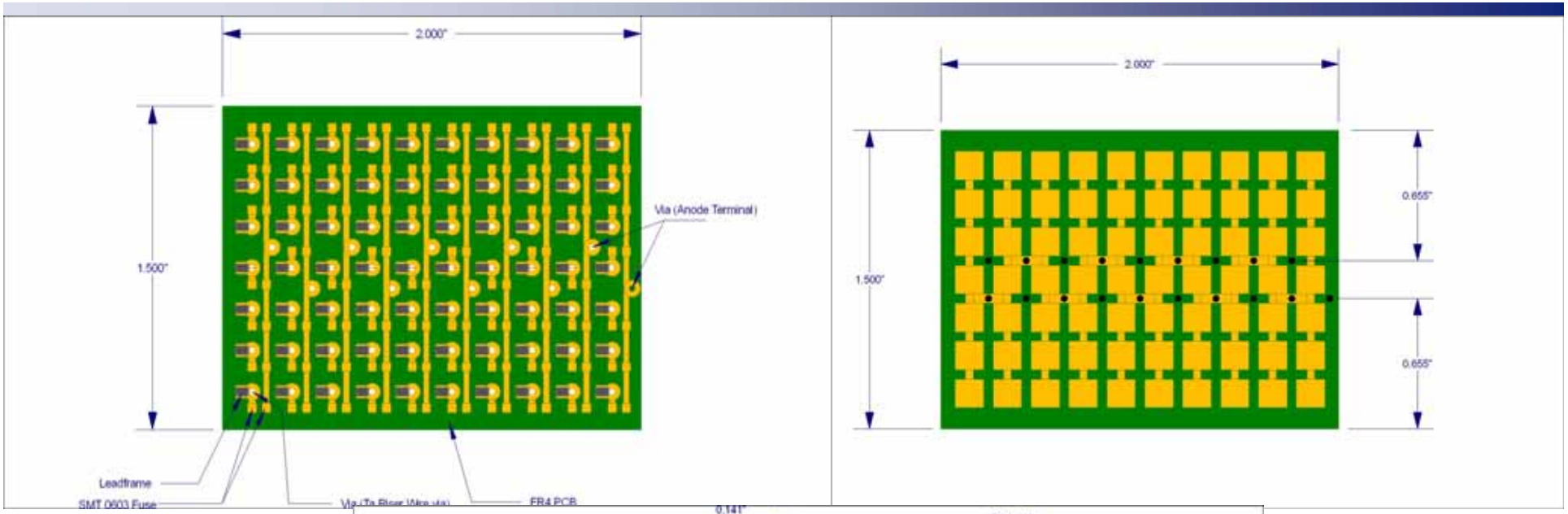
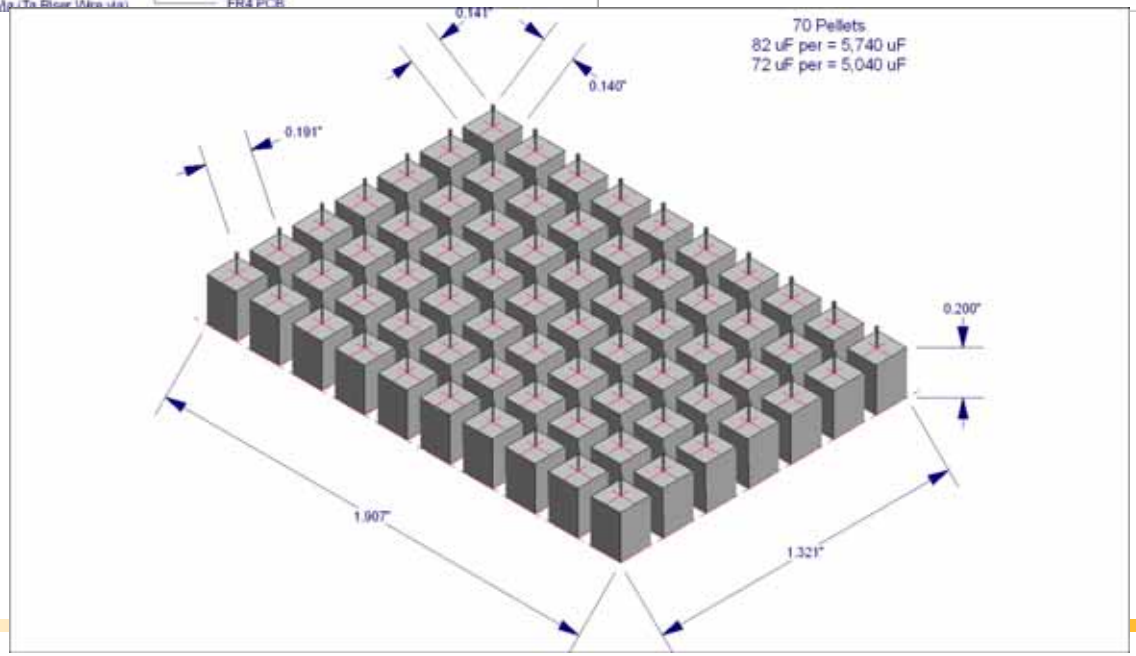
5000uF, 20V Fused Tantalum Module





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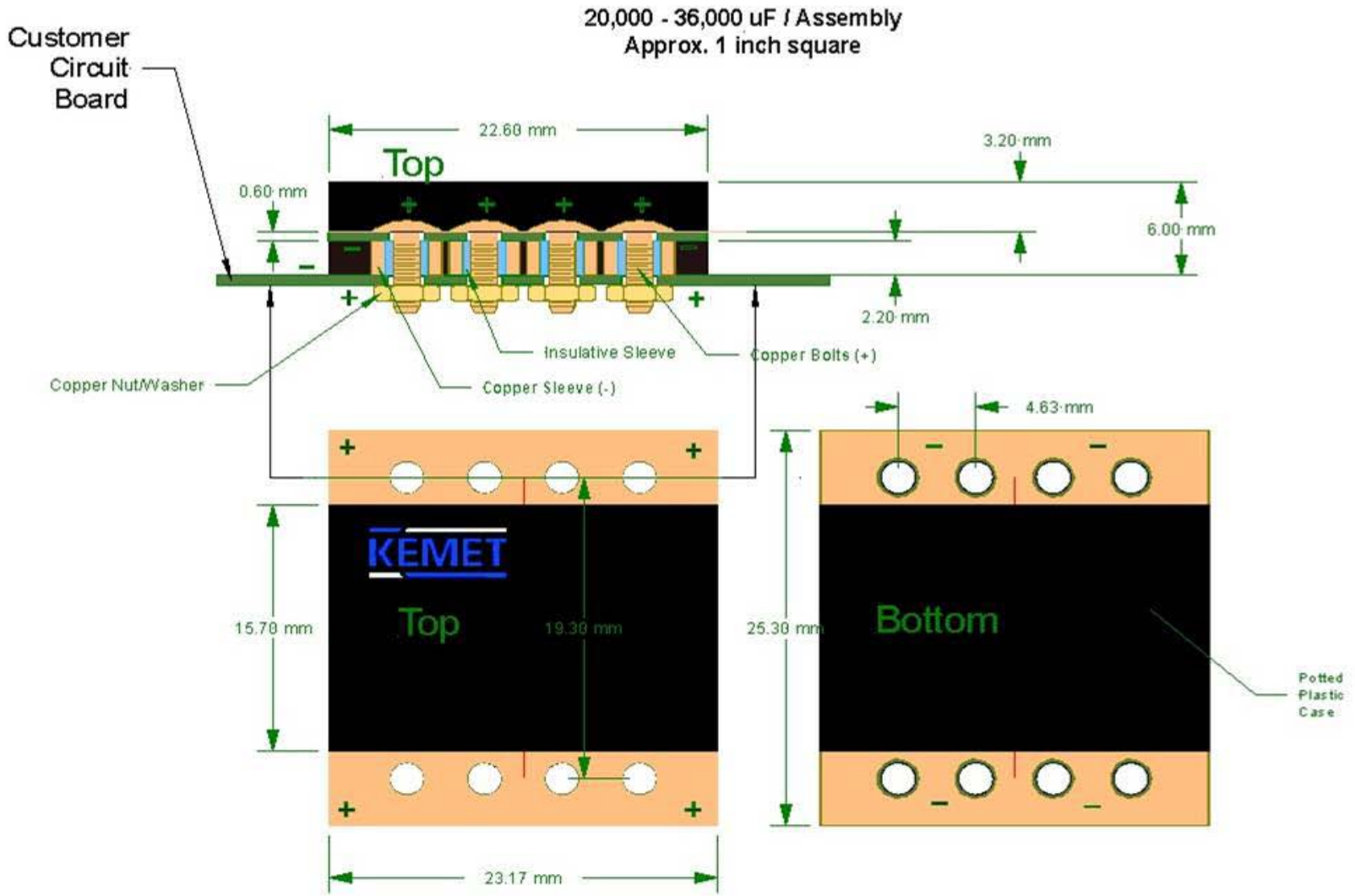
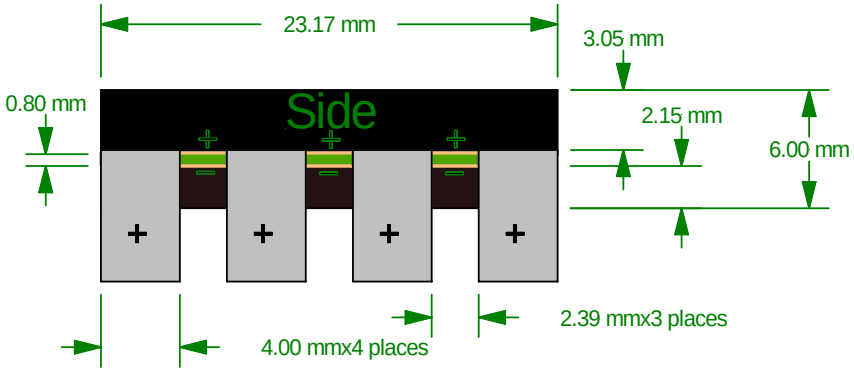
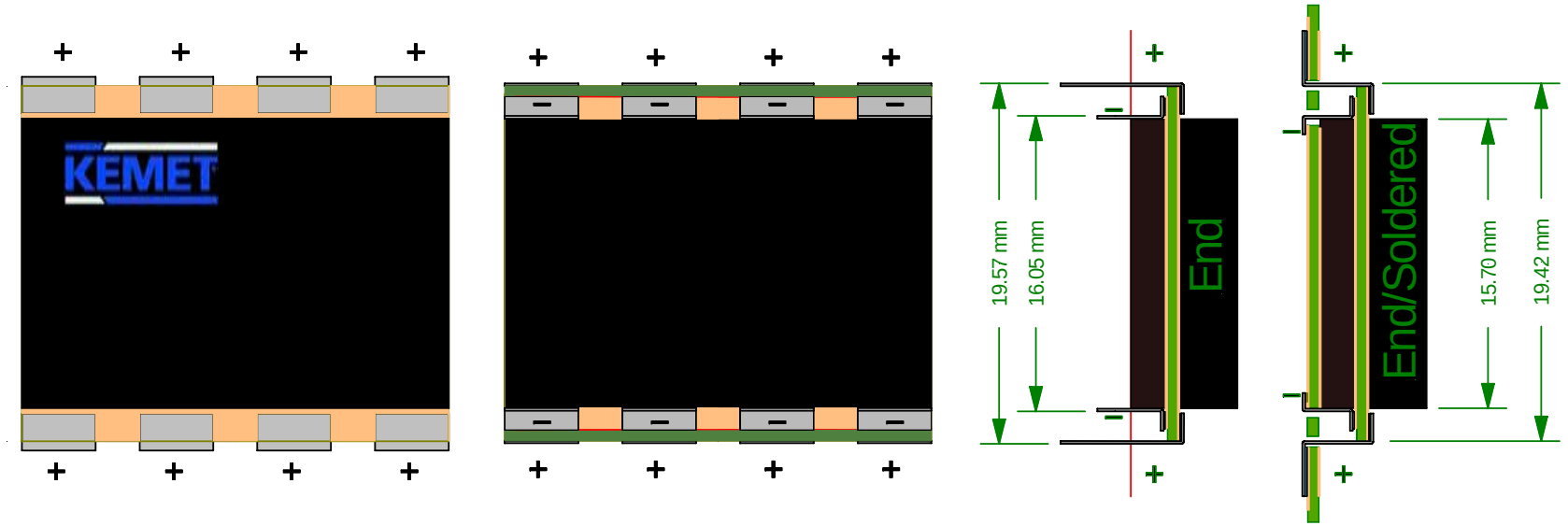
Mechanically Bolted Capacitor Assembly



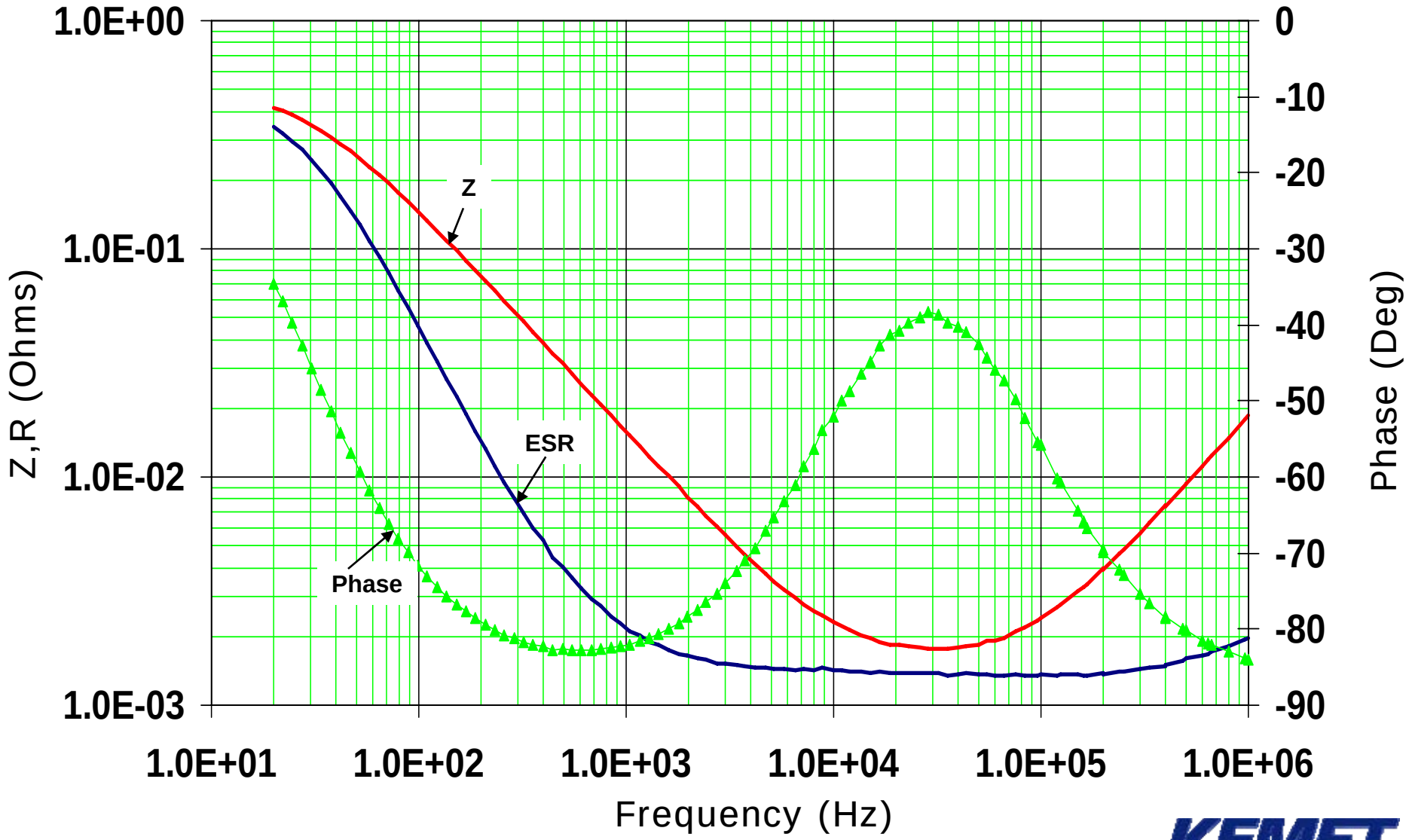
Through-Hole Leadframe Assembly



TH Leadframe
Wide Spacing



11,500 uF Cap Assembly



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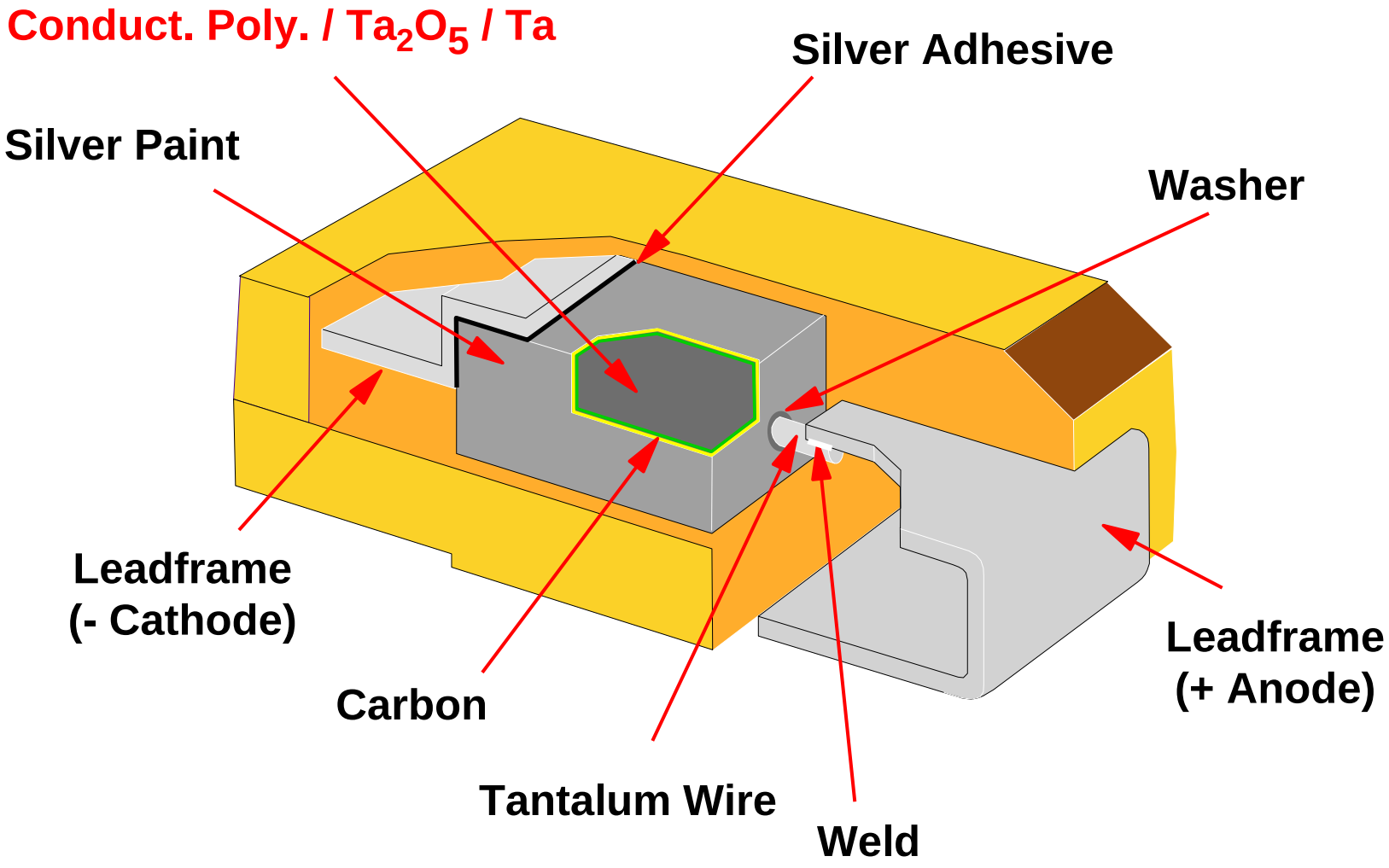
Organic Polymer Chips

T520/T525/T530

Polymer Tantalum Surface Mount Capacitor



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T520/530 Series KO-CAP Product Features

- KEMET Organic Capacitor (KO-CAP)
  - Conductive Polymer Cathode
  - Replaces MnO2
  - Reduces ESR
  - Non-ignition failure mode
  - Reduced derating
    - Use up to 90% for Vr<=10 VDC
    - Use up to 80% for Vr>10 VDC
- Series Name/Sizes
  - T520 (Single Anode)
    - A, B, C, D, Y and X Standard Case Sizes.
    - T, U, V and W Low Profile Case Sizes.
    - ***Developing New L(6032-19) Cases!***
    - ***ESR as low as 6 mOhm!***
  - T530 (MAT)
    - D, Y and X Sizes, ***ESR as low as 4mohm!***
  - T526 (Fail Open Polymer) **Under Development!**

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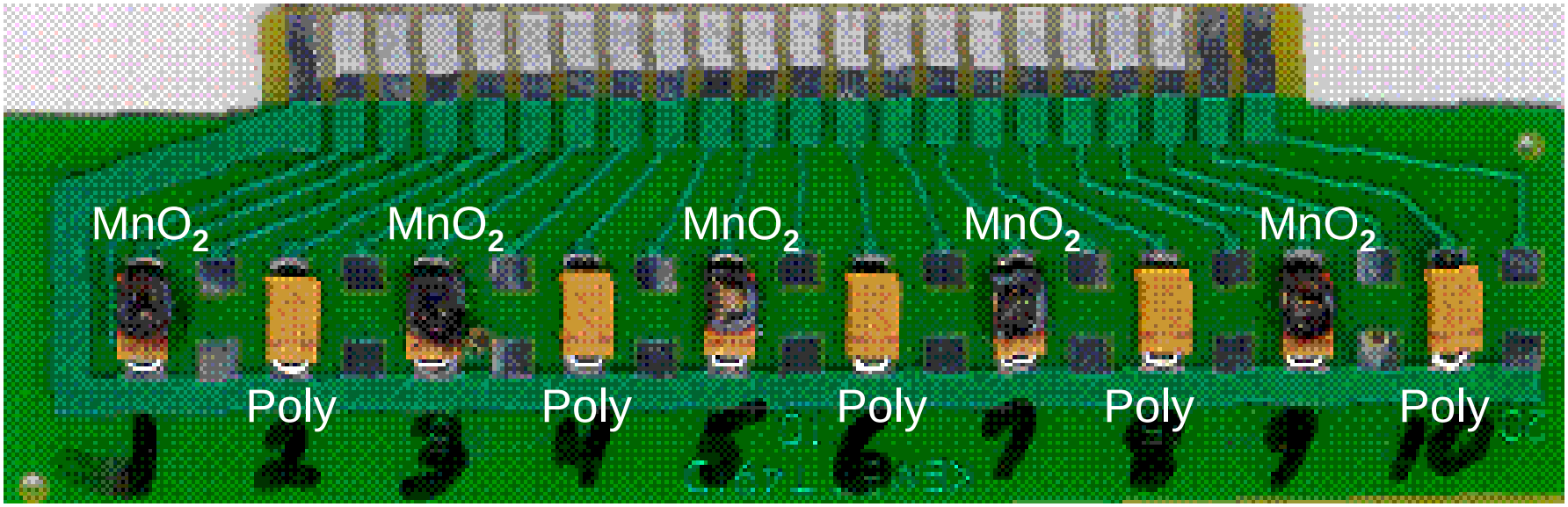
MnO_2 vs. Polymer



Test card with capacitors subjected to 2x Rated Voltage, applied with reverse polarity and > 20 amperes current capability.

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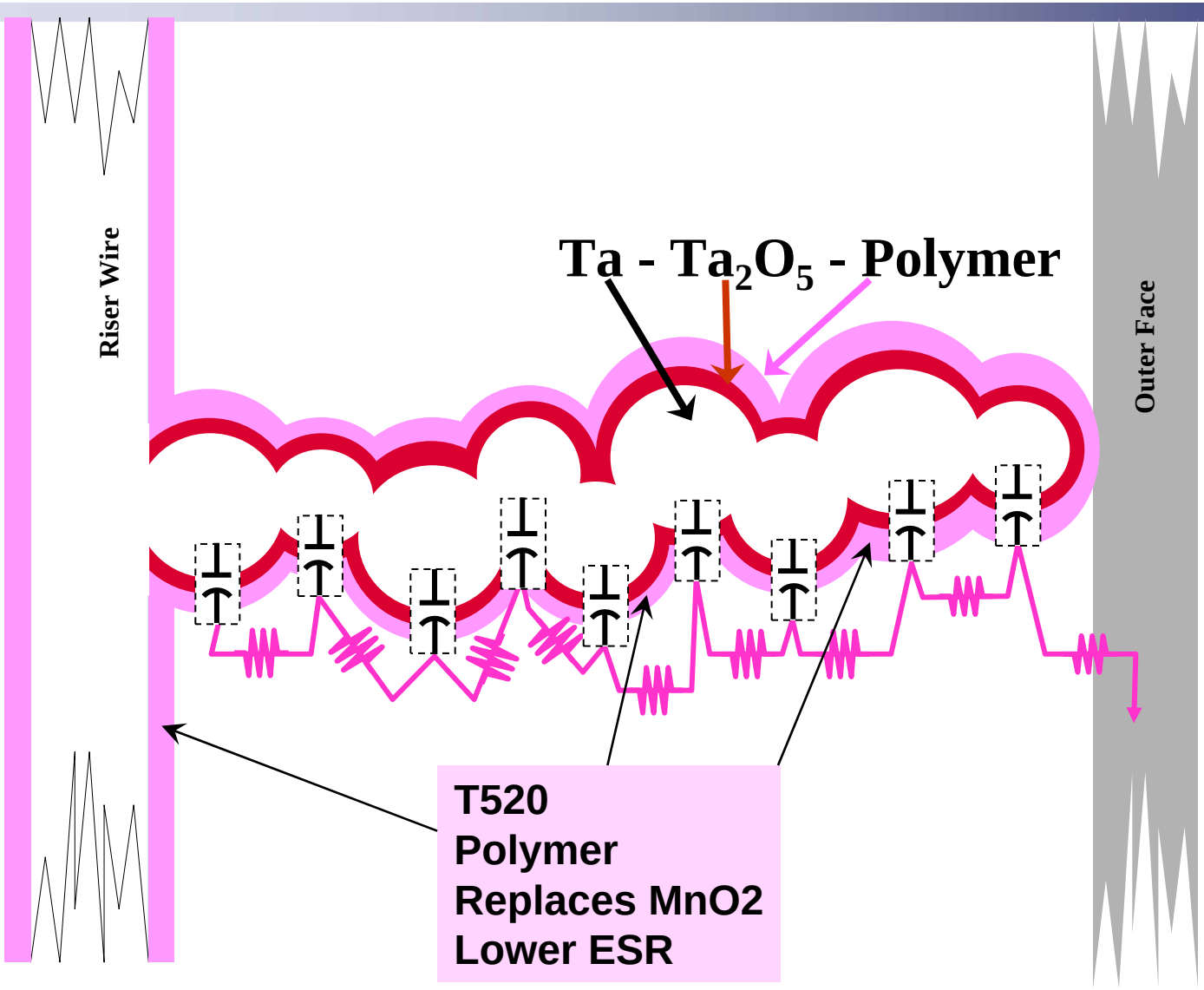
Conductive Polymer replacing MnO_2



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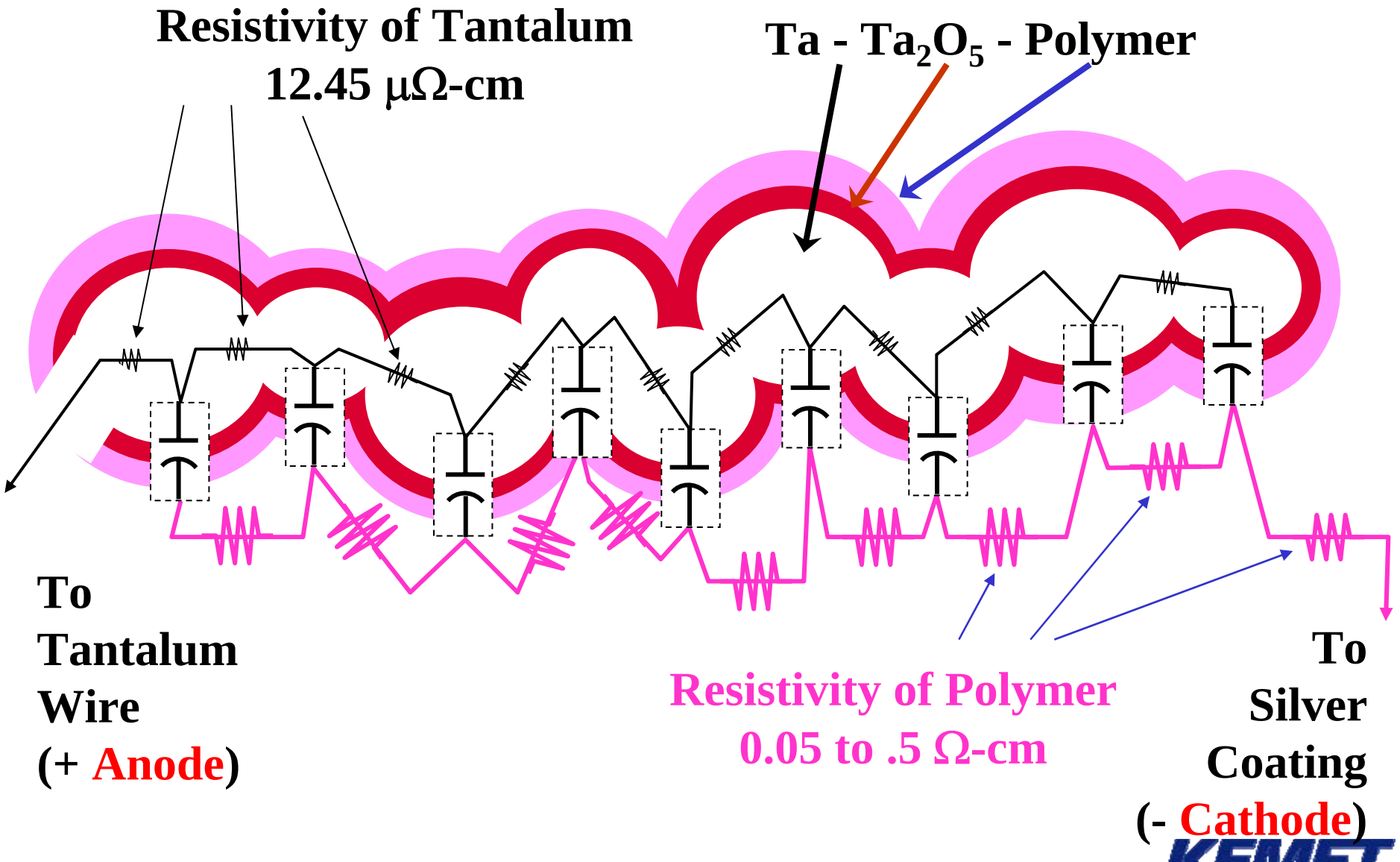
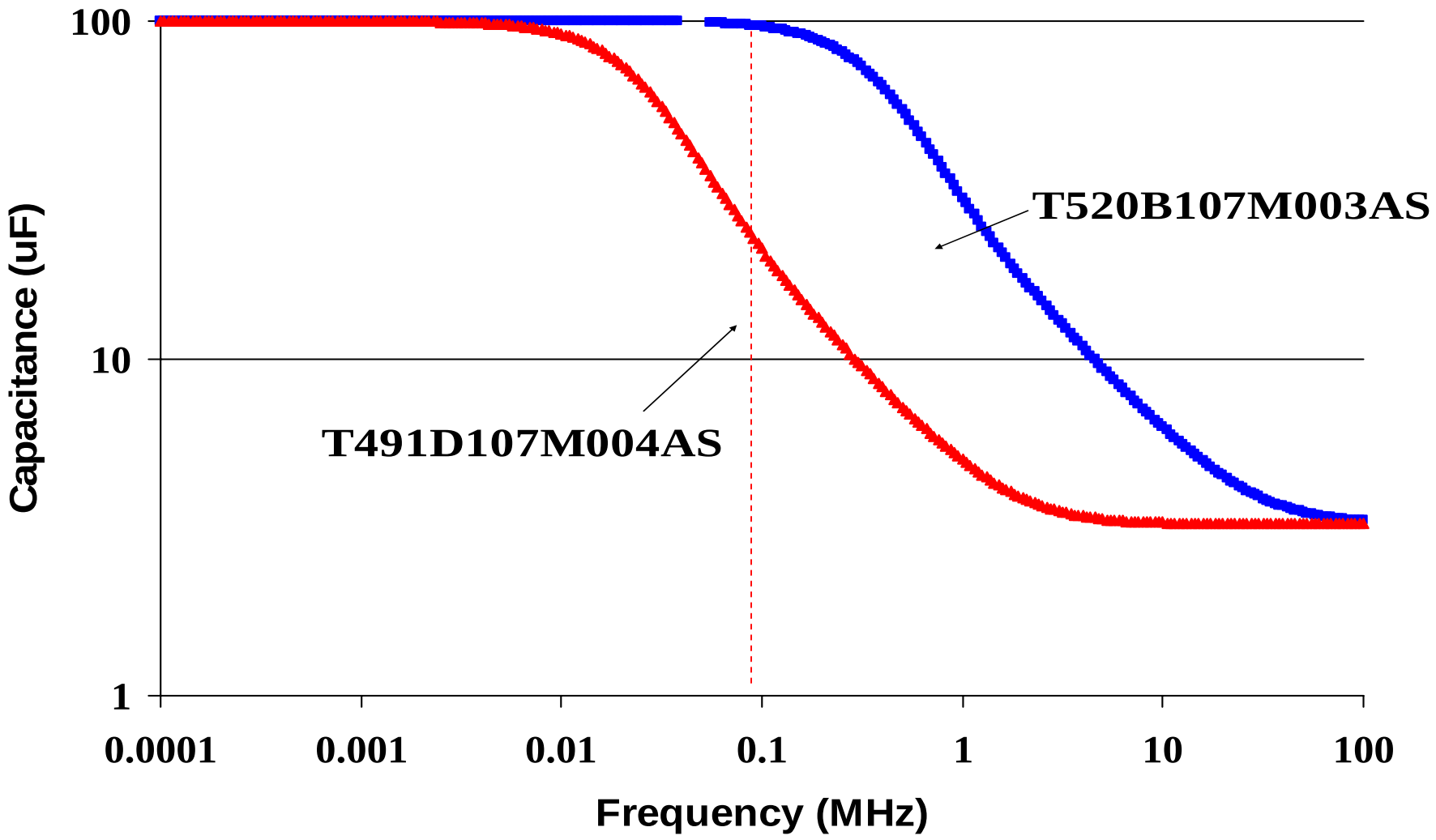
Poly-Distributed Capacitance

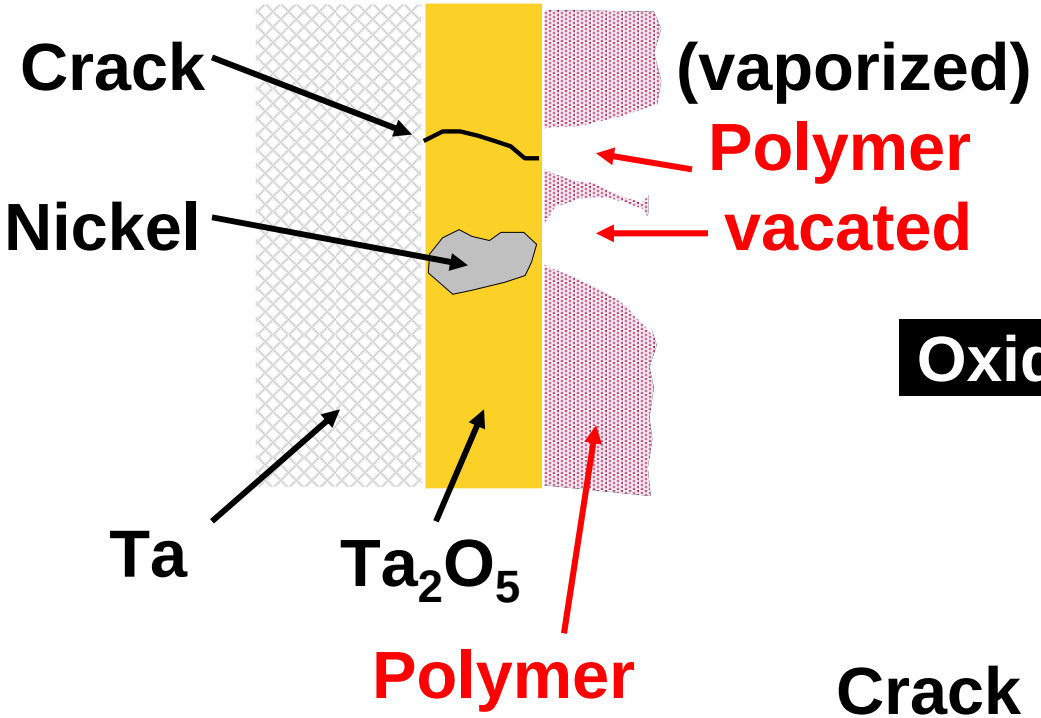


Polymer Improvement: Roll-Off

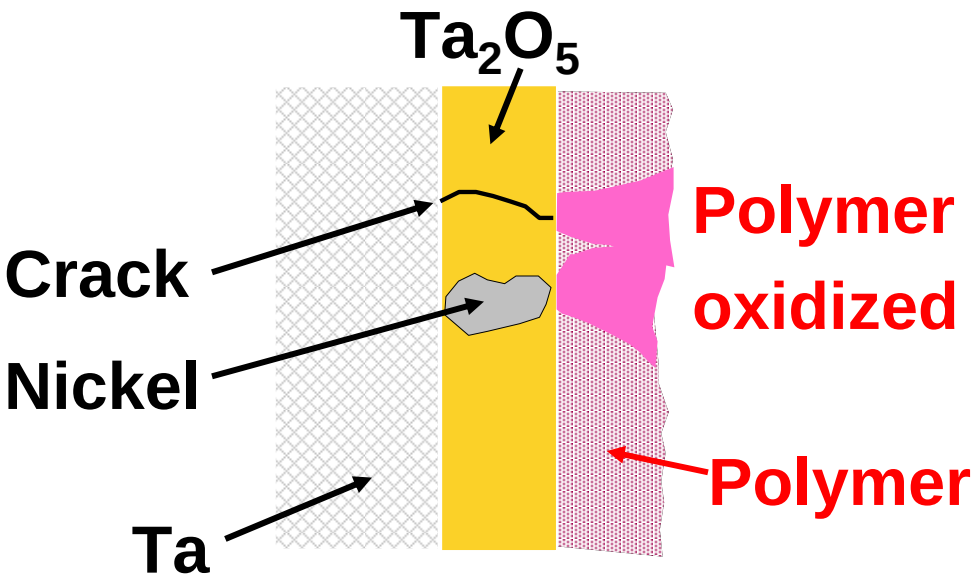


Polymer Self-Healing

Evaporation of Conductive Polymer Layer



Oxidation of Polymer Layer



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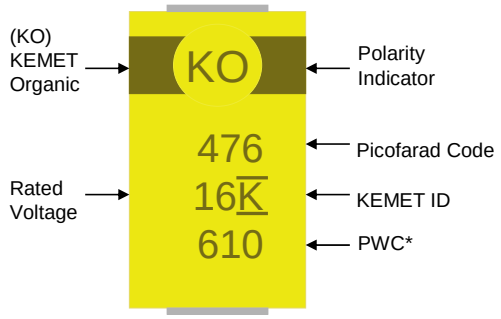
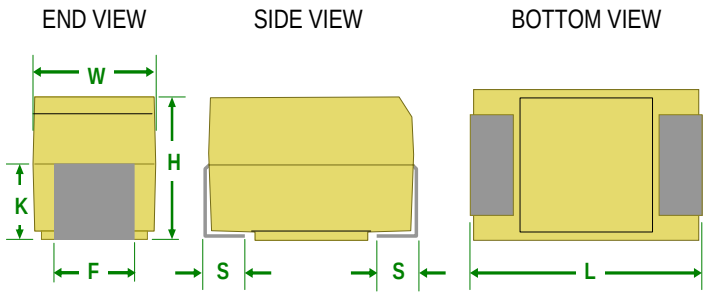
T520 Single Anode KO-CAP

Component Marking



* 610 = 10th week of 2006

Component Outline Drawing



- **Low ESR Polymer Technology: 6mohms**
- **High Frequency Cap Retention**
- **Capacitance 15 to 1000μF**
- **Operating temperature: -55° C to 105° C**
- **Voltage: 2.5V to 25V**
  - **10% Derating for PNs </= 10V**
  - **20% Derating for PNs > 10V**
- **RoHS Compliant**
- **3x260° C Reflow Capable**

Case Codes			Component Dimensions, mm		
KEMET	EIA		L	W	H
A	3216	3216-18	3.2±0.2	1.6±0.2	1.6±0.1
S	3216L	3216-12	3.2±0.2	1.6±0.2	1.2 max
B	3528	3528-21	3.5±0.2	2.8±0.2	1.9±0.1
T	3528L	3528-12	3.5±0.2	2.8±0.2	1.2 max
C	6032	6032-28	6.0±0.3	3.2±0.3	2.5±0.3
D	7343	7343-31	7.3±0.3	4.3±0.3	2.8±0.3
X	7343H	7343-43	7.3±0.3	4.3±0.3	4.0±0.3
W	N/A	7343-15	7.3±0.3	4.3±0.3	1.5 max
L	N/A	6032-19	6.0±0.3	3.2±0.3	1.9 max
U	6032L	6032-15	6.0±0.3	3.2±0.3	1.5 max
Y	7343	7343-40	7.3±0.3	4.3±0.3	4.0 max
V	7343L	7343-20	7.3±0.3	4.3±0.3	1.9 Max

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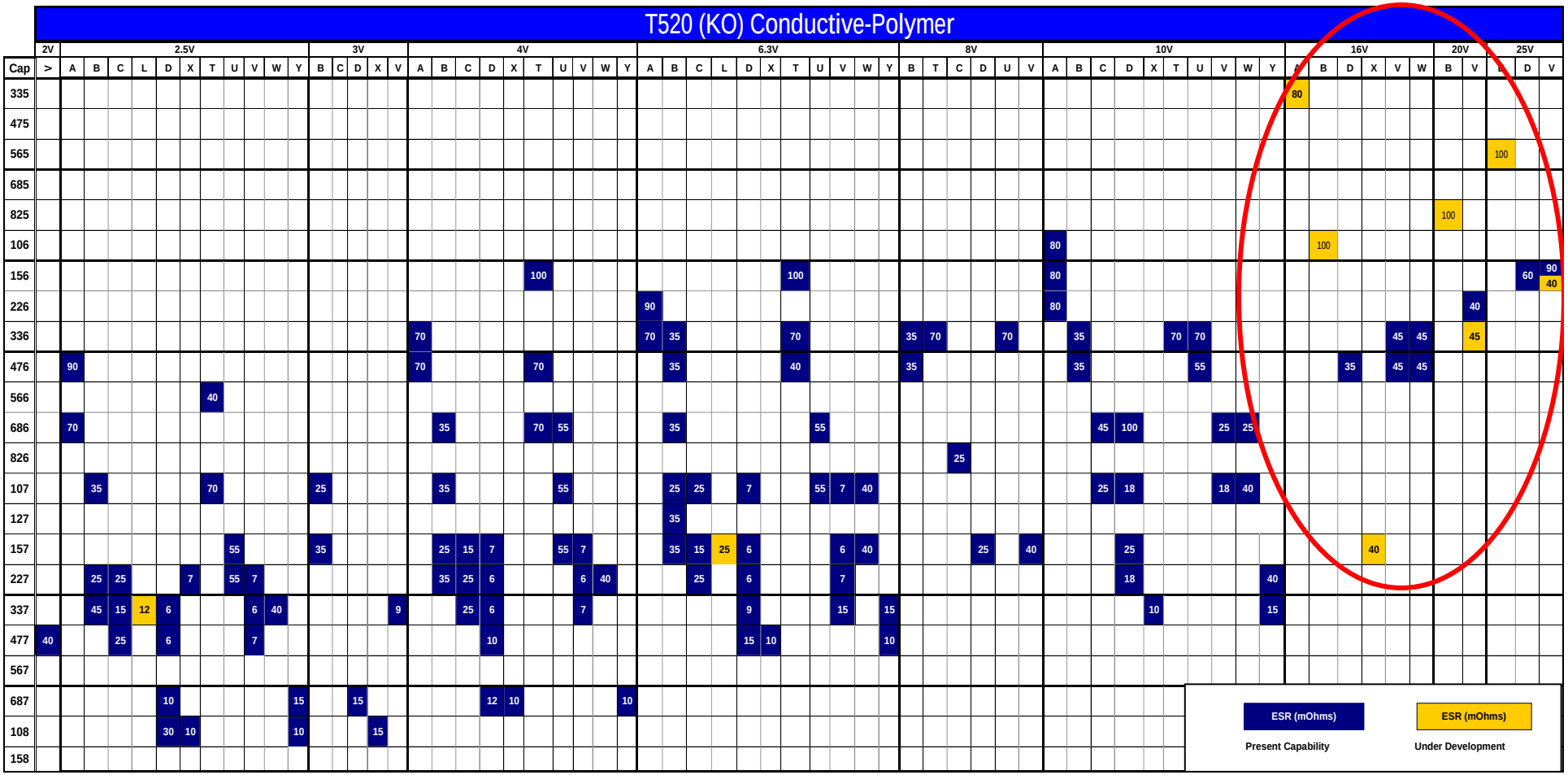
T520 Roadmap

Roadmap activities focused on higher voltage ratings (16V, 20V, 25V)



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T525 Series – High Temperature Polymer

- Polymer Technology
- Rated to 125^{o} C
- DSCC Source Control Drawing 04051

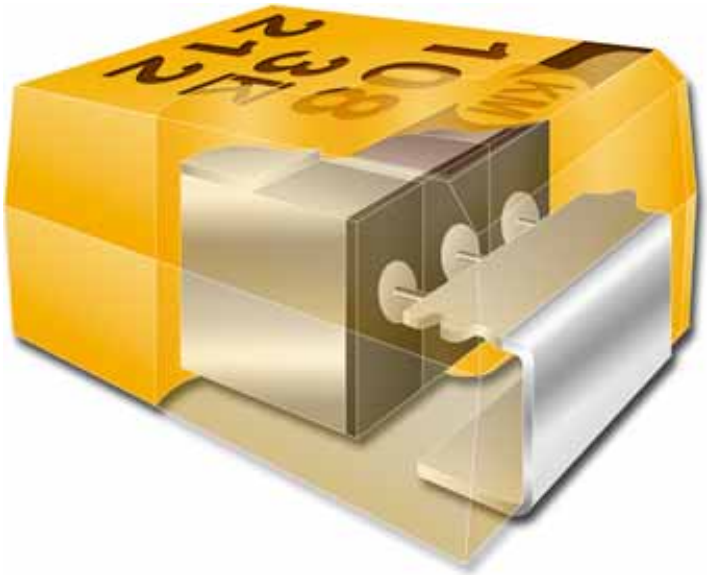
T525 (KO at 125°C)

Cap	2.5V							3V				4V							6.3V							10V						16V				20V		25V		
	A	B	D	X	T	V	Y	B	D	X	V	A	B	D	X	T	V	Y	A	B	D	X	T	V	Y	B	C	D	X	T	V	B	D	X	V	B	V	B	D	V
156																																								
226																										80														
336																										80				80										
476																				80												35								
566																				80			80																	
686													80			80				80																					
107					80			80					80																25												
157								80													25								25												
227														25							25								25												
337			25						25					25							25																				
477			25						25					25																											
567			25						25																															

ESR (mOhms) — Present Capability

ESR (mOhms) — Under Development

T530 Multiple Anode KO-CAP



- **Extremely low ESR: 4mohms**
- **High Frequency Cap Retention**
- **Highest CV in Standard EIA Size**
  - **1500uF in 7343 footprint**
- **Operating temperature: -55^{o} C to 125^{o} C**
- **Voltage: 2.5V to 10V**
  - **10% Derating**
- **RoHS Compliant**
- **3x260^{o} C Reflow Capable**
- **DSCC Source Control Drawing 04052**

Case Sizes - Size (mm)

KEMET	EIA	Length	Width	Height
'D' Case	7343-31	7.3 ± 0.3	4.3 ± 0.3	2.8 ± 0.3
'Y' Case	7343-40	7.3 ± 0.3	4.3 ± 0.3	4.0 max
'X' Case	7343-43	7.3 ± 0.3	4.3 ± 0.3	4.0 ± 0.3

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T530 Multiple Anode KO-CAP

T530 Mult-Anode

	2.5V			3V		4V				6.3V				10V				16V			
Cap	D	X	Y	D	X	D	E	X	Y	D	E	X	Y	D	E	X	Y	D	E	X	Y
107																					
157														5						15	
227										5				6			6				
337						5				6			5			4					
477	5			10		6			5			4	5								
567	5																				
687	6	6	5	10				4	5			10									
108		4	5		10			6													
158		5			8																

ESR (mOhms) — Present Capability

ESR (mOhms) — Under Development

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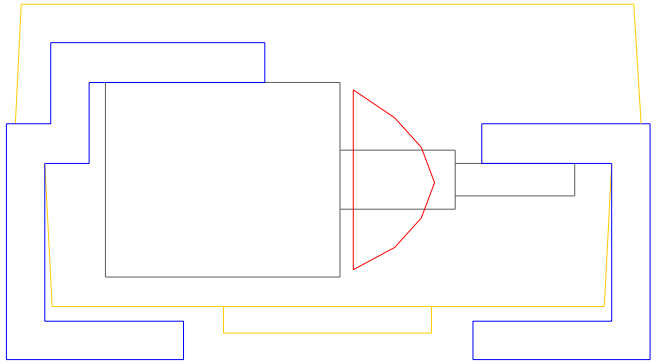
Face Down Termination, Low ESL Polymer Chips

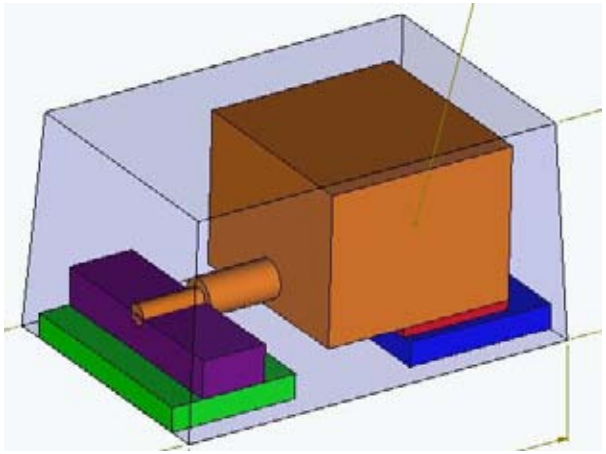
T528 (New)

Construction Improvements

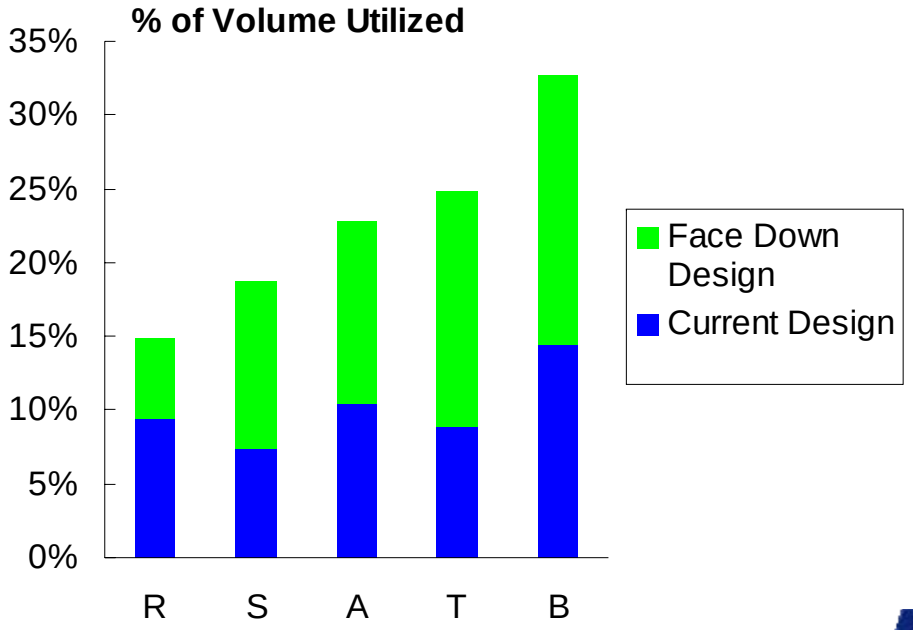
Standard Construction



Face Down Termination



Push Volumetric Efficiency To Even Higher Levels



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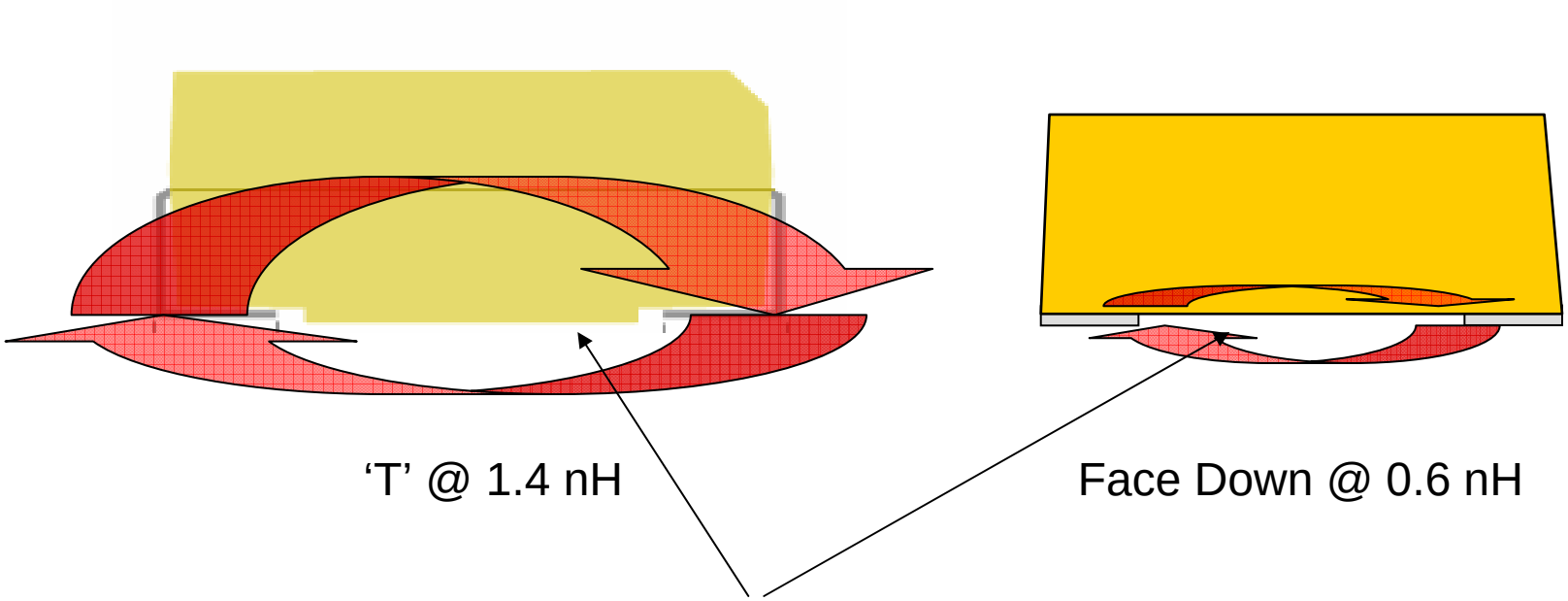
Reduced ESL Loop Areas

STD
Ta/Poly Chip

Face-Down
Ta/Poly Chip



‘T’ @ 1.4 nH

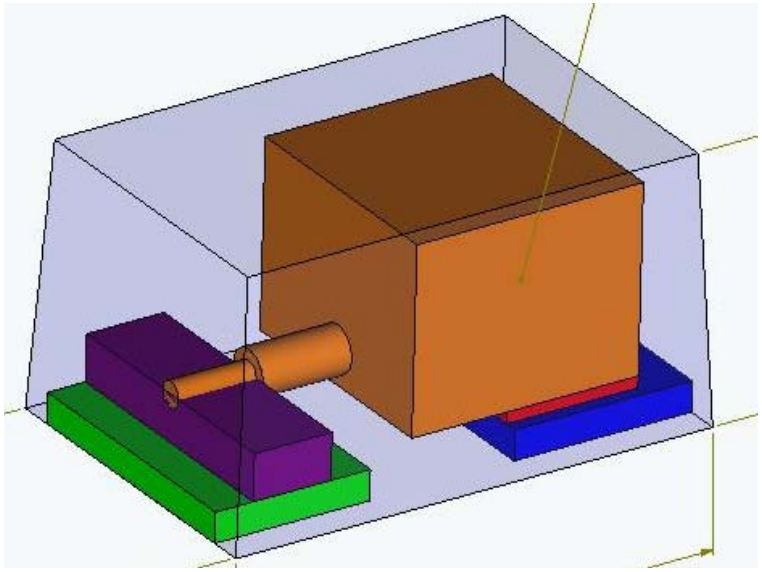
Face Down @ 0.6 nH

Reduction in “loop area” is proportional to a reduction in ESL.

New Series: T528 Face Down / Low ESL Polymer

What Is T528?

- Polymer Cathode Technology
- Face Down Termination Design
- Initial Development of Z case (7343-17)
  - T528Z337M2R5ATE009, E012 – Released!
  - T528Z477M2R5ATE009, E012 – Released!
  - T528Z337M2R5ATE007, E008
  - T528Z477M2R5ATE007, E008
- Low ESL: < 0.7nH@20MHz for Z Case size
- Low ESR: 9 mOhm for 7343 Case size
- Current Development of I case (3216-10), M case (3528-15) and R case (2012-12)
  - T528I336M010ATE200
  - T528M157M006ATE200
  - T528R476M006ATE200
- Lead (Pb) free 260C Capable
- RoHS compliant
- Samples available



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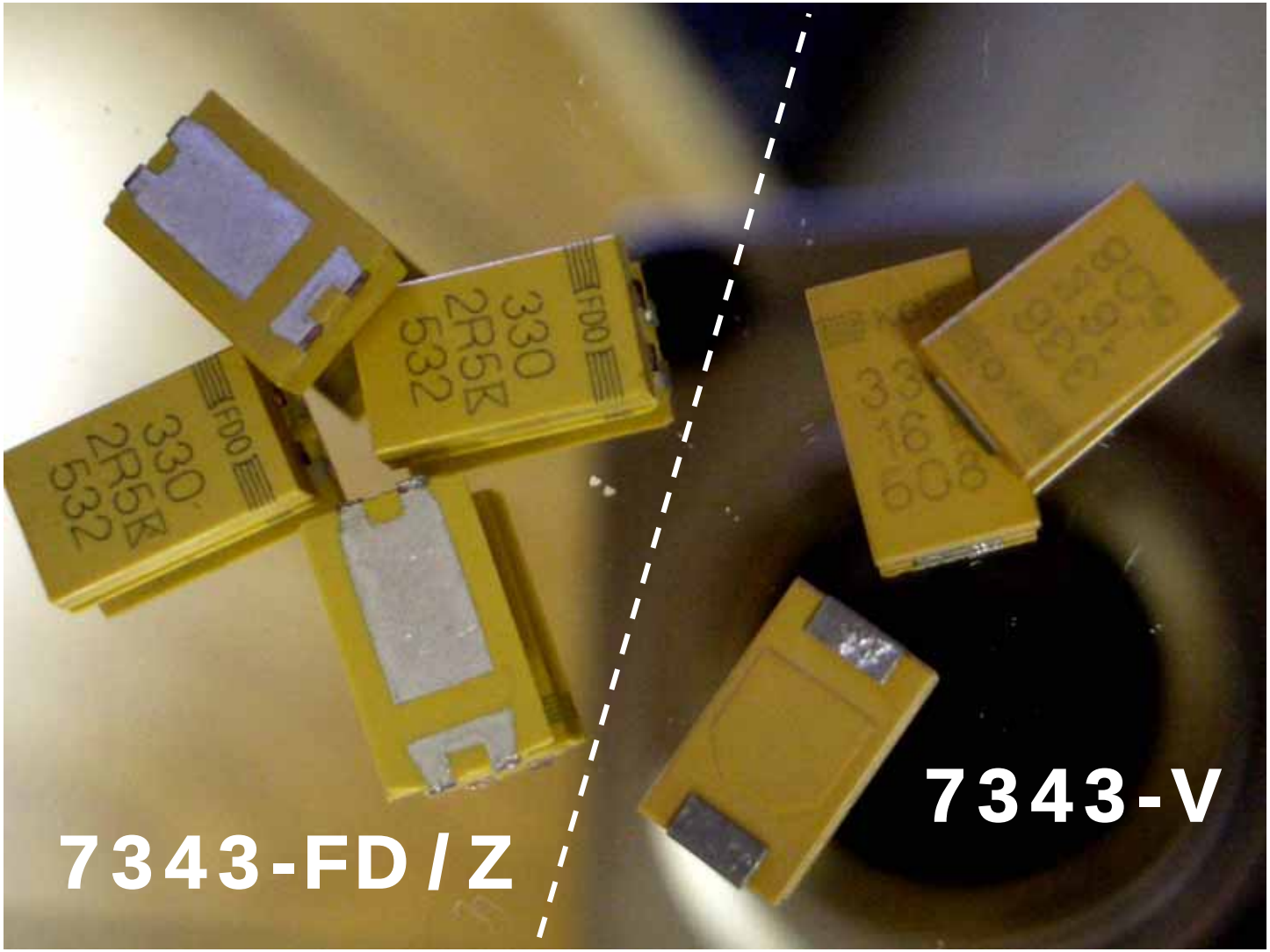
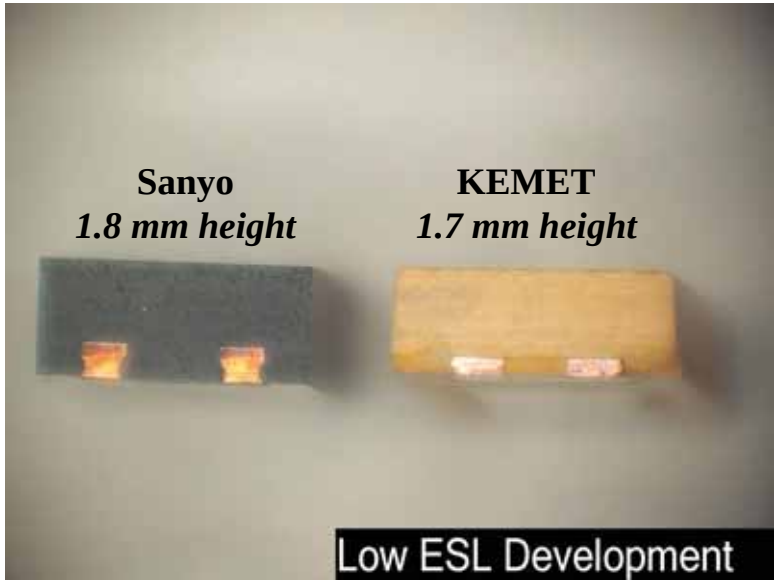
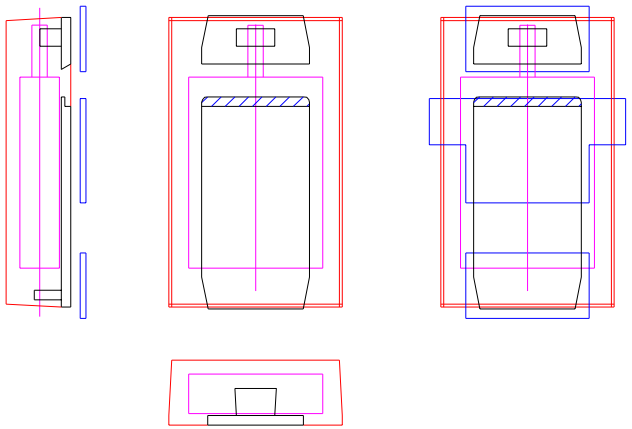
7343-FD/Z vs 7343-V



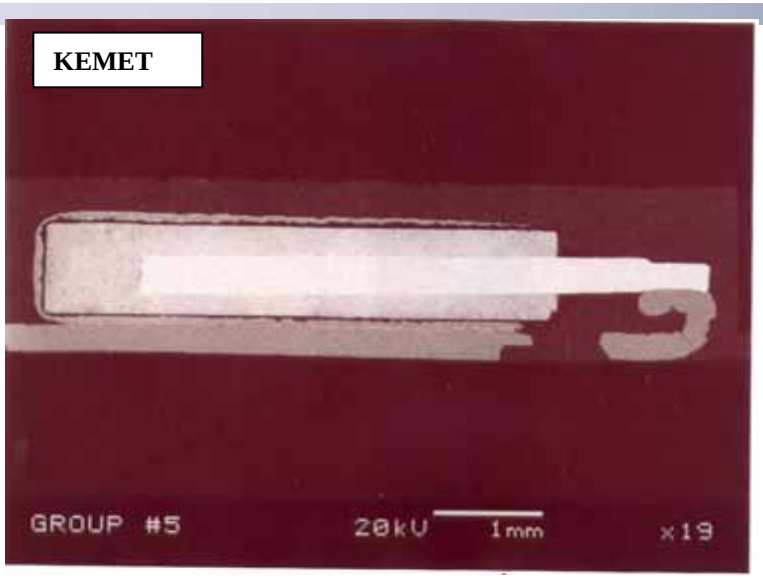
New Series: T528 Face Down / Development

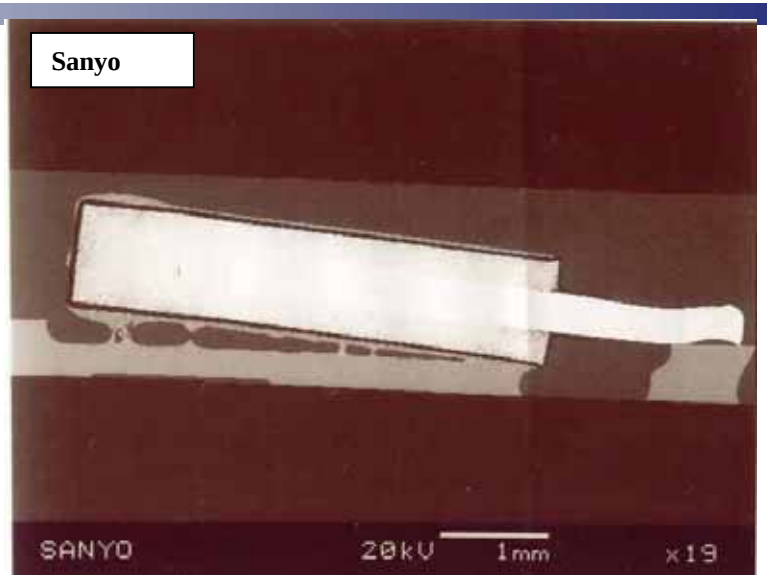


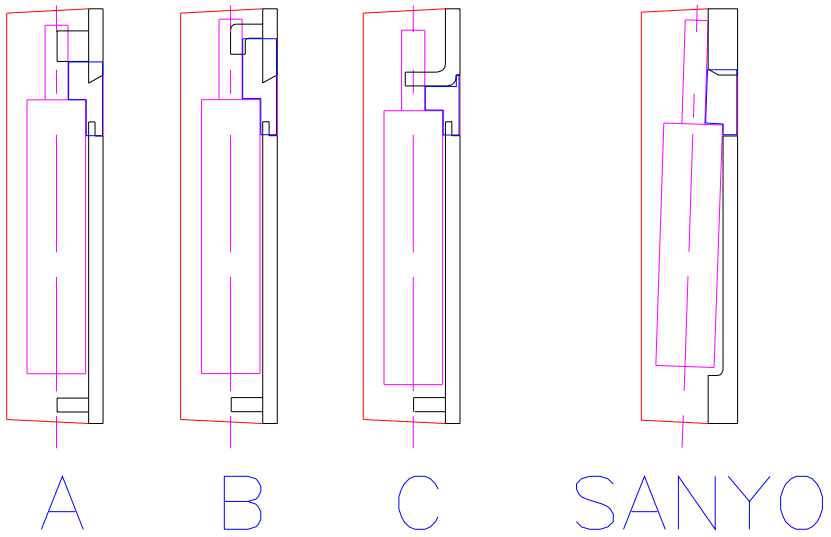
KEMET's FD Design on 3-pad



Ta KO T528 New Product Development



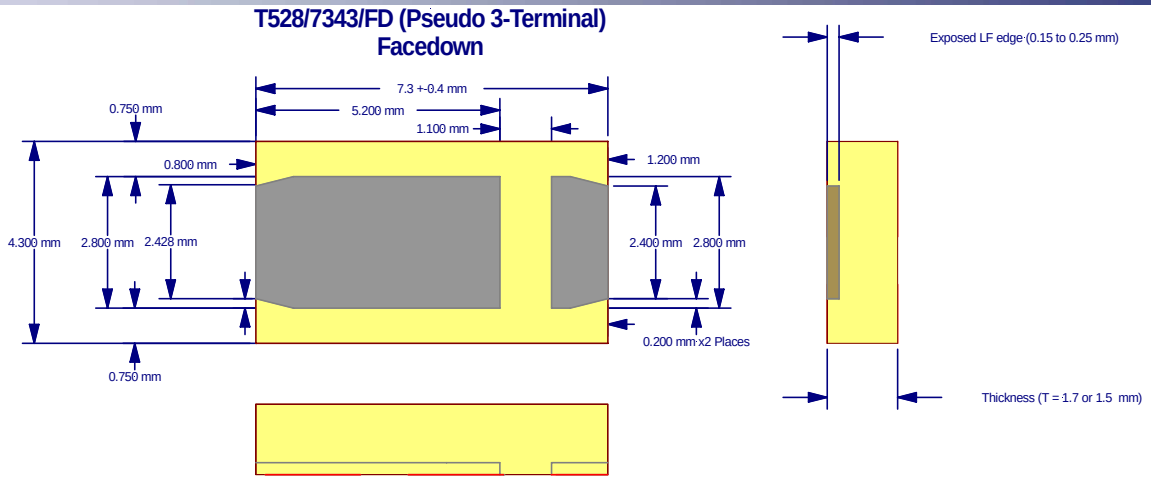




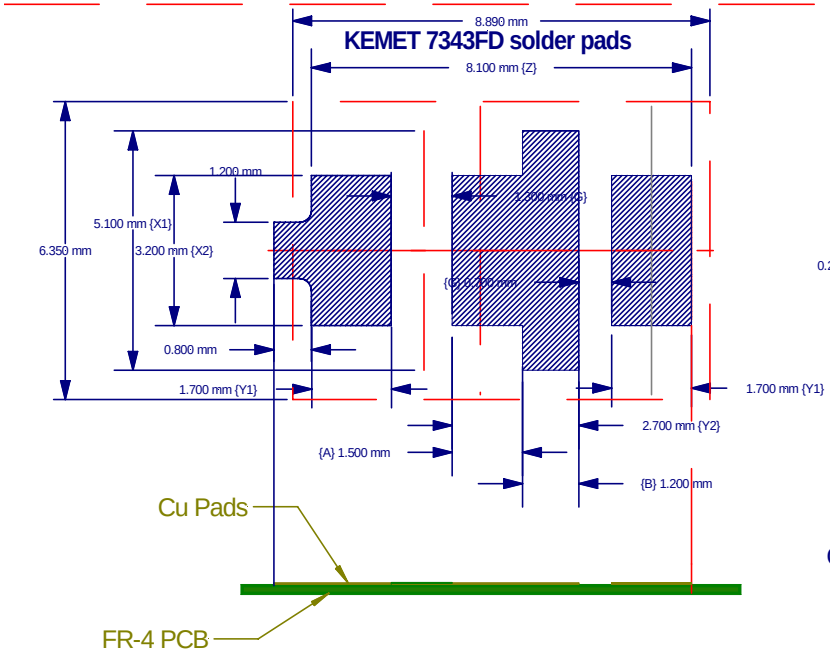
- **Design A**: Initially high % of opens. After optimization, had ~1.5% opens. This design has a higher risk of opens.
- **Design B**: Eliminates a process and lowers the risk of opens. Surface area of the positive terminal is minimized because of the bent-up tab. Must verify shear strength of positive termination.
- **Design C**: Minimizes loop area but also lowers volumetric efficiency. Team may consider for optimization.

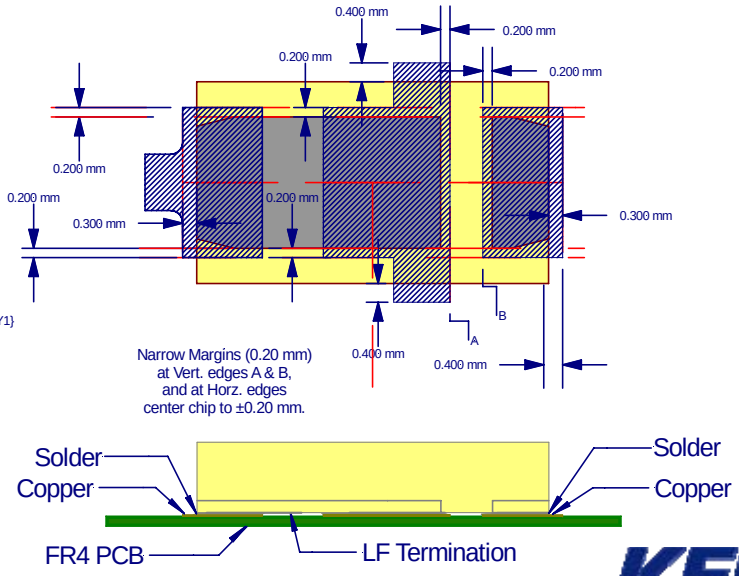
KEMET CHARGED.

Recommended Pad Size – V,W,Z Case



16 Mar 05





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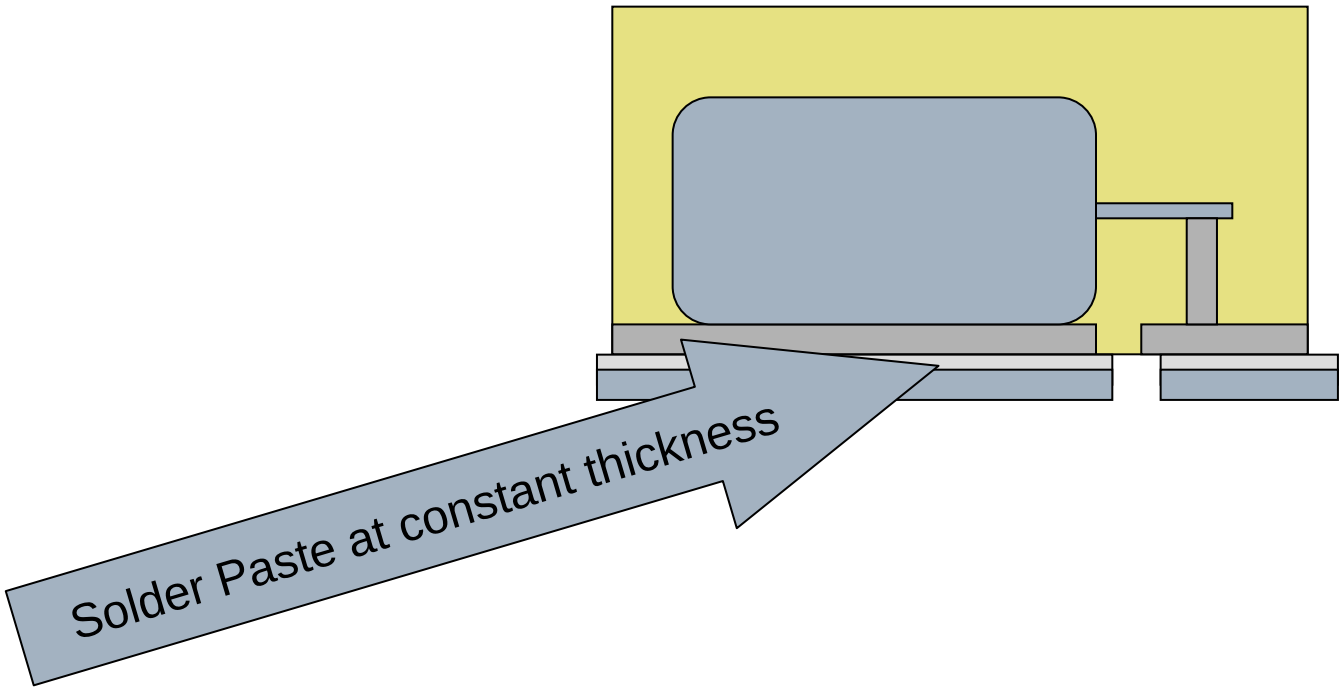
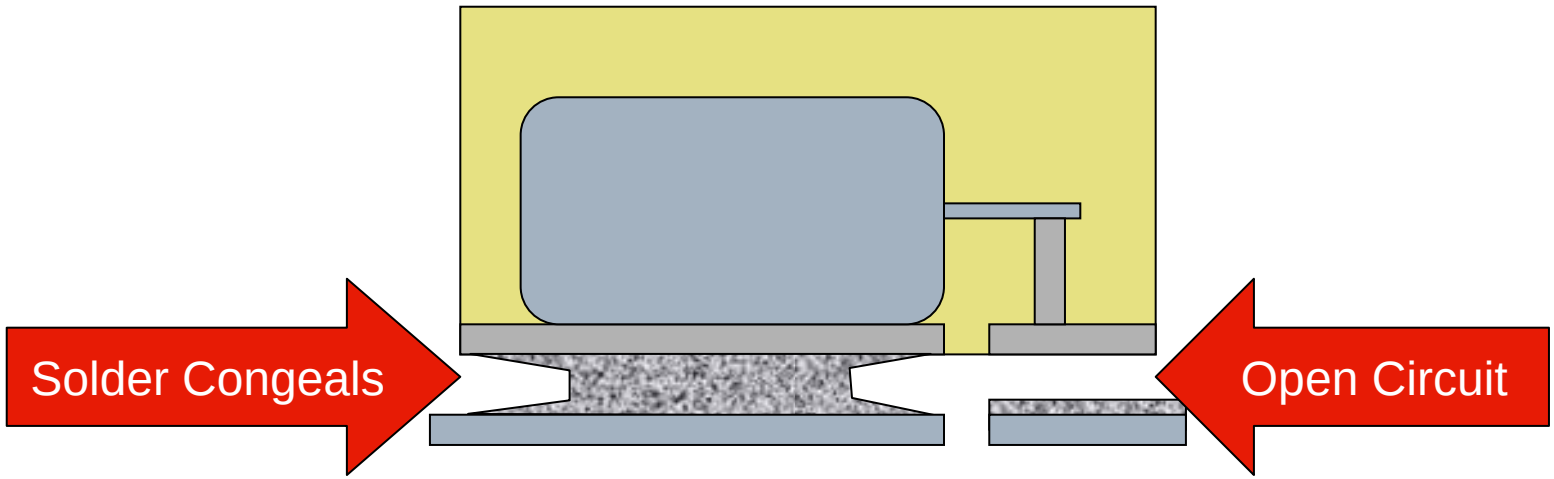
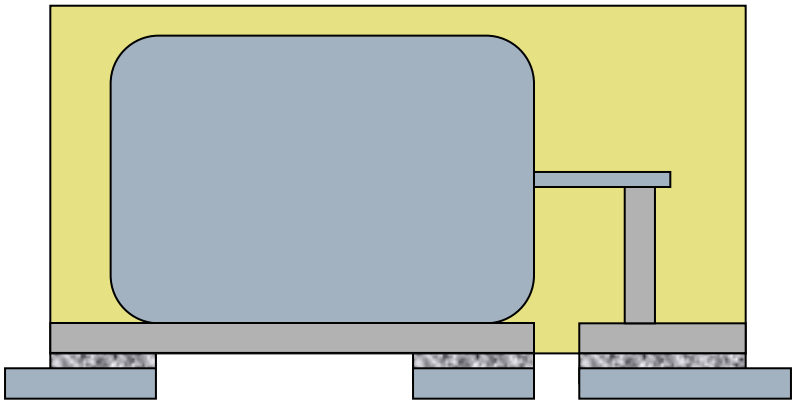
Ideal Solder Attach (Paste)



Solder Lift on Large Pad



KEMET 2-Pad/Pseudo 3-Pad Design



Requires 3 Solder Pads to prevent large pad from lifting.

KO-CAP Face Down Future Activities

- Lower ESR Values:
  - 7343 Footprint: (1.8mm max height) Low ESR/Low ESL – 7 & 8mOhm/< 0.8nH
- Small Case Sizes
  - 3216 and 3528 Footprint (I, R, M and T case) – maximize CV
    - 1.0mm 3216 and 3528 footprints: I case (3216-10), K case (3528-10)
    - 1.2mm 3528 footprint (3528-12)
    - 1.5mm 3528 footprint (3528-15)

Available 1st Quarter 2007

  - 2012 Footprint (R Case) - 1.2mm height
- High Cap/Low ESL
  - To 1000uF/<0.8nH
- Fail-Open Fused Devices

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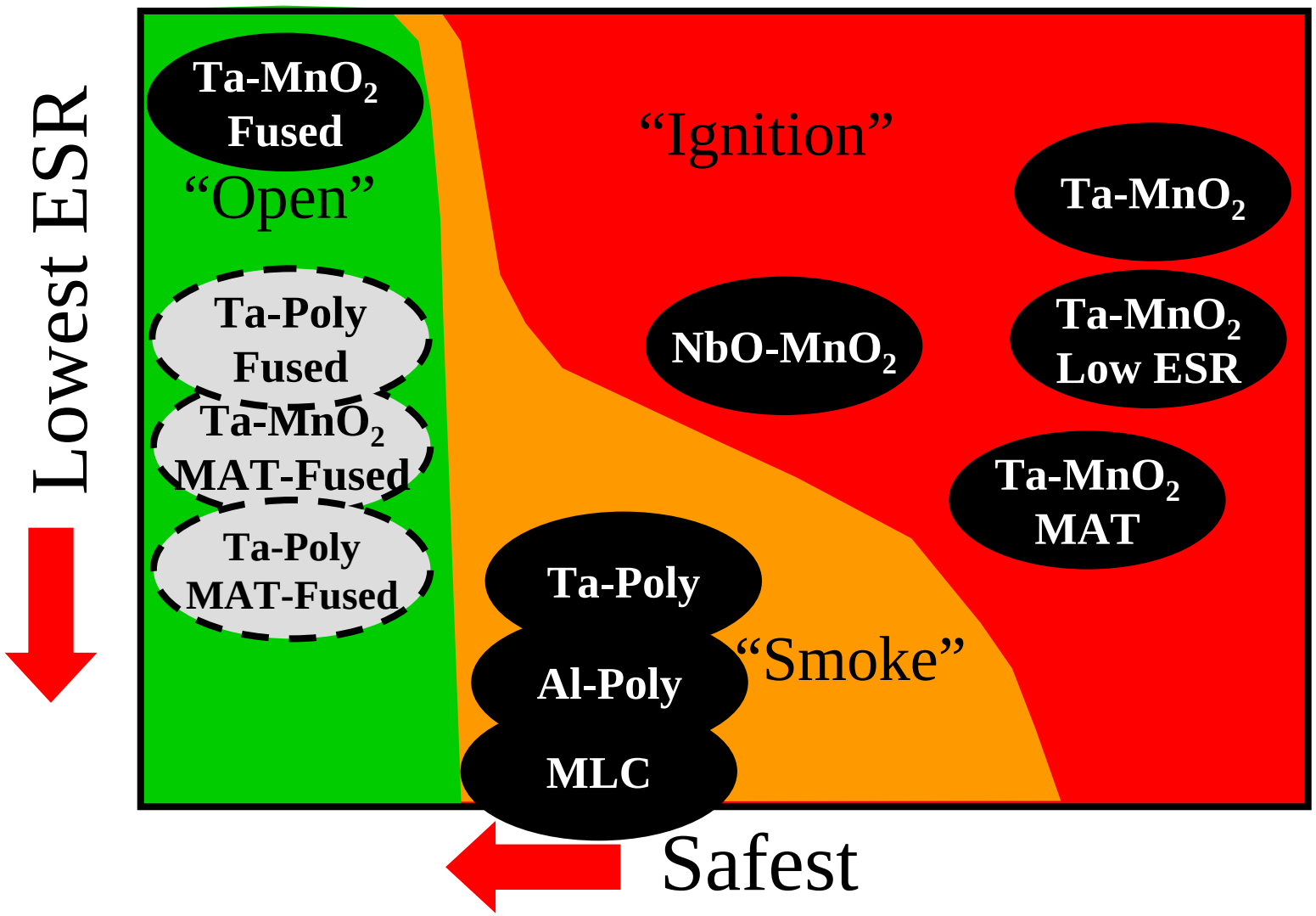
Fail-Open Tantalum & Polymer Chips

T496/T526/T536 (New)

Low-ESR vs. Safety – High Current Applications



T496 Key Features

- **Product started in 1980's**
- **"Fail-safe" operation**
- **OC R>10Megohms**
- **Small changes since conception**
- **Fuse R ~ 60 milliohms**
- **DSCC Source Control Drawing 04053**
- **Implementing Low ESR Options**
  - **E-Specs active on Feb 1, 07**

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T496 Product Listing

Vr	4V			6V			10V			16V			20V			25V			35V			50V		
Cap	Std	Ext	Dev	Std	Ext	Dev	Std	Ext	Dev	Std	Ext	Dev	Std	Ext	Dev	Std	Ext	Dev	Std	Ext	Dev	Std	Ext	Dev
104																								
154																						B(16,000)		
224																						B(14,000, 10,000)		
334																						B (10,000 2600)		
474																			B (8000, 2600)			C (8000, 1900)		
684																B (6500)			B(6500)			C (7000, 1700)		
105																B (5000, 3500)			B (5000, 3100)			C(5500, 2700)		
155													B (5000)			B (5000, 1600)			C (4500, 2600)			C (5000, 2000)		
225										B (3500)			B (3500, 1600)			C (3500)			C (3500, 1600)			D (2500, 900)		
335							B(3500)			B(3500, 2100)			B (3500)			C (2500, 2100)			C (2500, 900)			D (2000, 1000)		
475				B(3500)			B(3500)			B(3500, 1600)			C (2000)			C (2500, 1300)			D (1500, 700)			X (1500, 400)	D(400)	
685				B(3500)			B(3500)			C(2000, 600)			C (2000, 600)			C (2000, 600)			D (1300, 750)					
106				B(3500)			C(2000)			C (2000, 700)	B(3500)		C (2000, 800)			C (600) D(1200, 600)			X(1000, 500)	D(400)				
156				C(2000)			C(2000, 600)	B(3500)		C(2000, 600)			D (1000, 500)	C (500)		D (1000, 500)				X(900, 500) D(500)				
226				C (2000)	B(3500, 1500)		C(2000, 500)			D(1000, 500)	C (1600, 1000)		D(1000, 500)			D(800, 400) X(900, 400)				X (300)				
336				C(2000, 600)			D(1000, 400)	C(1600, 400)		D(1000,400)			X (900, 400)	D (400)										
476				D (1000)	C (1600, 600)		D(1000, 400)	C(1200, 400)		D (800, 400) X(900, 400)			X (300)	D (300)										
686		C (1600, 400)		D(1000)	C(1200)		D(800, 400) X(900)																	
107		C(1200)		X(900, 300) D(800, 400)	C(400)		X(400) D(700,400)				X (700)													
157	D(800)	C(1200)		X(300)	D(700, 300)			D(700, 400) X(700, 400)																
227		D(700, 400)			D(700, 300) X(700, 300)			X(500, 300) D(300)																
337	X(700)	D(700, 400)			X (500, 300)																			
477		X(500)																						
687																								

- "Fail-safe" operation
- OC R>10Megohms
- Small changes since conception
- Fuse R ~ 60 milliohms

- DSCC Source Control Drawing
- E-Specs active on Feb 1, 07
- Implemented Low ESR Options
  66 lower ESR Ratings
- 12 New CV Values

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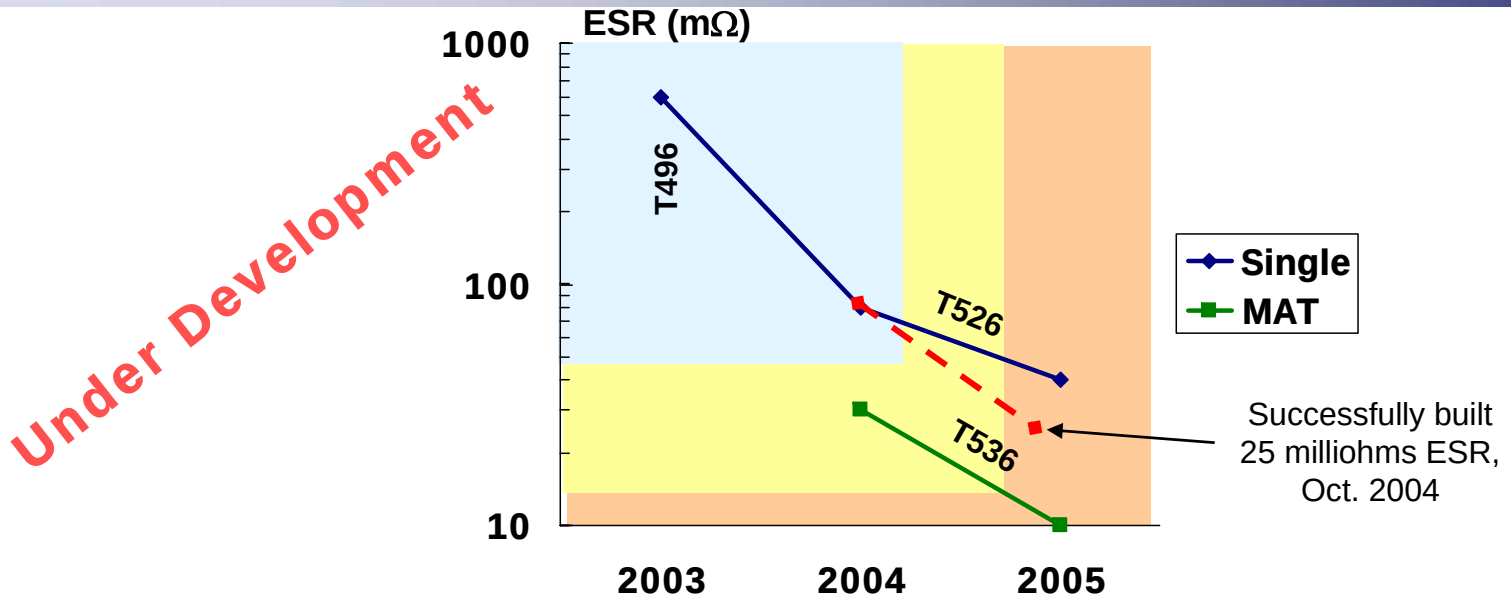
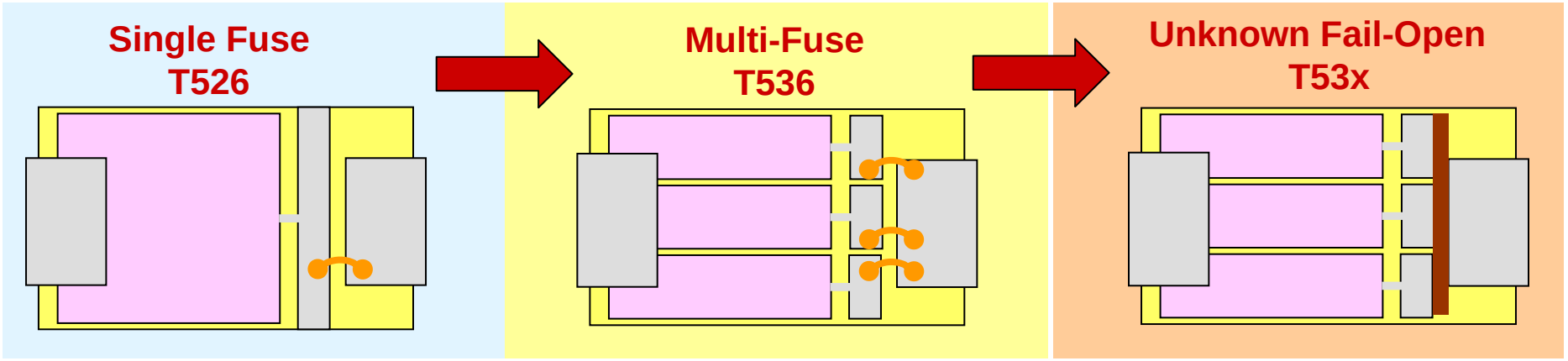
True Fail-Open – MnO2 to Poly to MAT





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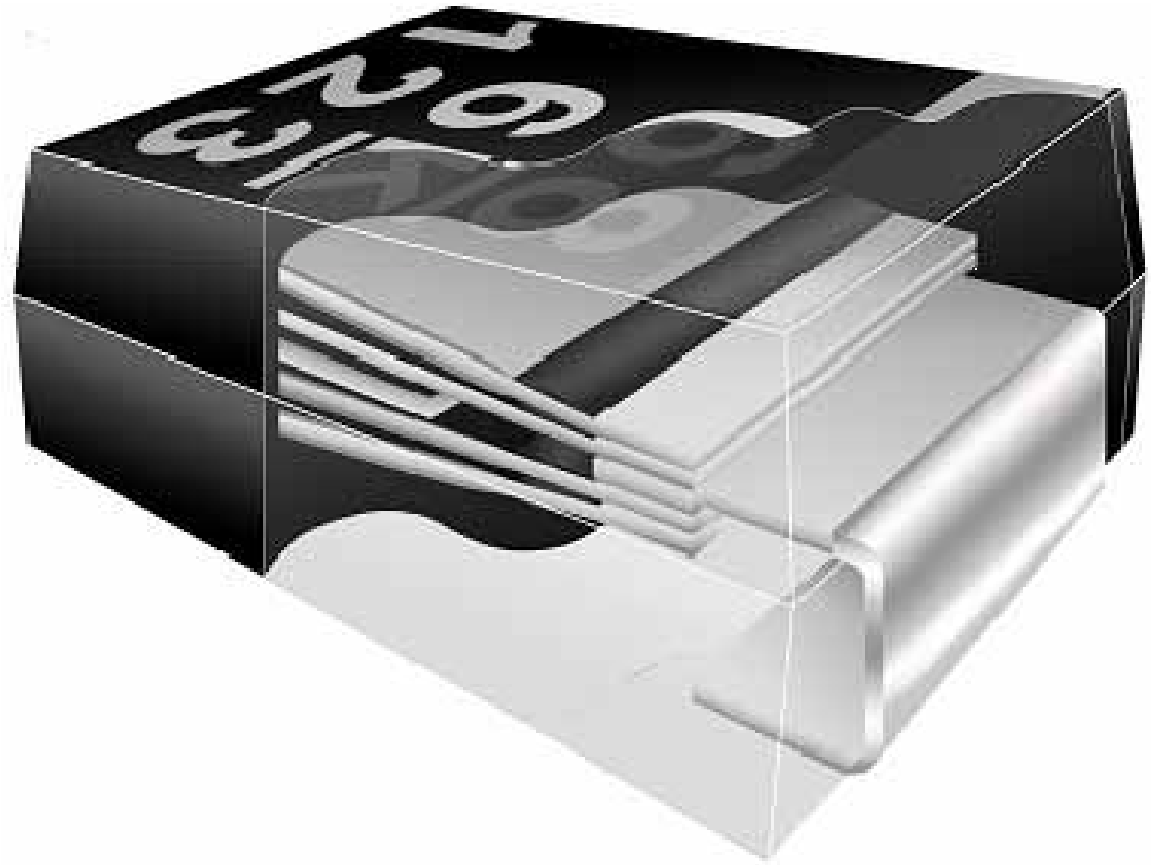
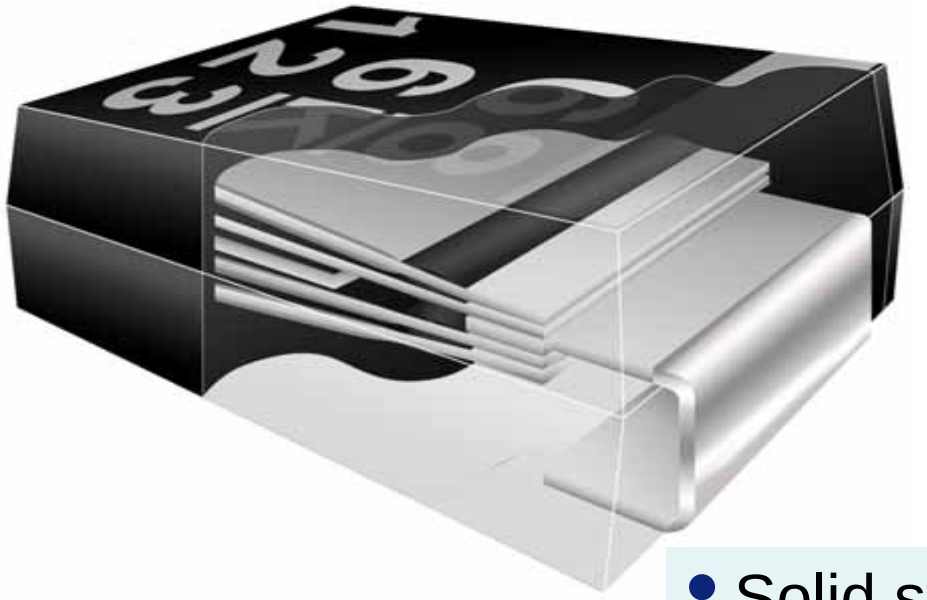
Aluminum-Polymer Chips

A700

A700 Aluminum Polymer



Aluminum Polymer



- Solid state polymer cathode system – similar to Ta - Poly
- Low ESR, small capacitance roll-off
- Aluminum Anode
- Surface mount

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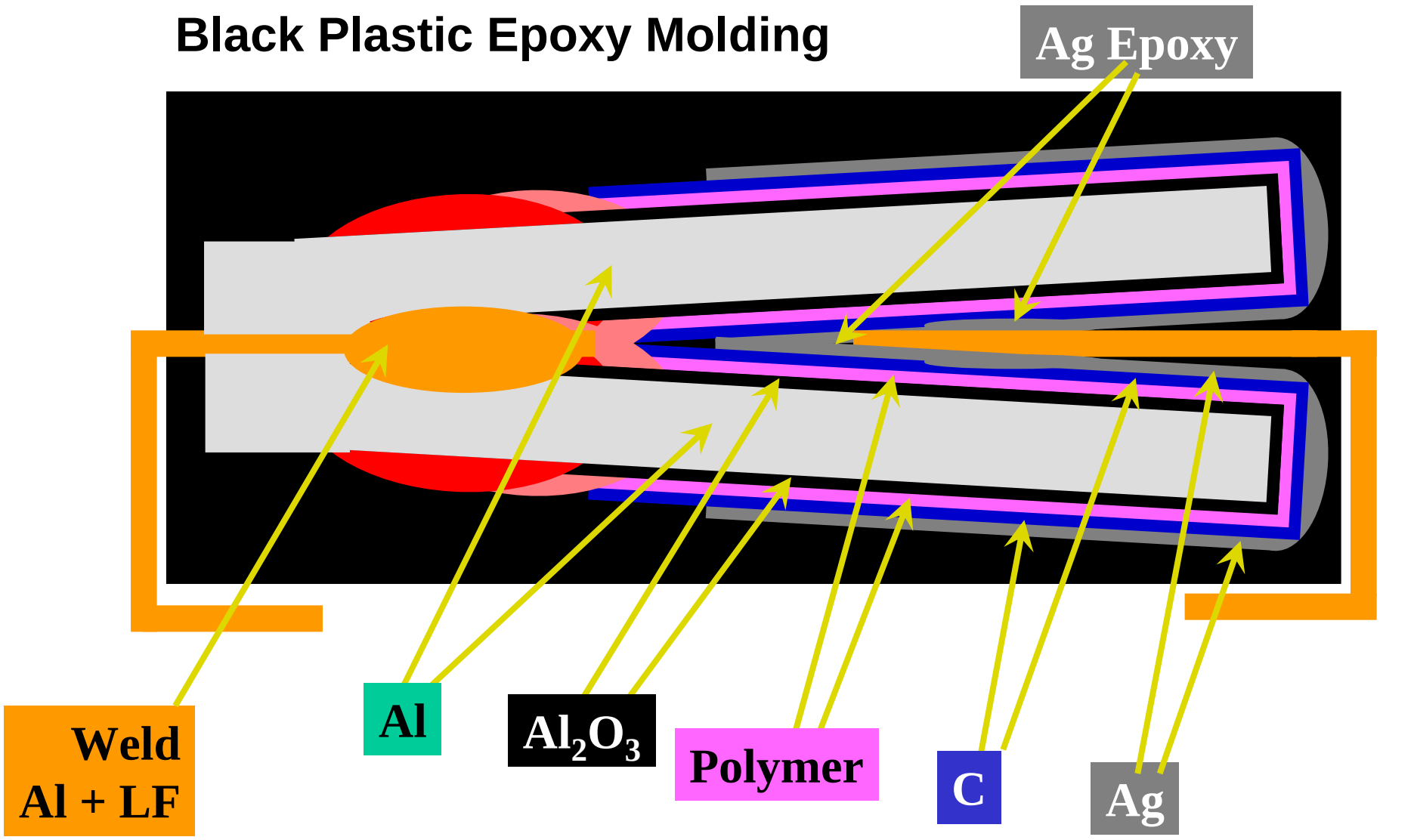
Molded Package



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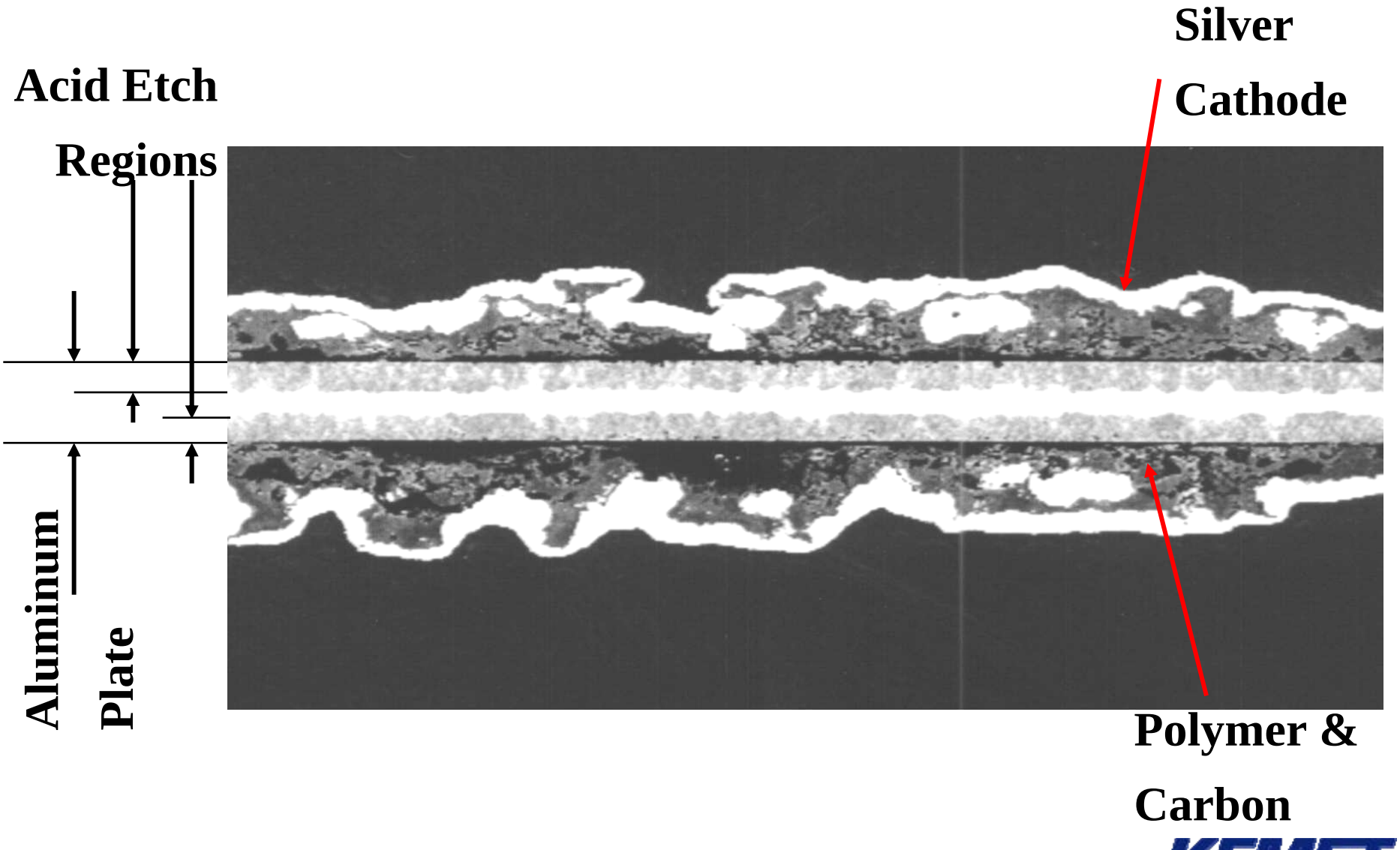
Aluminum Plate



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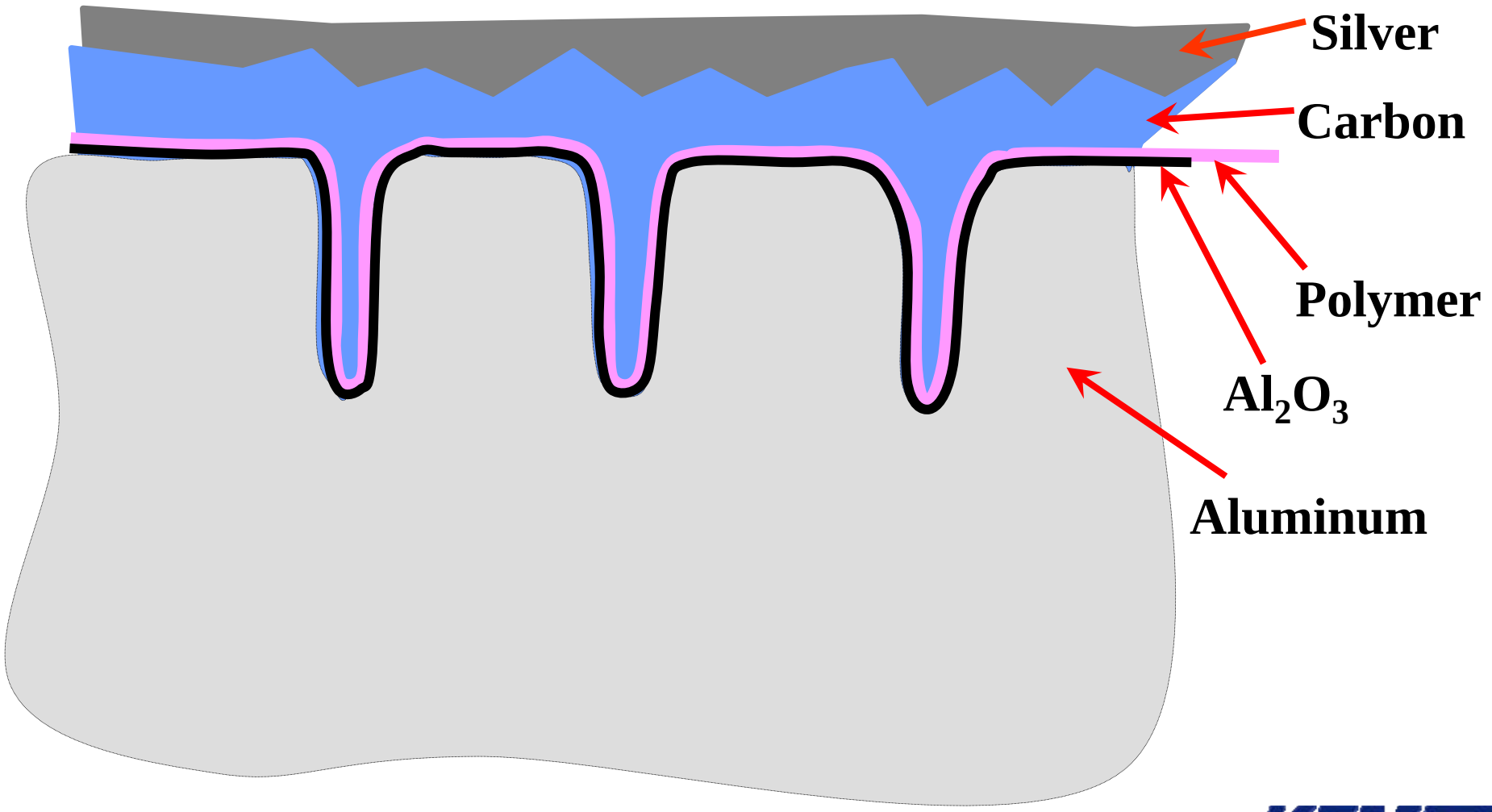
No “Wedges” in Al Structure



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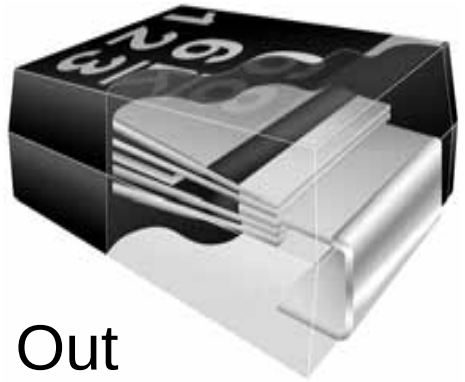
AO-CAP--Aluminum Organic Capacitor



- Extremely **Low** ESR
- **Non- Ignition** Failure Mode
- True **Surface Mount** Al Capacitor
- **Solid Counter - Electrode** Material (No Dry Out Failure Mechanism as in Al Electrolytics)
- Very Little Capacitance Loss at **High Operating Frequencies**
- Competes with **High Cap Ceramics** on Performance and Cost Basis
- Can be used at **Rated Voltage**, De-rating not required
- **125°C capability**
- **Lower DC Leakage** values than Ta polymer

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A700 Product Roadmap

A700 Aluminum-Polymer

Cap	2V			2.5V			4V			6.3V			8V			10V			12.5V			16V			20V		
	D	X	V	D	X	V	D	X	V	D	X	V	D	X	V	D	X	V	D	X	V	D	X	V	D	X	V
685																								70			
825																								45			
106																					60			45			
126																								45			
156																					40	25					
226												28			28			28			30						
336												18			18			18	25								
476												18						28									
566												18	15			15											
686												18	15			15											
826						18			18			18															
107			18							15				10			10										
127			18			18	15			12							10										
157			9	15			15			15	10						10										
187	15			15			15	10			10																
227	15		9		10		9	10																			
277		10						10																			
337	7	10			10			10																			
397		10																									
477		10 7																									
567																											
687																											

ESR (mOhms)	ESR (mOhms)
Present Capability	Under Development

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Derating Review

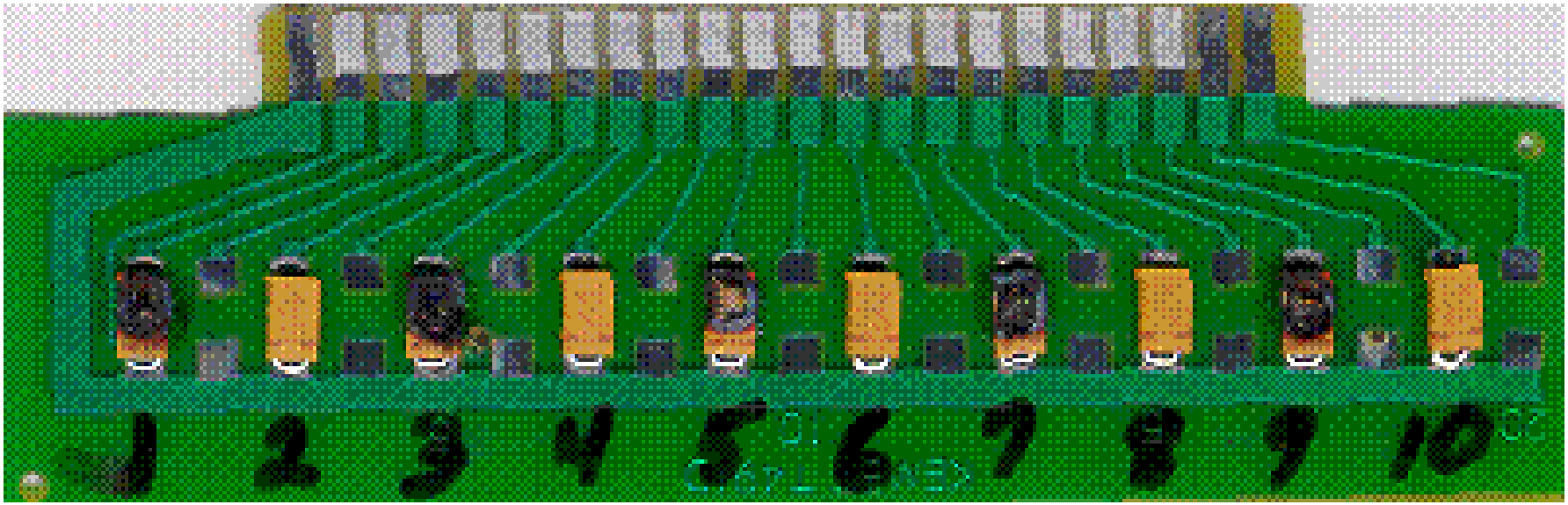
Ta-MnO2 vs. Ta-Polymer vs.

Al-Polymer vs. NbO-MnO2

Application / Voltage Derating

Question:

Why do some parts fail at the customer (Power On Failure) after they were tested to 1.32 x rated voltage at the factory?



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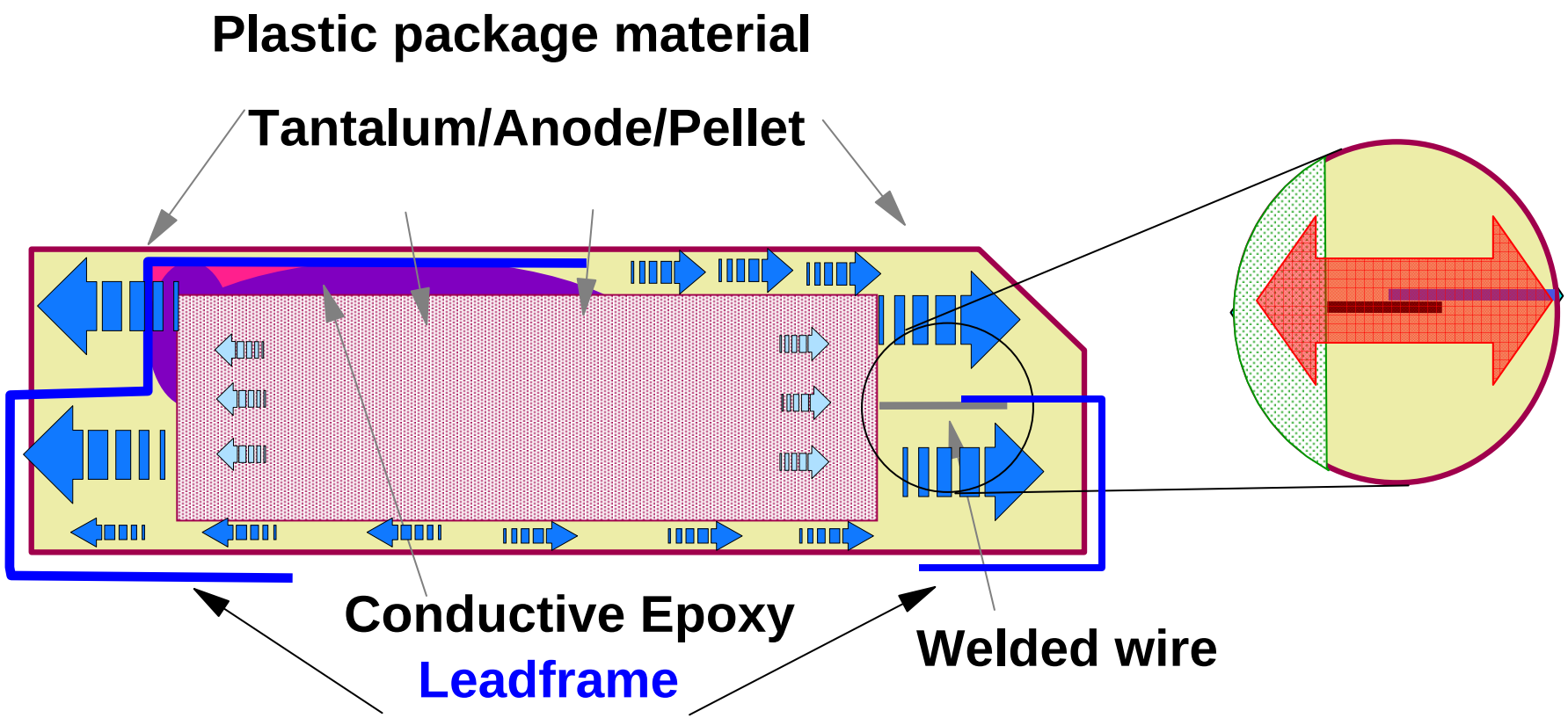
Solder Heat Expansion



Differences in coefficients of thermal expansion cause stresses to build up within the structure, the mold compound tries to pull (shear) the capacitor apart!

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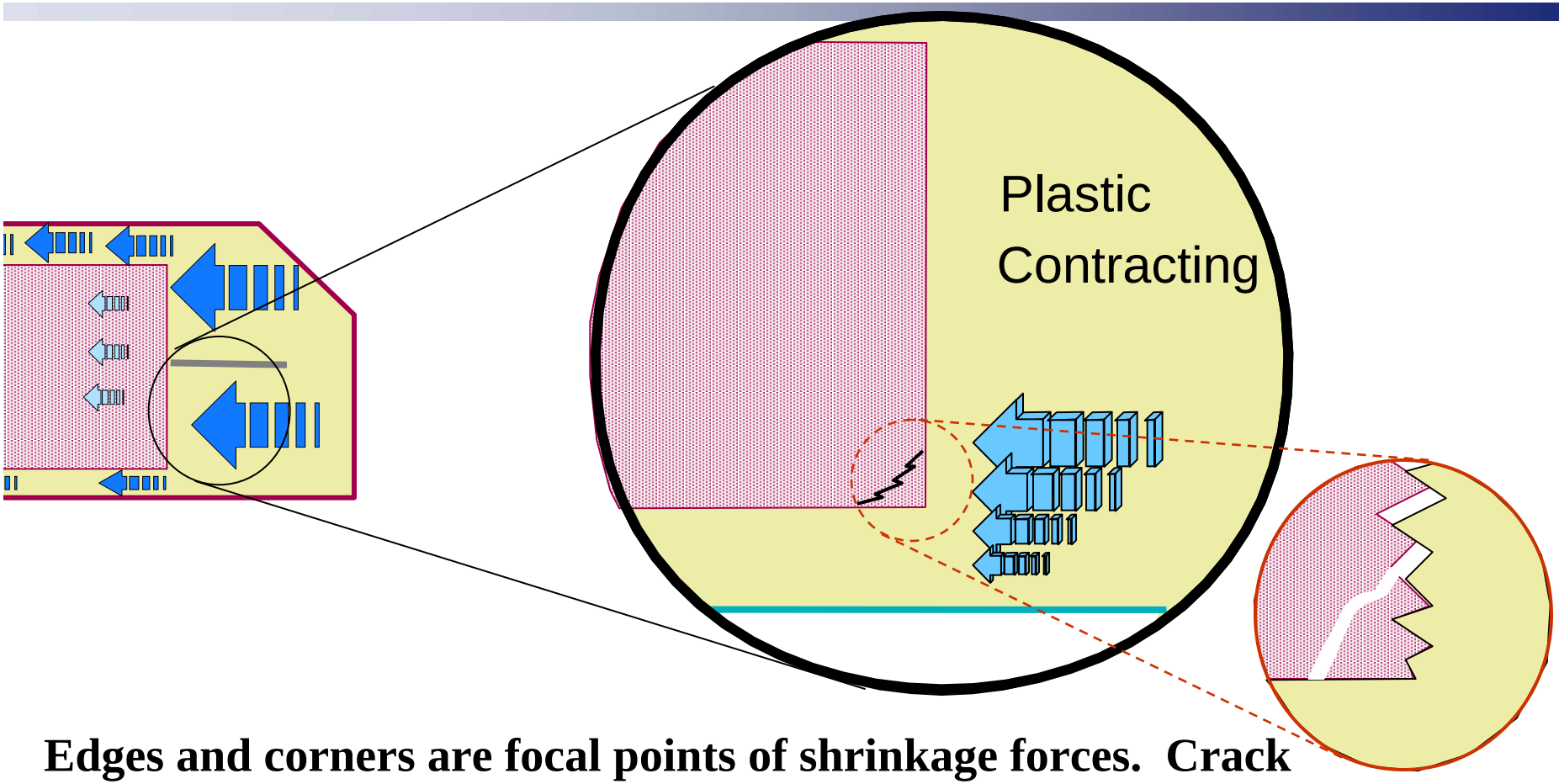
Cooling and Contraction



Edges and corners are focal points of shrinkage forces. Crack can develop in pellet that fractures Ta_2O_5 dielectric sites. Full power application results in ignition - not self-healing.

Faults are either created (pellet fracturing) or exacerbated (existing made worse).

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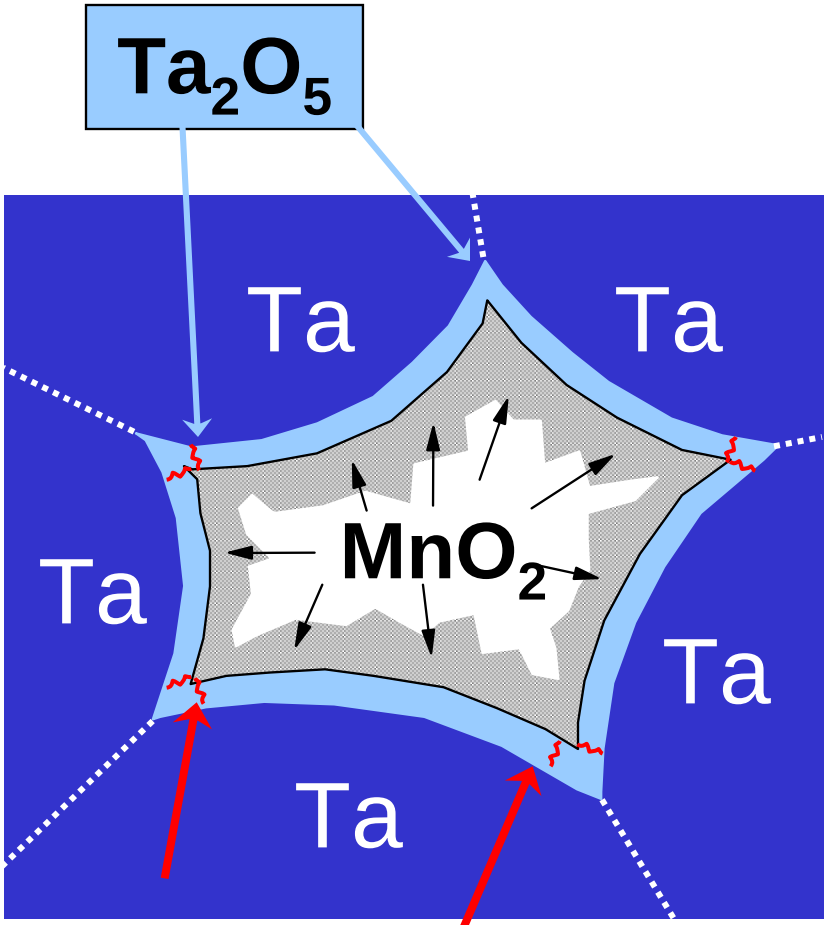
Induced Process Stress - MnO_2



Wedges
Concentrated strain

In tantalum anode pellet, areas of constriction exist where tantalum particles form a closed loop around an open channel. The MnO_2 filling this enclosure is a <u>hard</u>, <u>crystalline</u> material. Impregnation process involves dip at +25°C and conversion at +270°C. Stresses might be root of cracks *created* in dielectric.

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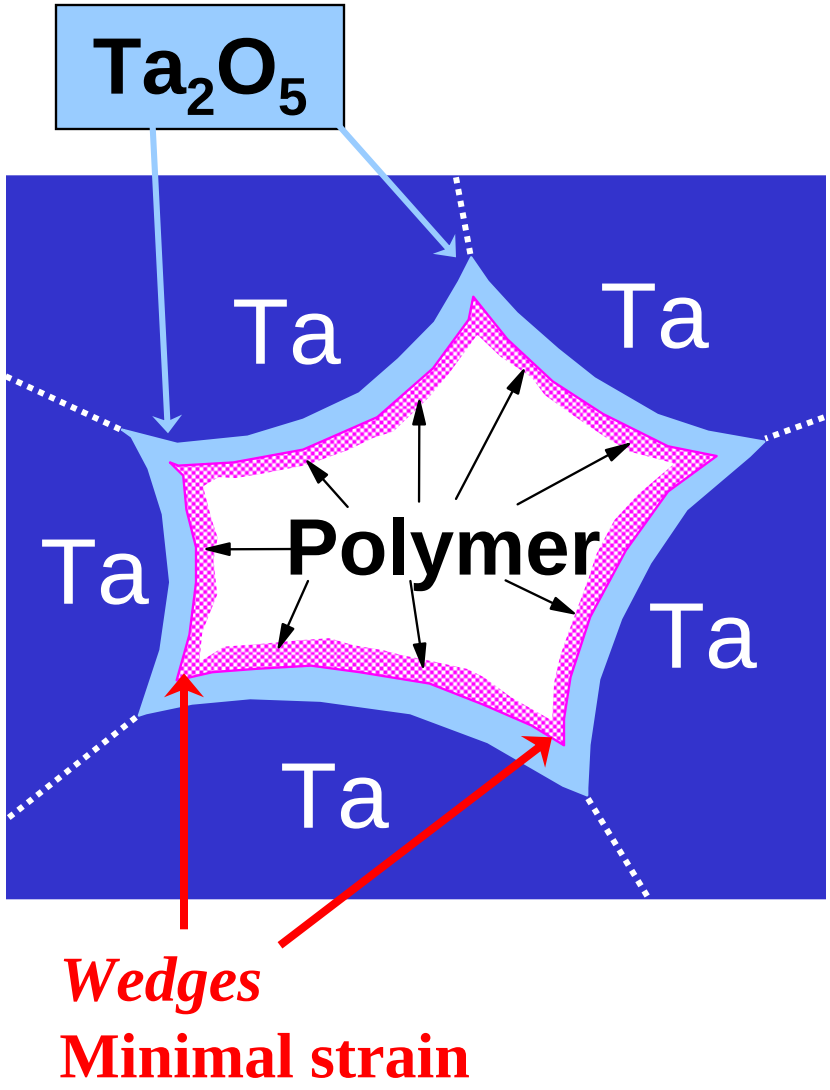
Reduced Process Stress - Polymer



The polymer material is soft and elastic. The forces generated because of mismatches in CTEs are insignificant when compared to MnO_2.

The process involves conversion at room temperature after each dip cycle -- *not* at any elevated temperatures.

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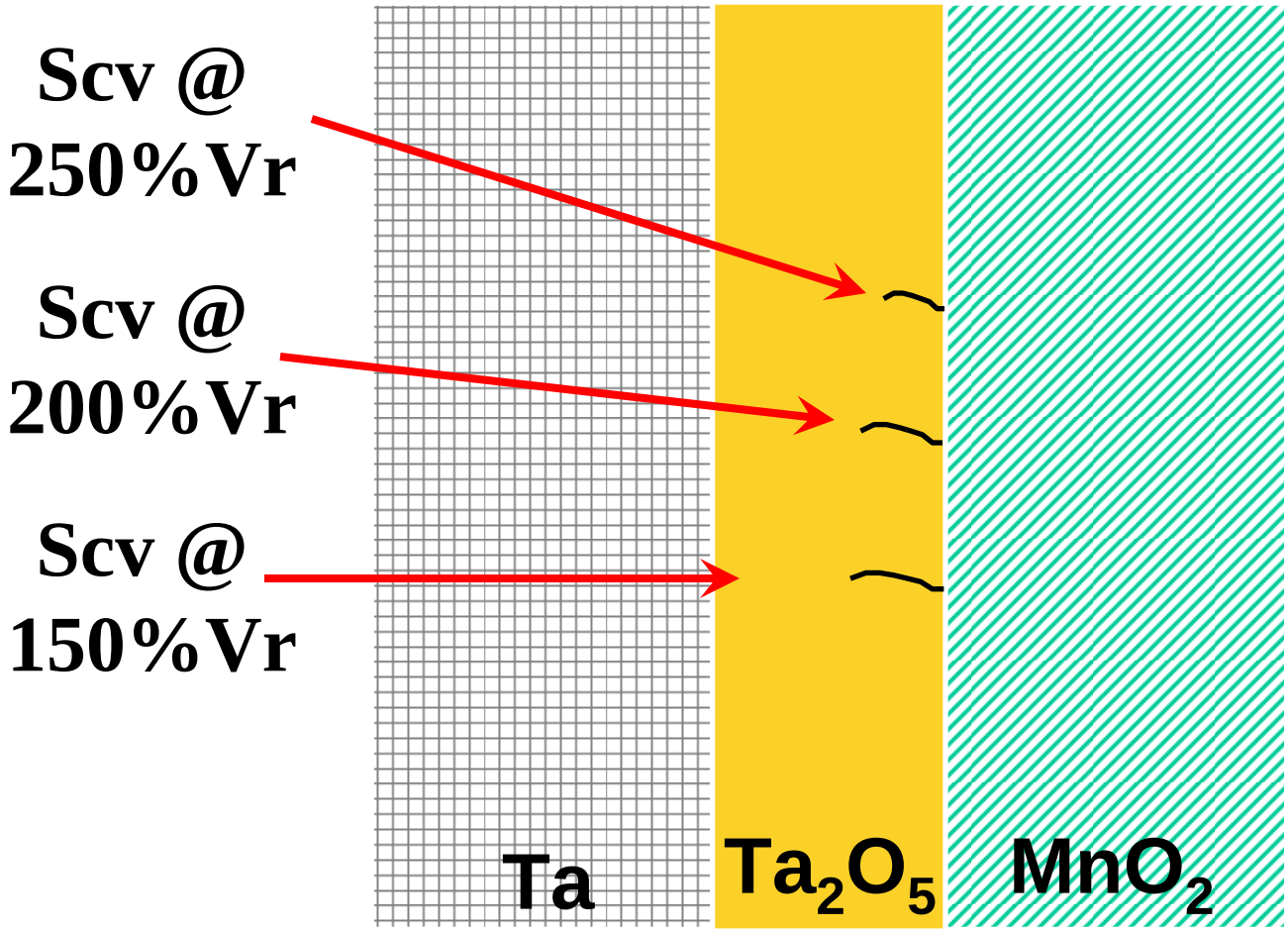
Variable Breakdown Levels
Post 100% Electrical Test

Breakdown Relationship to Crack Severity



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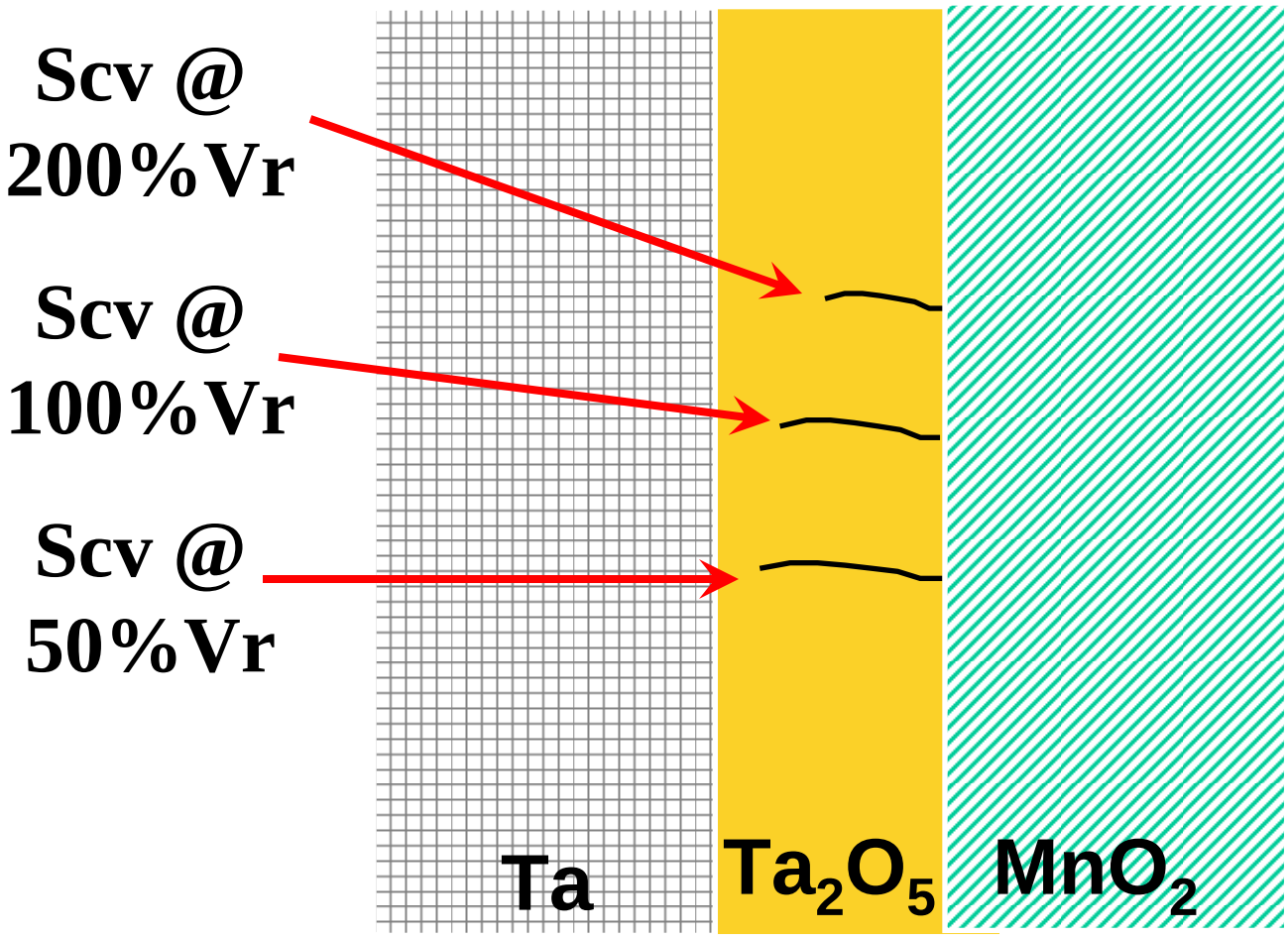
Variable Breakdown Levels Post Solder Process

Breakdown Relationship to Crack Severity



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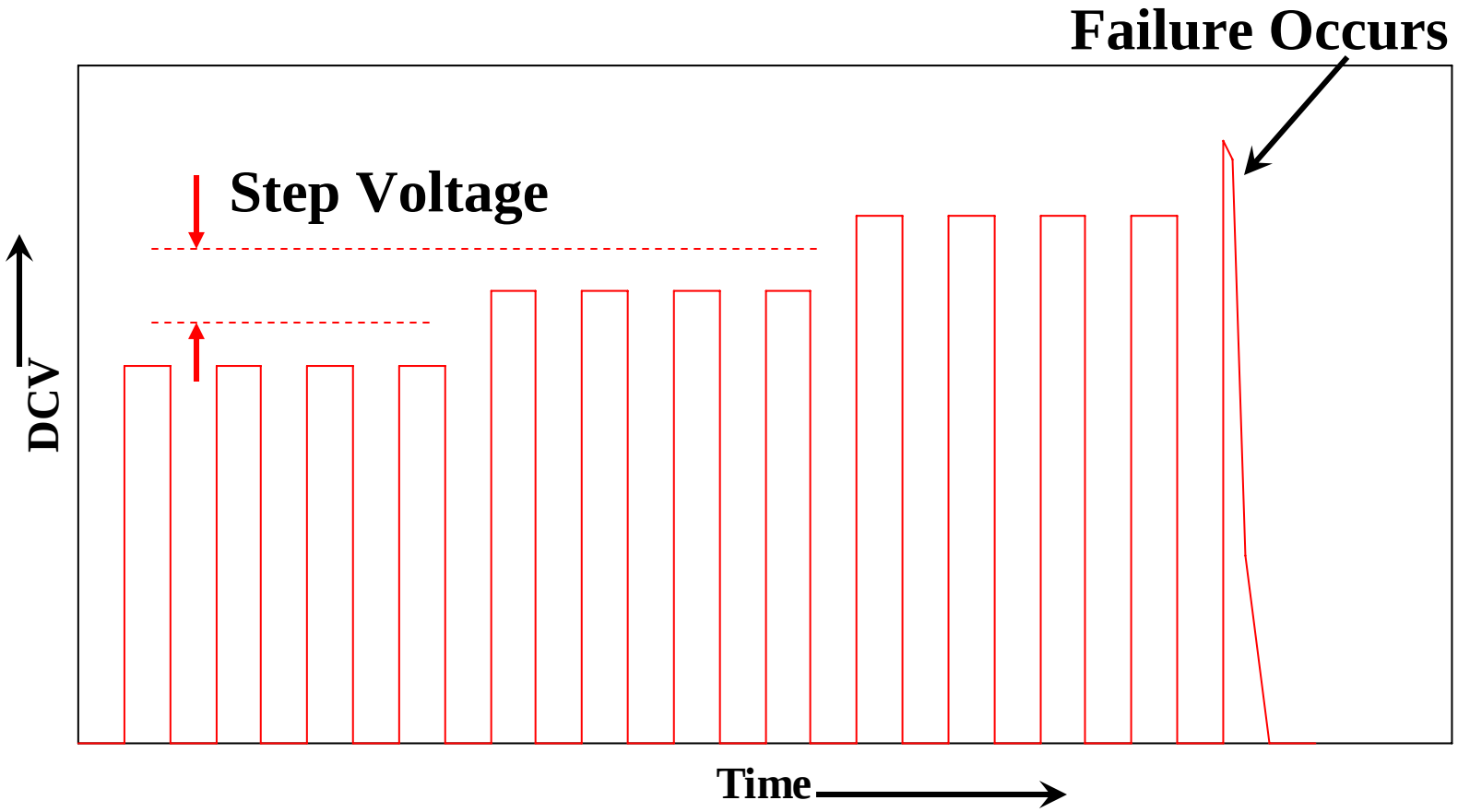
Surge Step Stress Test Pulse Train



To create conditions where scintillation or self-healing is minimized and failure is catastrophic. To simulate "Power-On" failure conditions.

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Recommended Derating

	$Ta\text{-}MnO_2$	Ta-Poly KO V_R>10VDC	Ta-Poly KO V_R<=10VDC	Alum-Poly AO
		$NbO\text{-}MnO_2$ V_R<=10VDC		
100 PPM FR % V_{Rated}	68%	126%	197%	235%
@50% V_{Rated} FR(PPM)	9	0	0	0
@80% V_{Rated} FR(PPM)	458	4	1	0
@90% V_{Rated} FR(PPM)	1,700	12	2	0
@100% V_{Rated} FR(PPM)	6,310	35	8	0

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Reference Material

Choosing the Right Capacitor

Quick Compare

	Al-Elect	Ta	Ceramic	Al-Poly	Film
SMT	Limited	Yes	Yes	Yes	Limited
Polar?	Yes	Yes	No	Yes	No
C>300uF	Yes	Yes	No	Yes	Large
+125°C	No	DR	By Diel.	Yes	By Diel.
Pb-Free 260°C	No	Yes	Yes	Yes	Limited
Lo-Freq	Excellent	Good	Poor	Good	Excellent
Hi-Freq	Poor	Fair	Excellent	Good	Excellent
TCC (%Lo/%Hi)	-xx/+15	-10/+15	By Diel. (X_R) -12/-13	-10/+13	By Diel
VCC	Stable	Stable	By Diel. (-0% to -90%)	Stable	Stable
SMT Cracks	No	No	Yes	No	No
Aging	No	No	1% to 10% Per Decade-Hour	No	No
Optimum Piezo	NA	NA	By Diel. (DC-30 kHz)	NA	NA

DR Derating Required

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Quick Compare - Ranking

	Al-Elect	Ta	Ceram	Al-Poly	Film
ESR	5	4	1	3	2
ESL	5	3	1	3	3
DCL	5	3	1	4	2
Self-Healing	Yes (Reform)	Yes	No	Yes	Yes
Wear-Out	Yes	No	Aging	No	No
Shelf Decay	Yes	No	No	No	No
Volumetric Eff.	4	1	3	2	5
Over-Volt Capability	3	5	1	2	4
Cost	2	3	1	3	5
Pb-Free	No	Yes	Yes	Yes	Yes
Failure Mode	Open/Short	Short	Short	Short	Open/Short
Piezoelectric	No	No	Yes	No	No

Ranking 1 = Best, 5 = Worst

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Aluminum (WET) Failure Modes

- ✗ Reverse polarity damage
- ✗ Solder heat evaporation of electrolyte (wet)
- ✗ Cleaning solvent susceptability
- ✗ Leakage increase
  - ✓ Outgassing
  - ✓ Loss of electrolyte
  - ✓ Drying
- ✗ Early Catastrophic Failures
- ✗ Increasing DF, ESR, Z
- ✗ Shelf Life loss of memory
  - ✓ Requires "Refresh"
  - ✓ Low voltage applications create "shelf life"

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Film Failure Modes

- ✗ **Sensitive to mild overstress (surge voltage)**
- ✗ **Foil type**
  - ✓ Short Circuits
  - ✓ Increasing ESR with temp/time
- ✗ **Metalized Electrodes**
  - ✓ Self-healing / noise generation
  - ✓ Loss of cap / open circuits
  - ✓ Parametric degredation with life
  - ✓ Surge susceptability
  - ✓ Aluminum attacked by moisture

Ceramic Failure Modes

- **No wear-out mechanisms of undamaged part**
- **Sensitive to mechanical damage**
- **Crack induced failures**
  - ✓ Short Circuits / Catastrophic
  - ✓ Increasing Leakage / degradation of IR
  - ✓ Increasing ESR / DF

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Tantalum (Poly-Al) Failure Modes

- **Sensitive to mild overstress (surge), reverse polarity**
- **No wear-out mechanisms / self-healing**
- **Stress induced failures**
  - ✓ Short Circuits / Catastrophic
  - ✓ Increasing Leakage / degradataion of IR
  - ✓ Increasing ESR / DF
  - ✓ Capacitance decay
- **Plastic package hydroscopic venting during reflow disturbing smaller adjacent components (0603 chips)**

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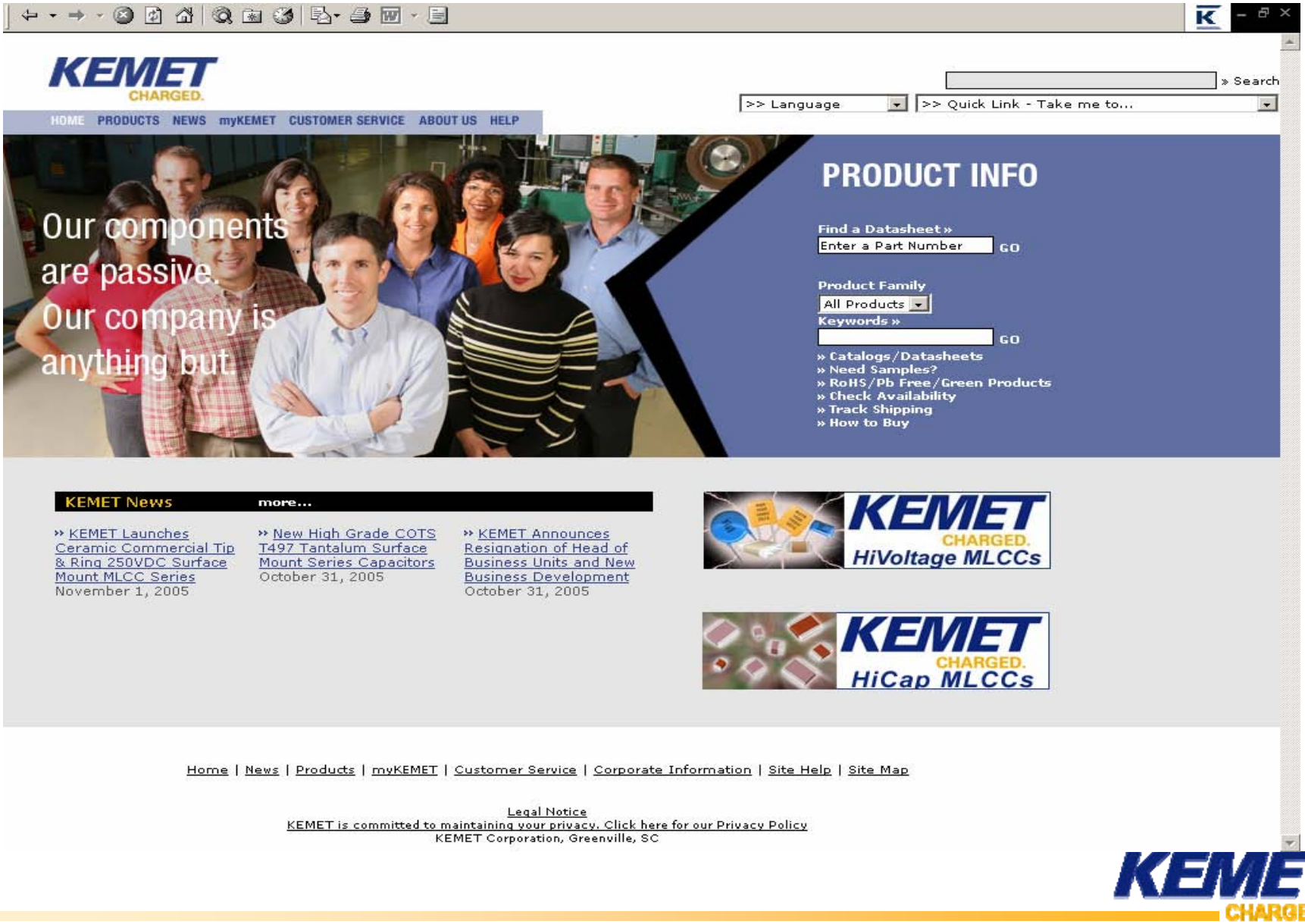
New KEMET WEB Site – www.kemet.com



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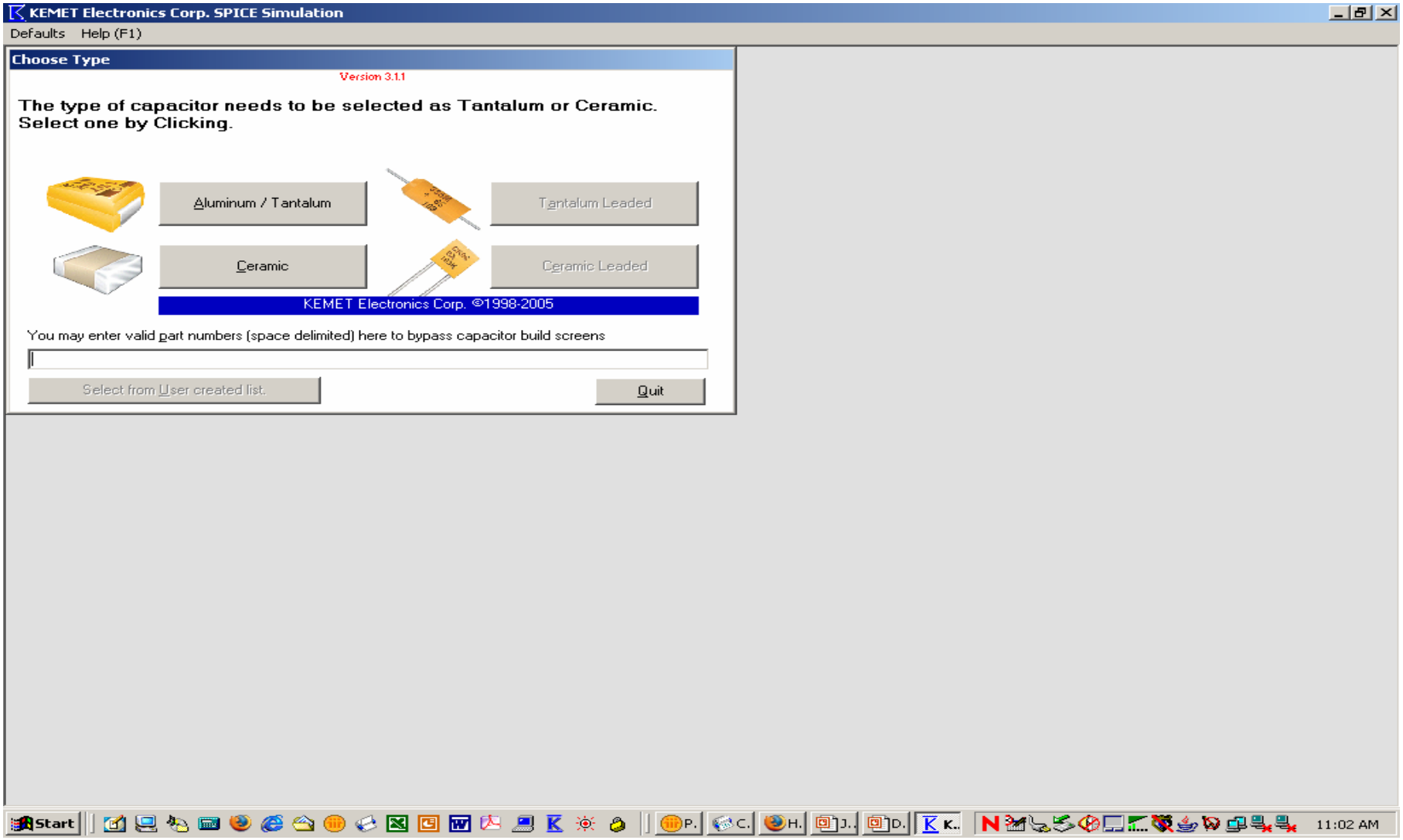
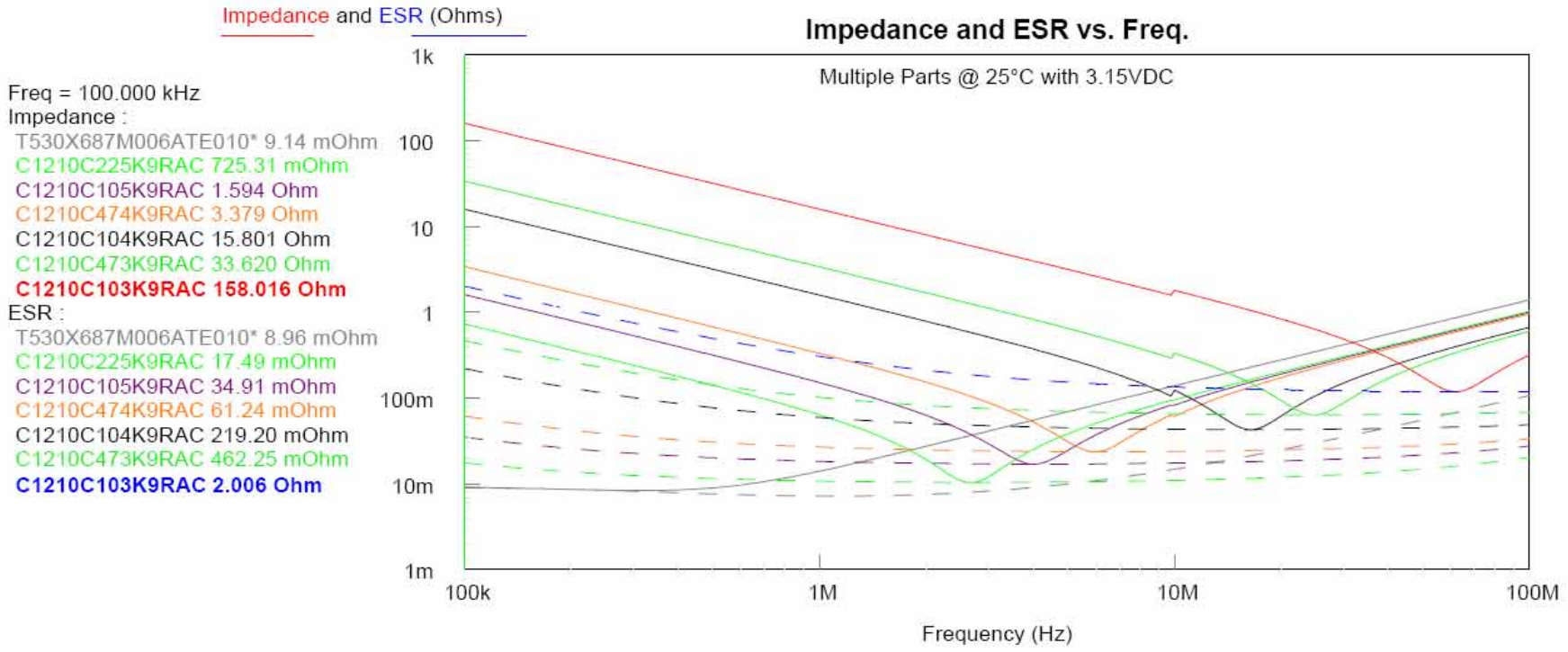
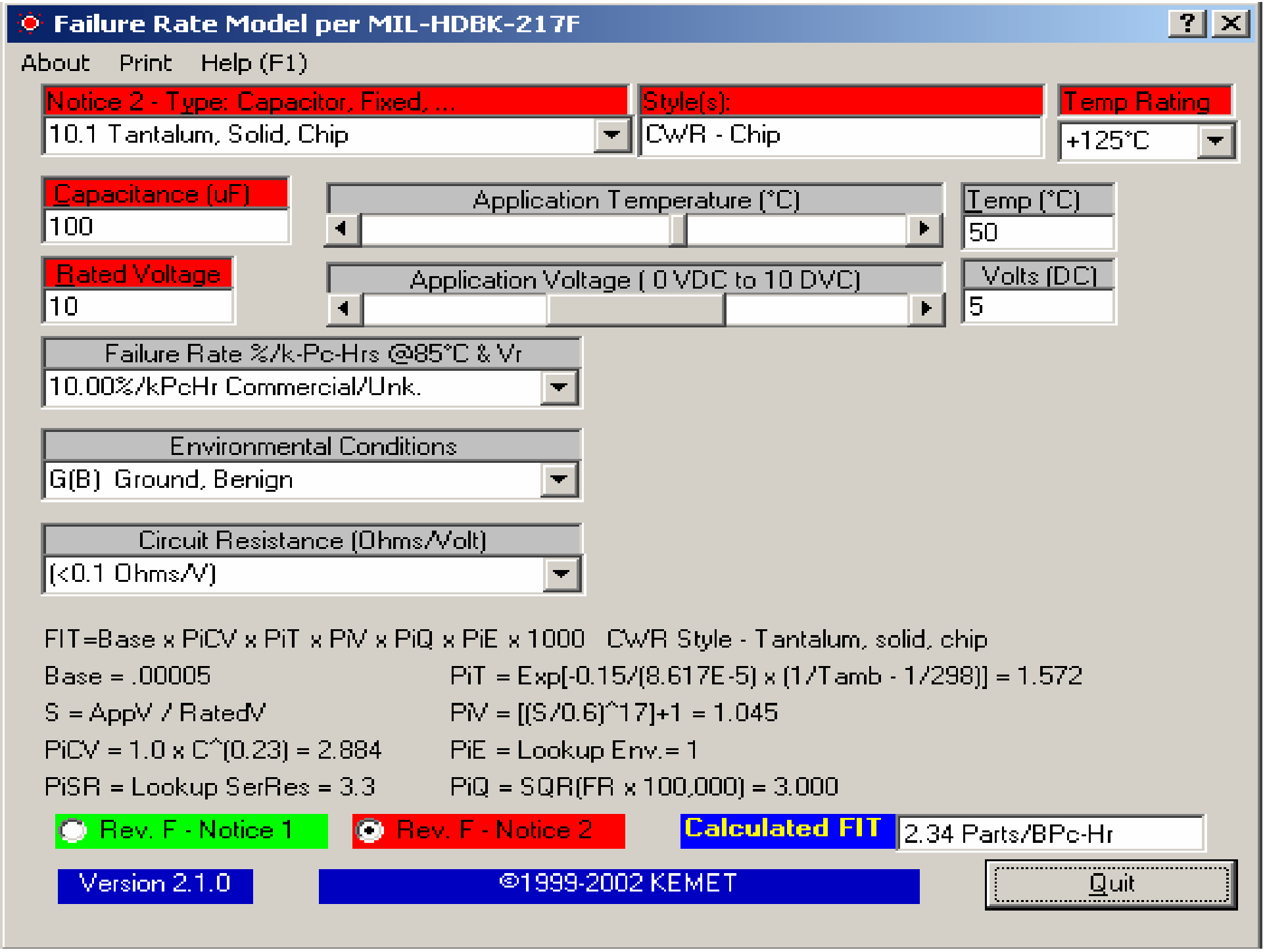
KEMET Spice Simulation Software



Example Spice Decoupling Output




Failure Rate Model per MIL-HDBK-217F
About
Print
Help (F1)
Notice 2 - Type: Capacitor, Fixed, ...
10.1 Tantalum, Solid, Chip
Style(s):
CWR - Chip
Temp Rating
+125°C
Capacitance (uF)
100
Application Temperature (°C)
Temp (°C)
50
Rated Voltage
10
Application Voltage (0 VDC to 10 DVC)
Volts (DC)
5
Failure Rate %/k-Pc-Hrs @85°C & Vr
10.00%/kPcHr Commercial/Unk.
Environmental Conditions
G(B) Ground, Benign
Circuit Resistance (Ohms/Volt)
(<0.1 Ohms/V)
FIT=Base x PiCV x PiT x PiV x PiQ x PiE x 1000 CWR Style - Tantalum, solid, chip
Base = .00005
PiT = Exp[-0.15/(8.617E-5) x (1/Tamb - 1/298)] = 1.572
S = AppV / RatedV
PiV = [(S/0.6)^17]+1 = 1.045
PiCV = 1.0 x C^(0.23) = 2.884
PiE = Lookup Env.= 1
PiSR = Lookup SerRes = 3.3
PiQ = SQR(FR x 100,000) = 3.000
Rev. F - Notice 1
Rev. F - Notice 2
Calculated FIT
2.34 Parts/BPc-Hr
Version 2.1.0
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Quit

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- **Latest News -** Product Releases & General Info
- **SPICE Models -** (Performance vs Frequency/Temperature/Voltage)
- **FIT Calculator** (Failure rate model)
- **CapacitorEdge -** Part Number Builder, Competition Part Number Cross Reference, Delivery Stock Check
- **KnowledgeEdge -** Searchable Technical Assistance
- **Product Datasheets/Catalogs**
- **Engineering Bulletins & TechTopics**
- **Listings -** Sales Offices & Distributors
- **Shipment Tracking**

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Thank you!

Any Questions?

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