Electronic Components

KEMET

CHARGED.®

Tantalum Capacitors

Design and Characteristics

Dielectric Materials

Electronic Components
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Paper

Carbon	Hydrogen	Oxygen
6	1	8
C	H	O
12.011	1.0078	15.999

Ceramic

Barium	Titanium
56	22
Ba	Ti
137.33	47.867

Plastic Film

Carbon	Hydrogen	Oxygen
6	1	8
C	H	O
12.011	1.0078	15.999

Tantalum

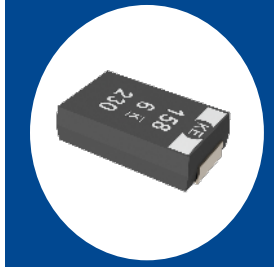
Tantalum	Oxygen
73	8
Ta	O
180.95	15.999

Aluminum

Aluminium	Oxygen
13	8
Al	O
26.982	15.999

KEMET – Ta / Al Polymer Products

7
Manufacturing Plants*



3 billion
Components Shipped per Year*

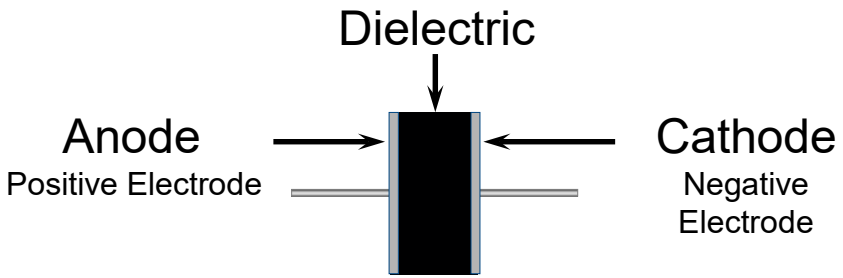
2
Innovation Centers

* Includes *TOKIN*

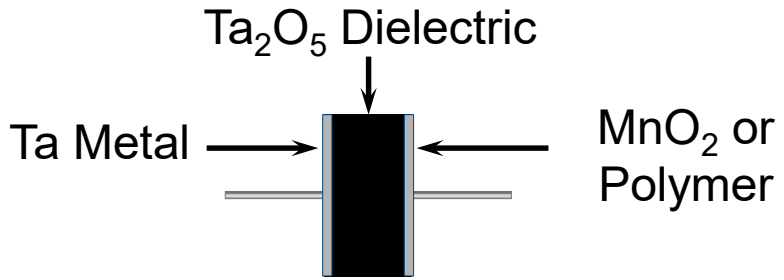
Design

Construction

General



Tantalum



constant

$$C = \frac{k\ \varepsilon_0 A}{d} \longrightarrow C \propto \frac{A}{d}$$

where: C = capacitance, Farad

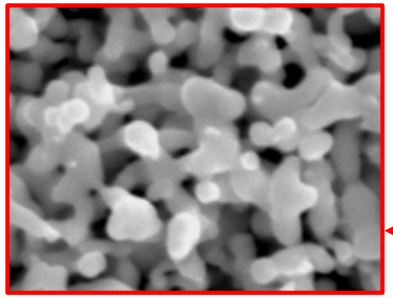
k = dielectric constant, unitless; for Ta_2O_5, k = 27

ε_0 = permittivity in vacuum, 8.854 x 10^{-12} Farad / meter

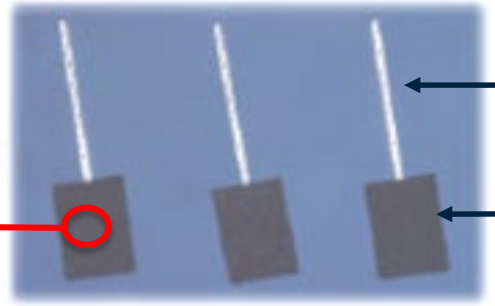
A = surface area of conductive plate, meter

d = dielectric thickness, meter; Ta_2O_5, thickness is 20 x 10^{-10} meter per applied formation volt

Construction

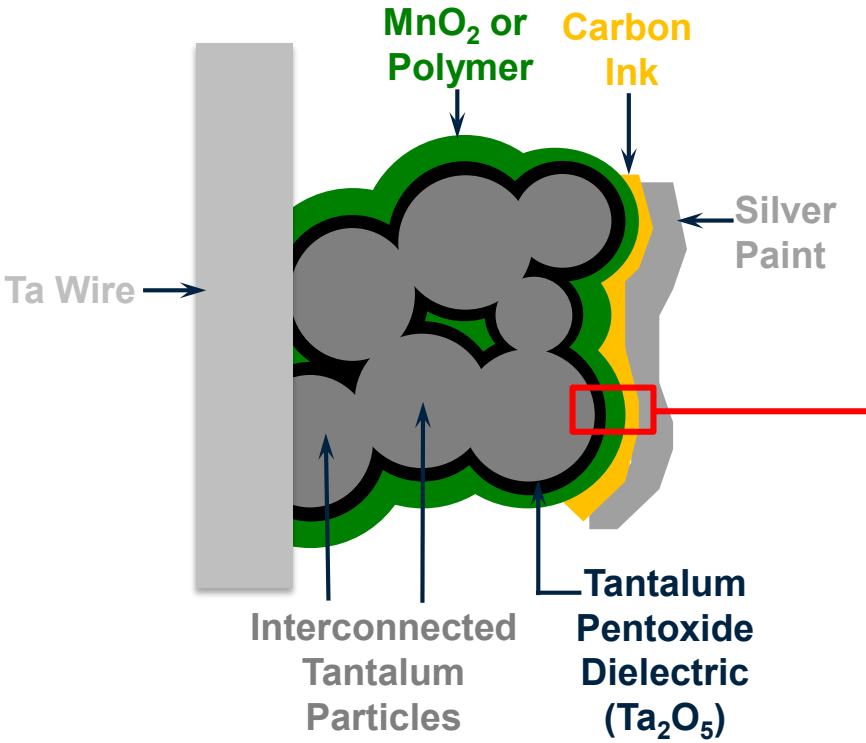


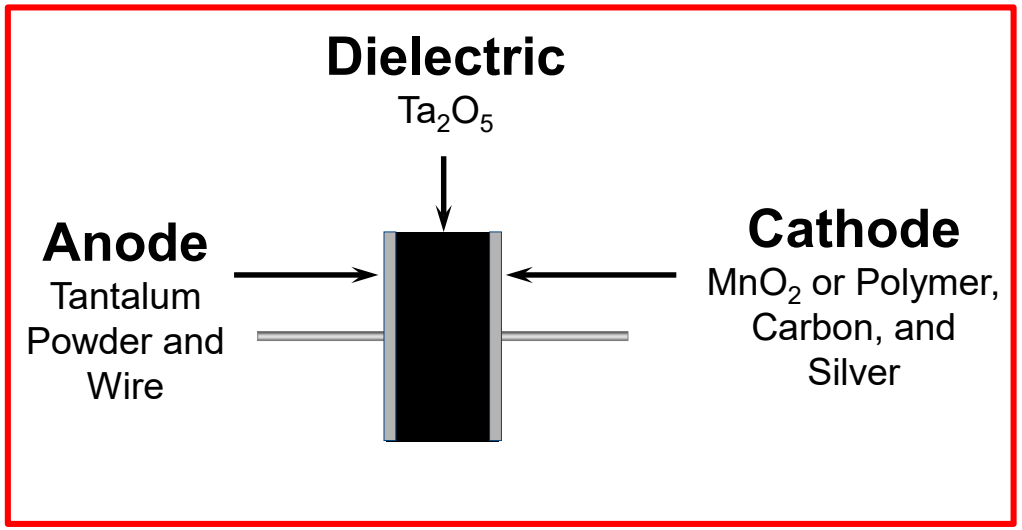
SEM Photo of Anode Surface



Tantalum Wire
$\rho_{Tantalum}$ = 16.69 g/cm^3

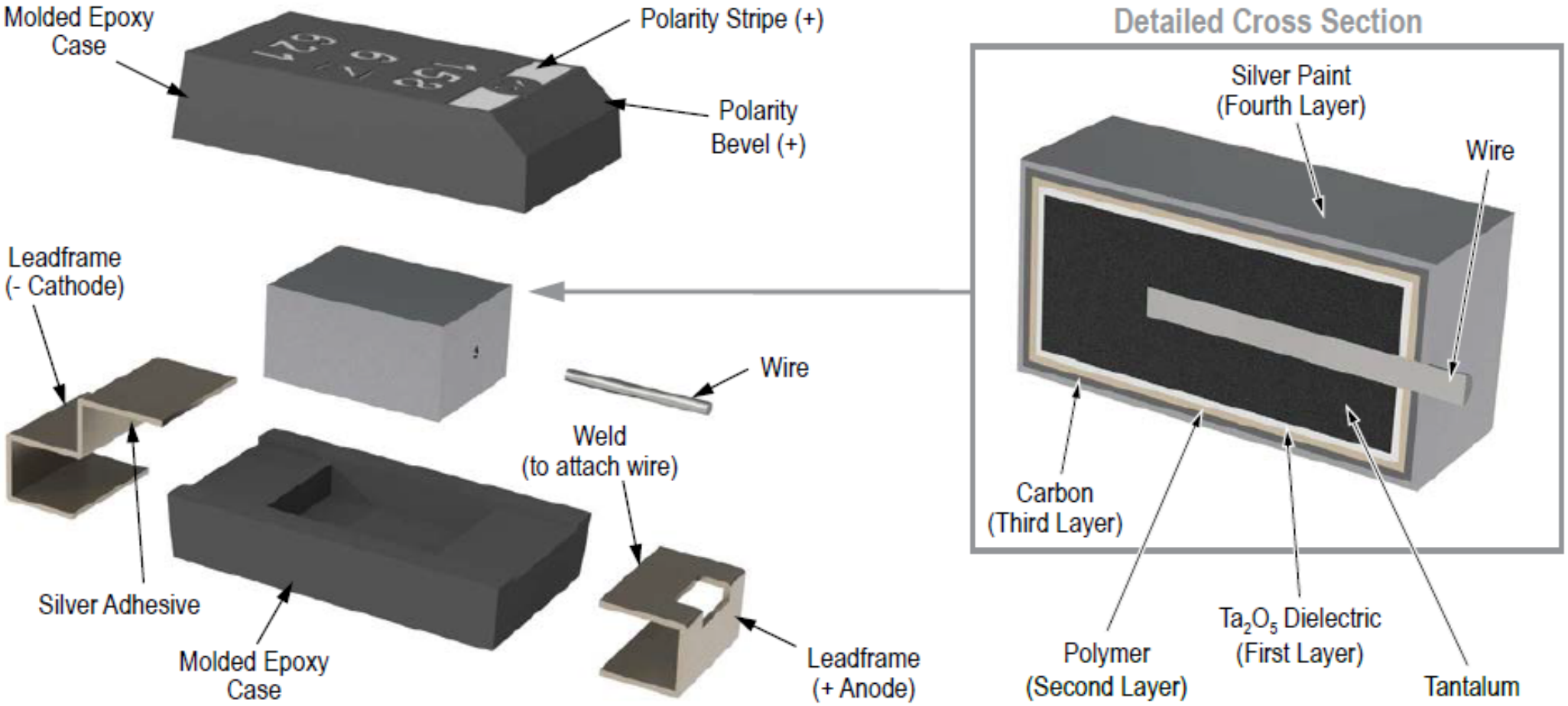
Tantalum Anode
(Porous Body)
$\rho_{Pressed\ Anode}$ = 5.0 to 7.0 g/cm^3





Construction

Standard Package



Materials and Processes

Tantalum

- High ductility
- High corrosion resistance
- High melting point (3020°C)
- High resistance to heat and wear
- High biocompatibility

Tantalum has many Applications

Electronics
- Capacitors
- Resistors
- Hard Disk Drives
- Acoustic Filiters

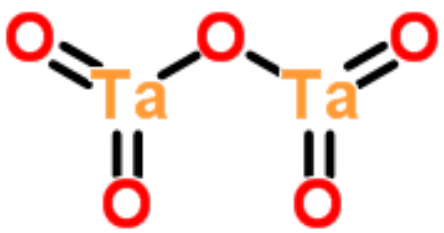
Optics
- Camera Lenses
- Phone Display
- Ink Jet Printers
- X-Ray Film

Superalloys
- Aircraft Frames
- Turbine Blades
- Jet Engine Discs

Medical
- Joint Replacement
- Skull Plates
- Screws/clamps
- Wires

High Temp
- Rocket Nozzles
- Furnaces
- Cutting Tools
- Chemical Resistant

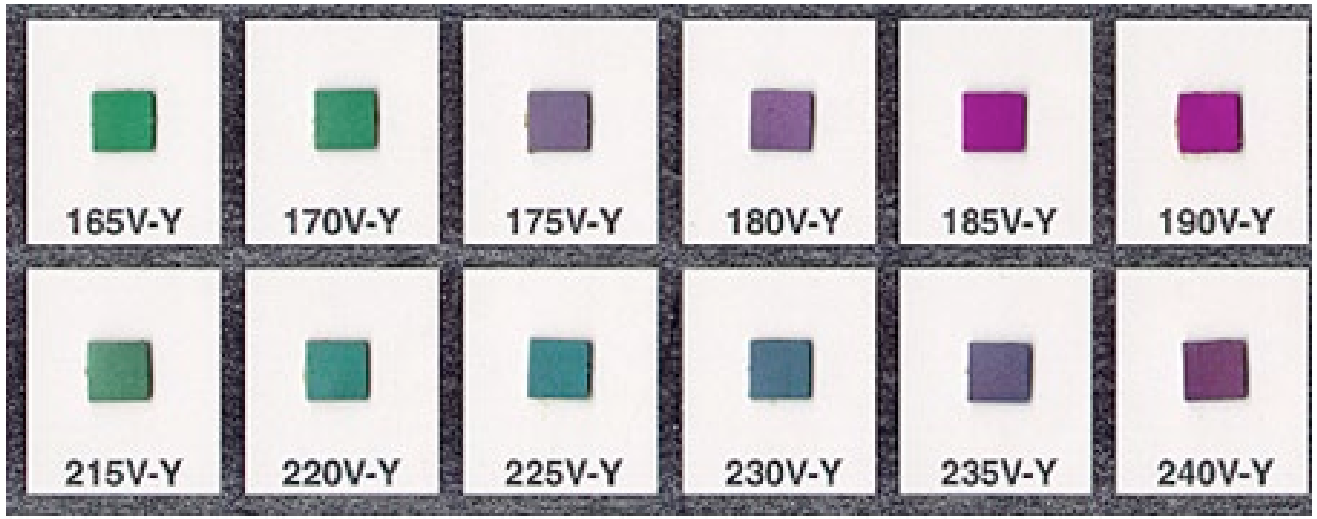
Tantalum Pentoxide (Ta_2O_5)



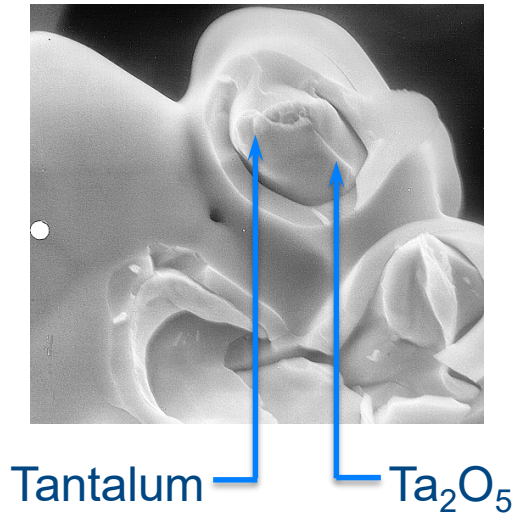
- Dielectric constant: 27
- Dielectric breakdown: 470 volt/mm
- Dielectric thickness: 2.0 nm/volt
- Resistant to chemical attack

V_R	Dielectric Thickness (nm)	
	Ta	**MLCC**
2	20.7	600
4	27.6	600
6	36.8	600

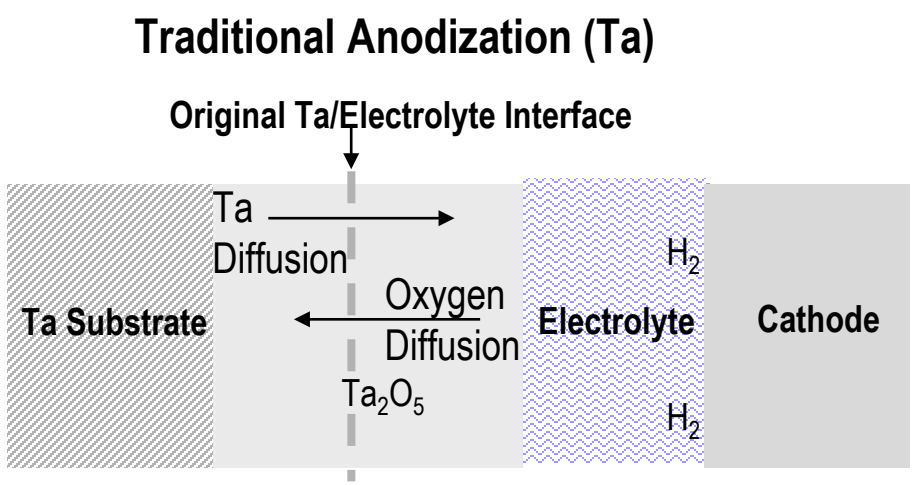
Interference Color



Fractured Anode (Post Formation)



Formation



Half Reactions

Cathode : $10H^+ + 10e^- \rightarrow 5H_2$

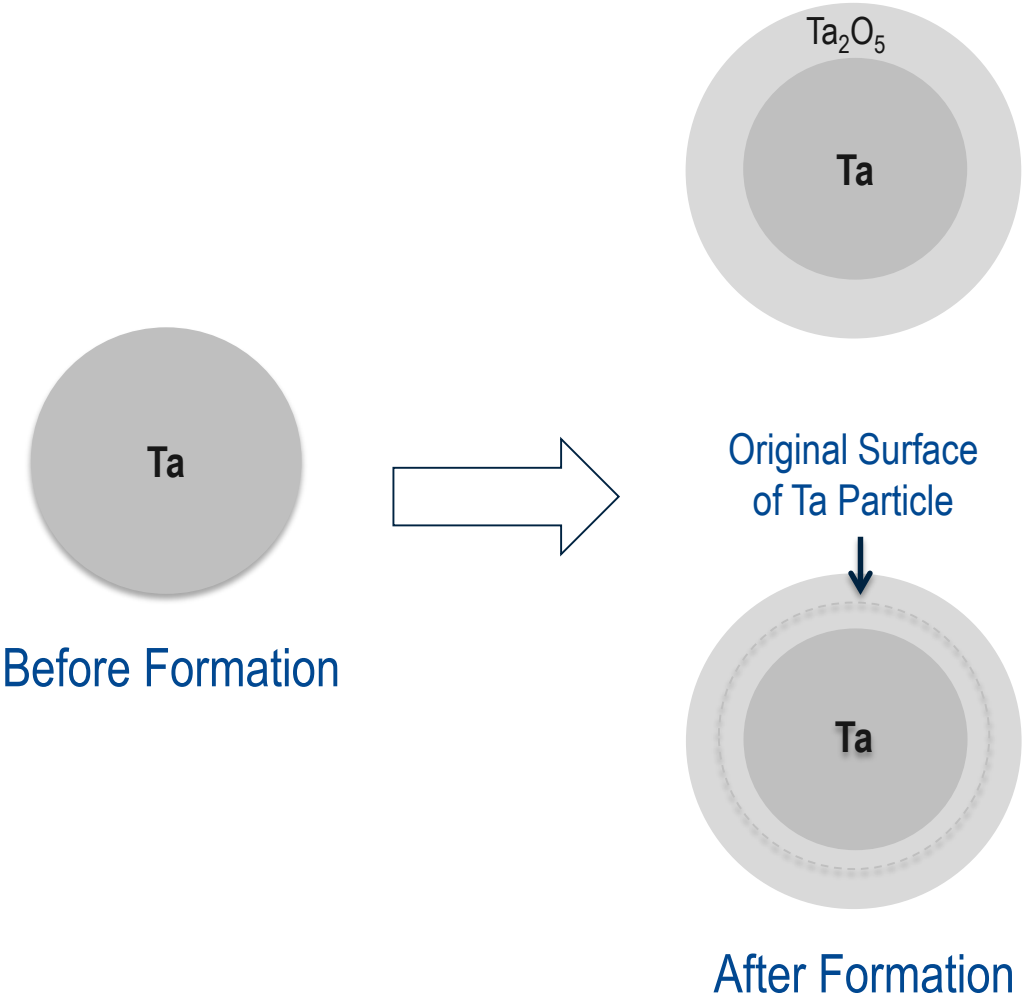
Anode: $2Ta \rightarrow 2Ta^{+5} + 10e^-$

$10H_2O \rightarrow 10H^+ + 10OH^-$

$2Ta^{+5} + 10OH^- \rightarrow 2Ta(OH)_5$

$2Ta(OH)_5 \rightarrow Ta_2O_5 + 5H_2O$

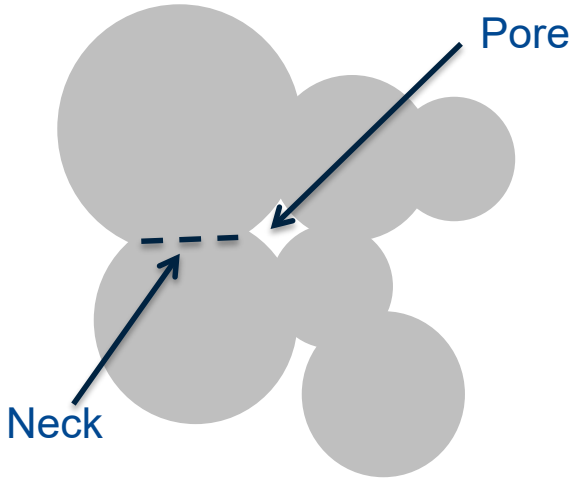
$2Ta + 5H_2O \rightarrow Ta_2O_5 + 5H_2$



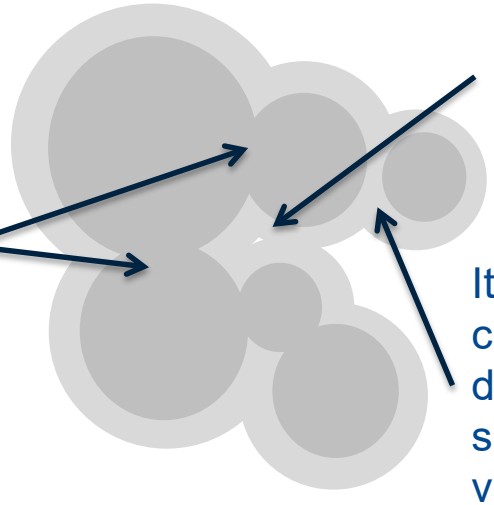
Dielectric (Ta_2O_5) grows inwardly and outwardly from the original surface of Tantalum particle

Formation

Before Formation



After Formation

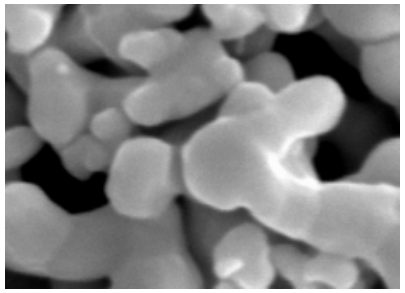


Pore becomes smaller or even can close off.

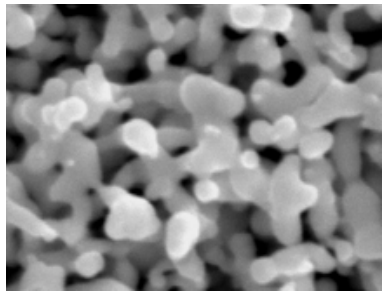
Smaller neck sizes (higher resistance)

It is possible to isolate cap during formation depending on initial neck size and formation voltage.

SEM Photos (10,000x) of Anode Surface

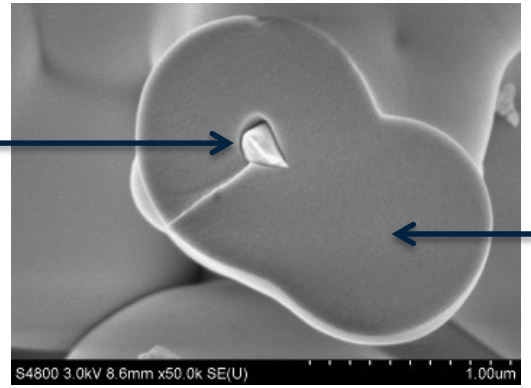


50K Powder



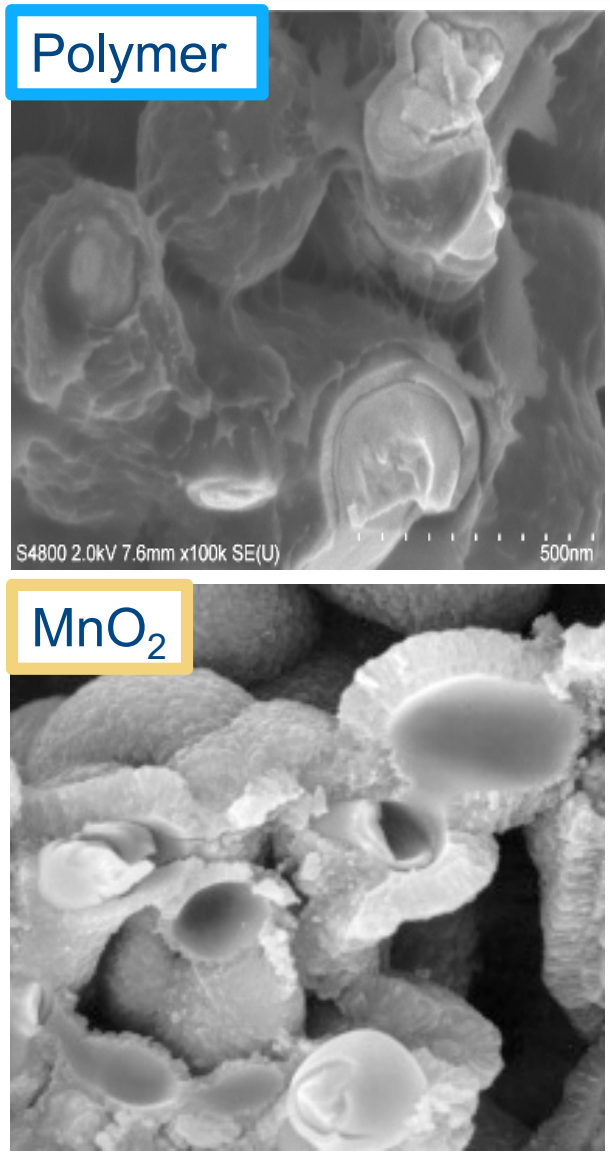
150K Powder

Small Neck of Effective Tantalum



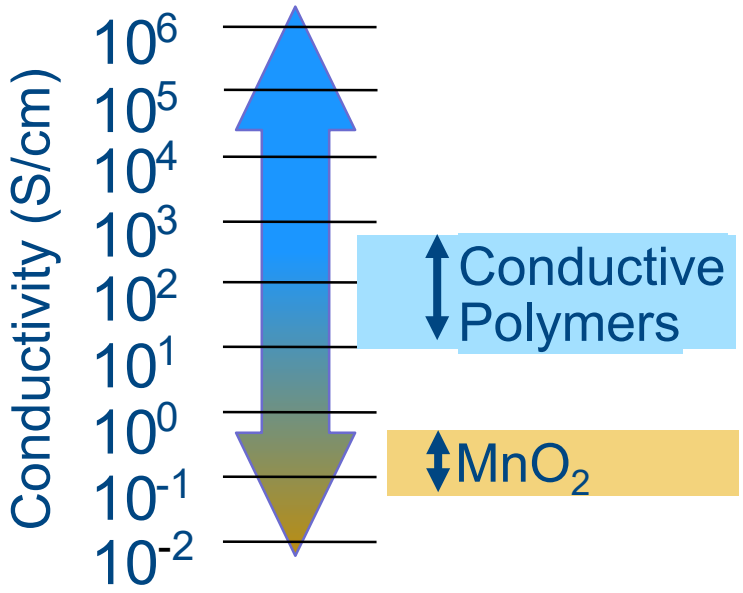
Dielectric has formed completely through neck

Cathode



Cathode forms the negative connection:

- Polymer is an intrinsically conductive polymer.
- MnO_2 is manganese dioxide.



Characteristics

Why Use Tantalum?

Electronic Components
KEMET
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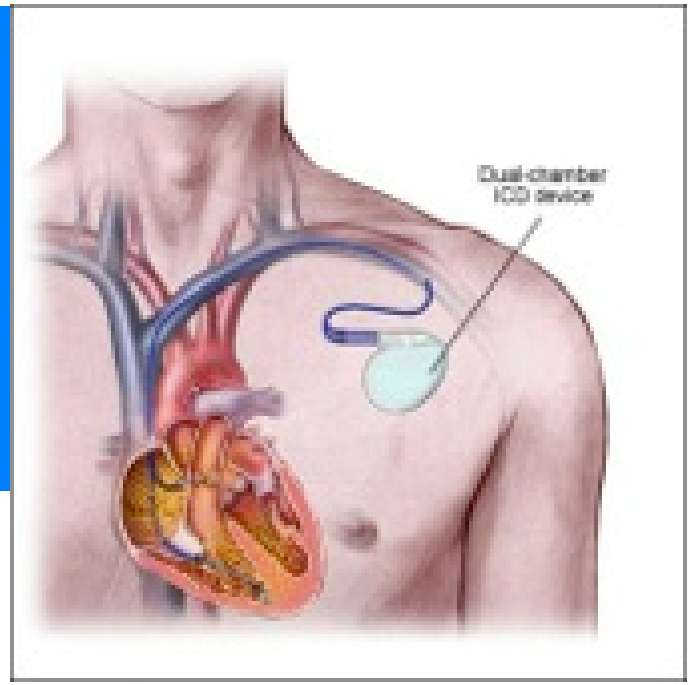
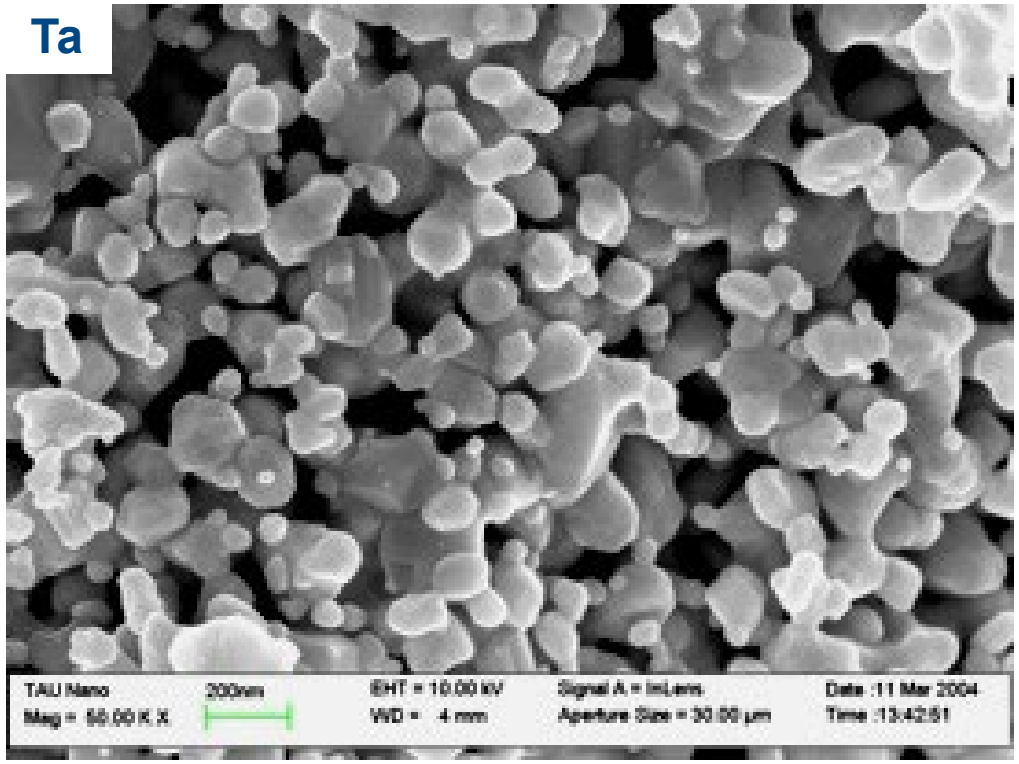
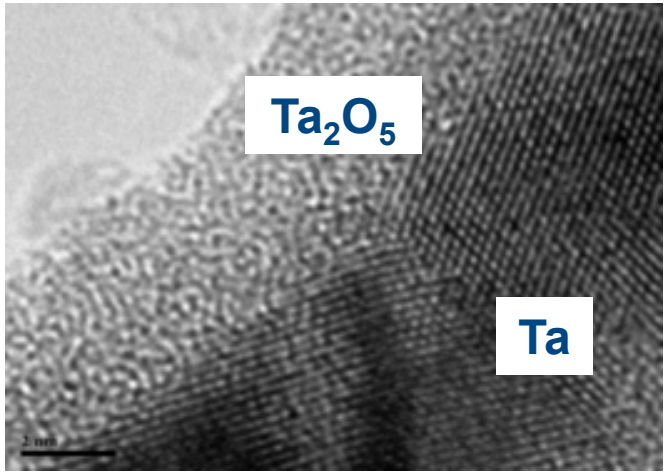
- Military
- Space
- Medical
- Automotive
- Computers
- Telecom



SEM of a Sintered Ta Anode

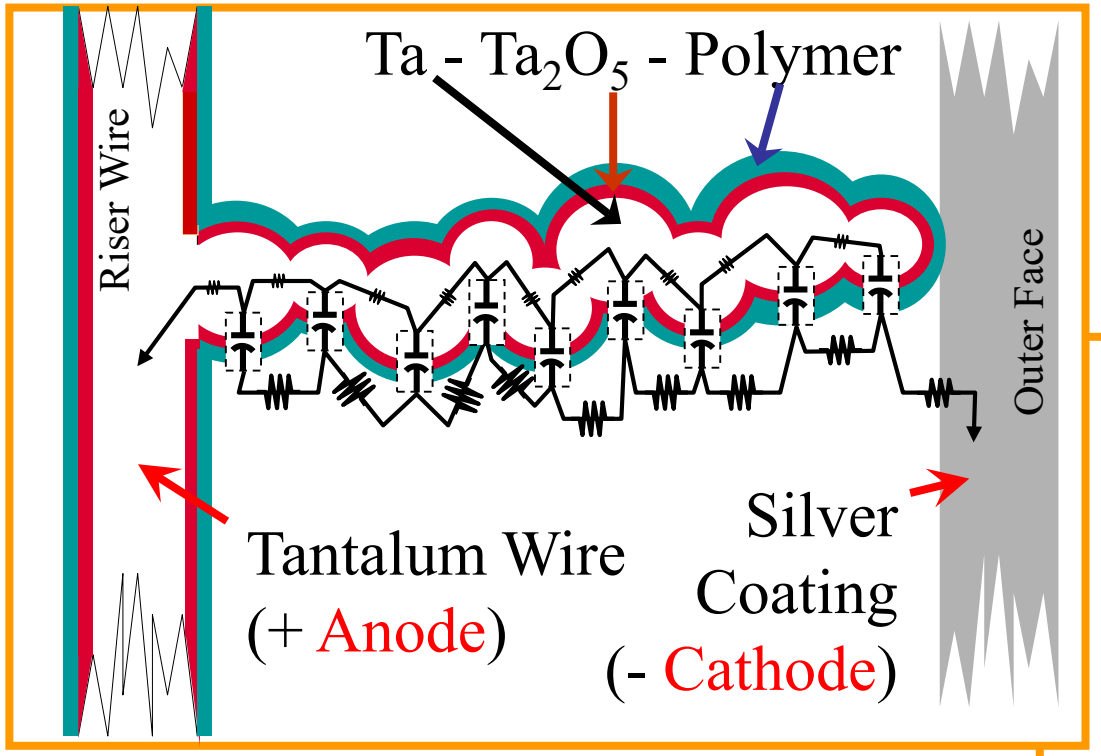


Ta Oxide Dielectric

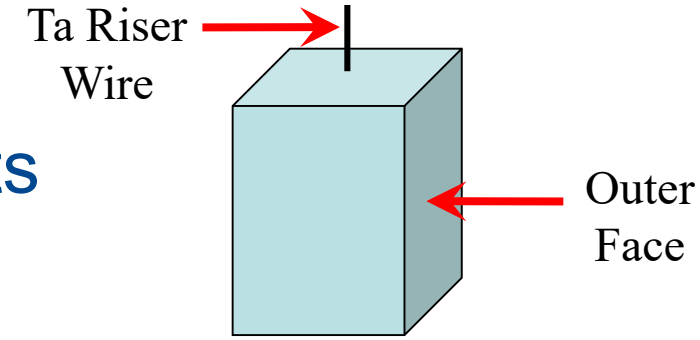


- Stable C (No Temp or Bias Effects), DCL (t)
- Reliable (Decreasing Failure Rate)
- Long Life (Exceeds Expected Life of All Hardware)
- Most Volumetrically Efficient (CV/cc, E/cc)

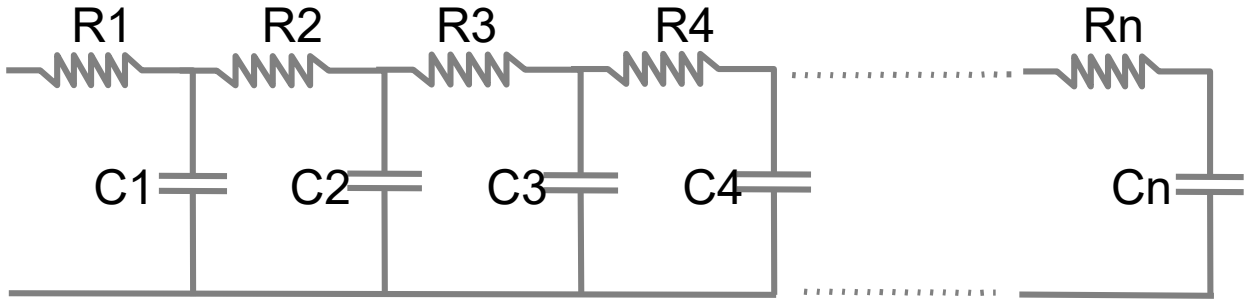
RC-Ladder Effect



RC-Ladder Effects

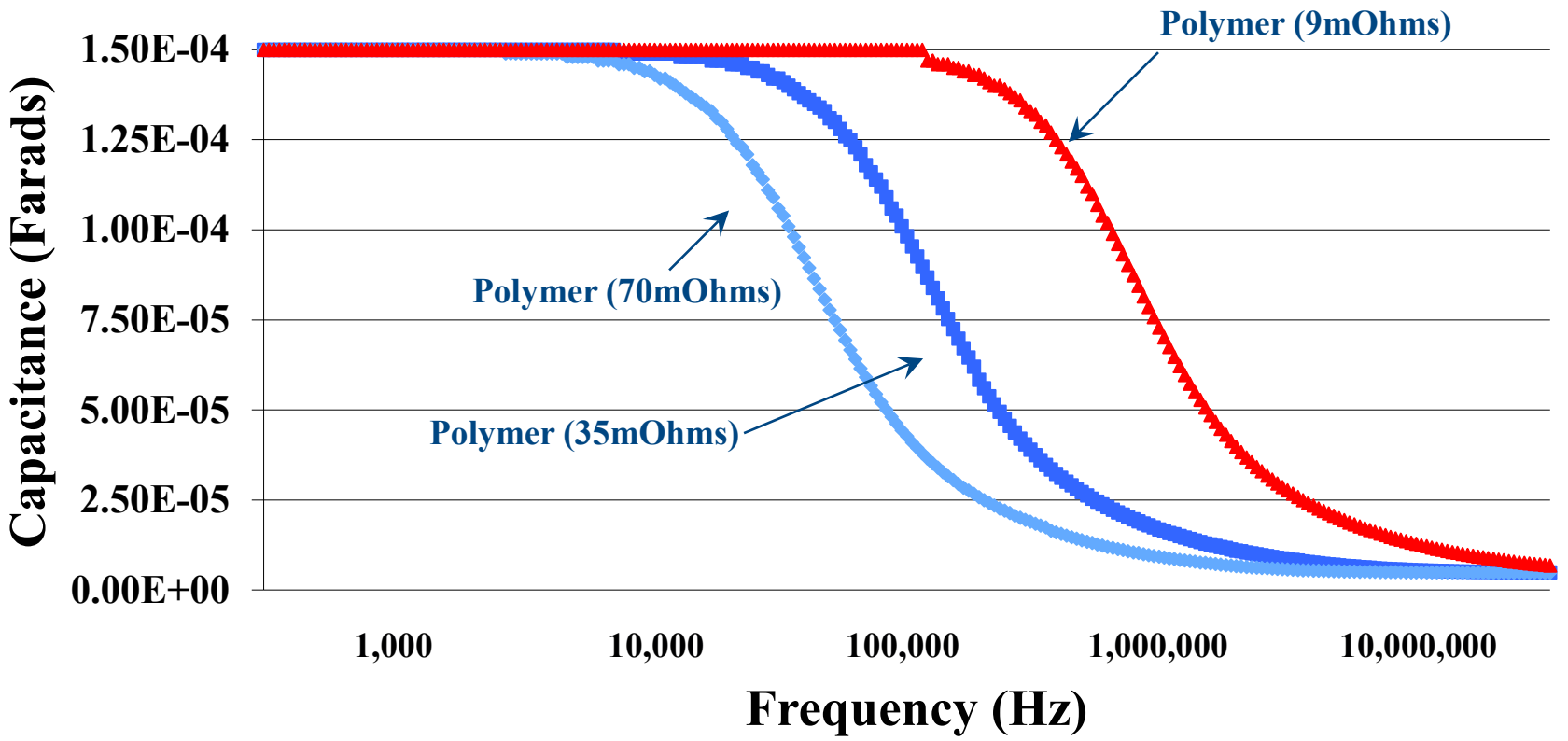


$tc1 = C1 \times R1$
$tc2 = C2 \times (R1+R2)$
$tc3 = C3 \times (R1+R2+R3)$
$tcn = Cn \times (R1+R2+R3...+Rn)$



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

Capacitance vs. Frequency

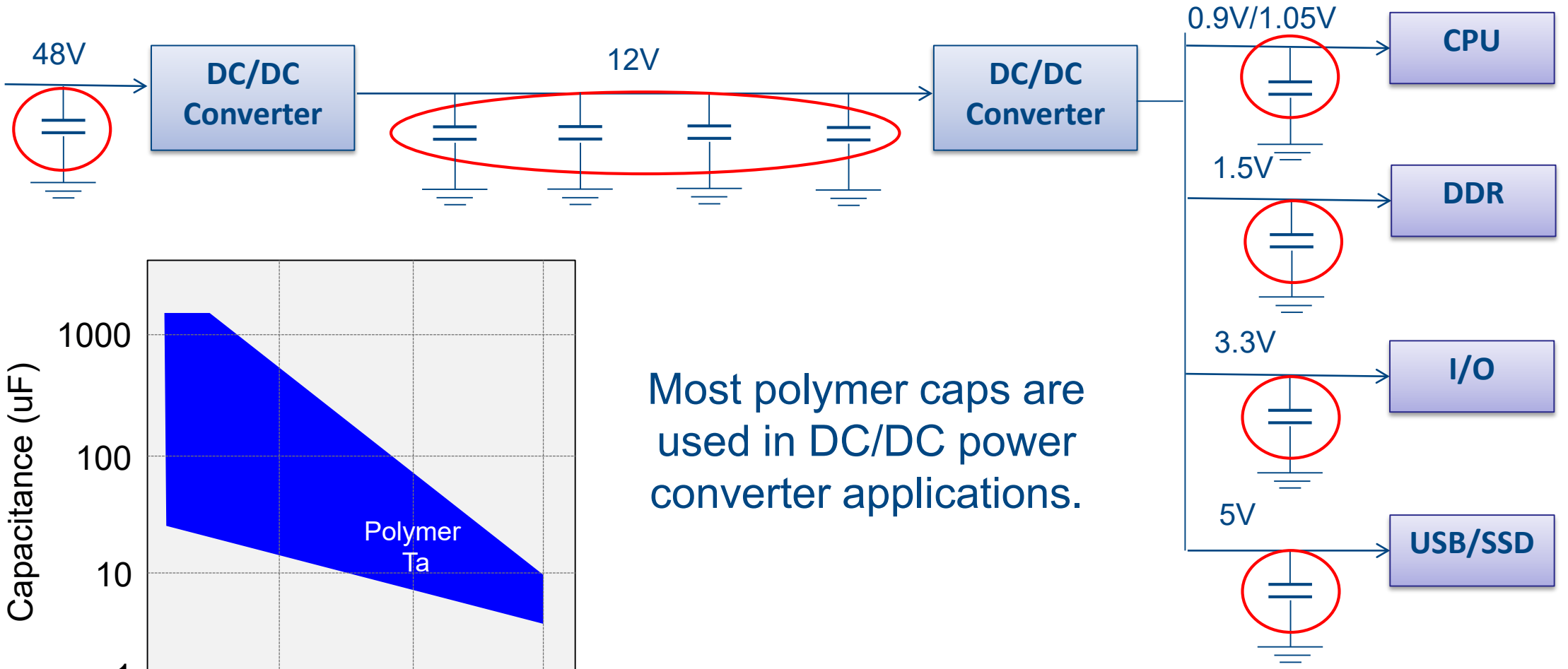


Polymers are commonly used in applications up to 1MHz. Applications exceeding 1MHz typically call for MLCCs.

Applications Most Suitable For Polymer Capacitors

DC/DC Converter

Filtering, Decoupling, and Hold Up



Most polymer caps are used in DC/DC power converter applications.

Reliability Models

Reliability Model

Leakage

KO-CAP capacitors have an average failure rate of 0.5 %/1,000 hours at category voltage, V_C, and category temperature, T_C. These capacitors are qualified using industry test standards at V_C and T_C. The minimum test time (1,000 or 2,000 hours) is dependent on the product series.

The actual life expectancy of KO-CAP capacitors increases when application voltage, V_A, and application temperature, T_A, are lower than V_C and T_C. As a general guideline, when $V_A < 0.9 * V_C$ and $T_A < 85°C$, the life expectancy will typically exceed the useful lifetime of most hardware (> 10 years).

The lifetime of a KO-CAP capacitor at a specific application voltage and temperature can be modeled using the equations on the next slide. A failure is defined as passing enough current to blow a 1-Amp fuse. The calculation is an estimation based on empirical results and is not a guarantee.

Reliability Model

Lifetime

Electronic Components KEMET CHARGED.

$$V_{AF} = \left(\frac{V_C}{V_A}\right)^n$$

Inverse Power Law

where: V_{AF} – acceleration factor due to voltage, unitless
V_C – category voltage, Volt
V_A – application voltage, Volt
n – exponent, 16

$$T_{AF} = e^{\left[\frac{E_a}{k}\left(\frac{1}{273+TA}-\frac{1}{273+TC}\right)\right]}$$

Arrhenius Equation

where: T_{AF} – acceleration factor due to temperature, unitless
E_a – activation energy, 1.4 eV
k – Boltzmann's constant, 8.617E-5 eV/K
T_A – application temperature, °C
T_C – category temperature, °C

$$A_F = \mathrm{V_{AF}} * \mathrm{TAF}$$

where: A_F – acceleration factor, unitless
T_{AF} – acceleration factor due to temperature, unitless
V_{AF} – acceleration factor due to voltage, unitless

$$Life_{U_{A,}\,TA} = \mathrm{Life_{U_{C,}\,TC}} * \mathrm{AF}$$

where: $\mathrm{Life_{V_A,T_A}}$ – guaranteed life at application voltage and temperature, years
$\mathrm{Life_{V_C,T_C}}$ – guaranteed life at category voltage and temperature, years
A_F – acceleration factor, unitless

Constants (n, E_a) were agreed upon by technical teams based on empirical results. These values can vary based on part type. For the product line, these are accepted values for the purpose of giving guidance.

Reliability Model

Derating

Electronic Components KEMET CHARGED.

Qualification Plan: 105°C, Vr, 2000 hours.

Ur	Equivalent Time (hours) at Specified Temperature (°C)				
	45°C	65°C	85°C	105°C	125°C
1.00	6,587,826	321,712	22,011	2,000	231
0.90	35,551,833	1,736,149	118,785	10,793	1,248
0.80	234,046,611	11,429,505	781,992	71,054	8,215
0.67	3,995,262,380	195,105,889	13,348,893	1,212,923	140,238
0.50	431,739,793,834	21,083,715,712	1,442,520,611	131,072,000	15,154,549

De-Rating Recommendations

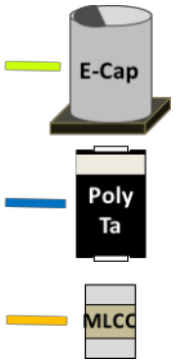
Ur	Equivalent Time (years) at Specified Temperature (°C)				
	45°C	65°C	85°C	105°C	125°C
1.00	752	37	3	0.2	0.03
0.90	4,058	198	14	1.2	0.1
0.80	26,718	1,305	89	8	0.9
0.67	456,080	22,272	1,524	138	16
0.50	49,285,365	2,406,817	164,671	14,963	1,730

Baseline Condition

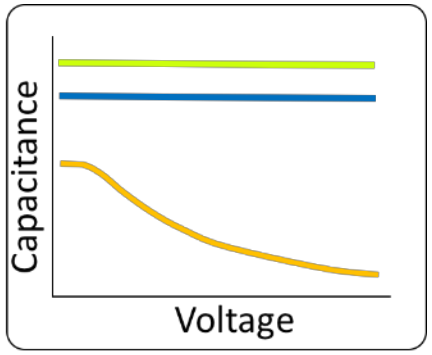
Strengths And Weaknesses By Dielectric

Dielectric Comparison

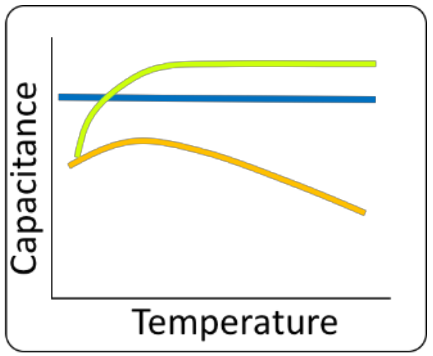
Stable Capacitance



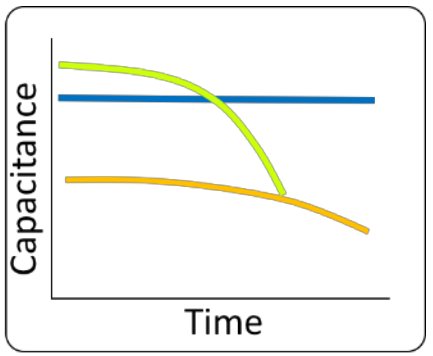
Cap vs Voltage



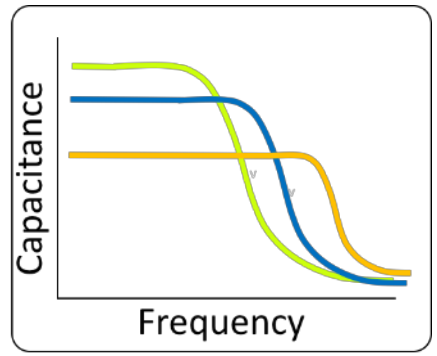
Cap vs Temp



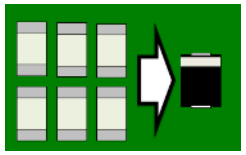
Cap vs Time



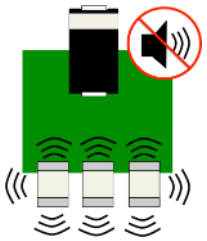
Cap vs Freq



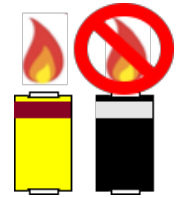
Delivered Capacitance



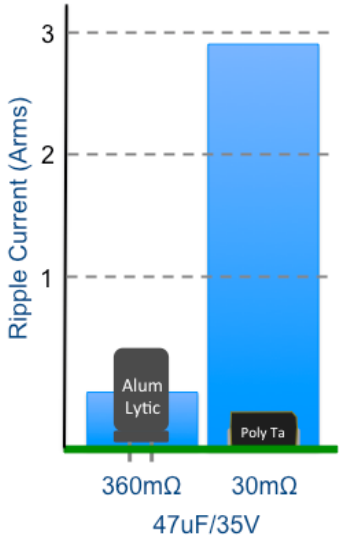
No Piezo Noise



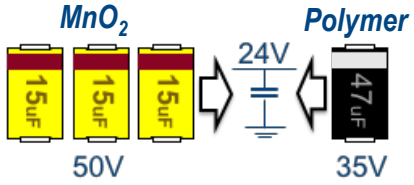
Non-Ignition Failure Mode



High Ripple Handling



De-rating

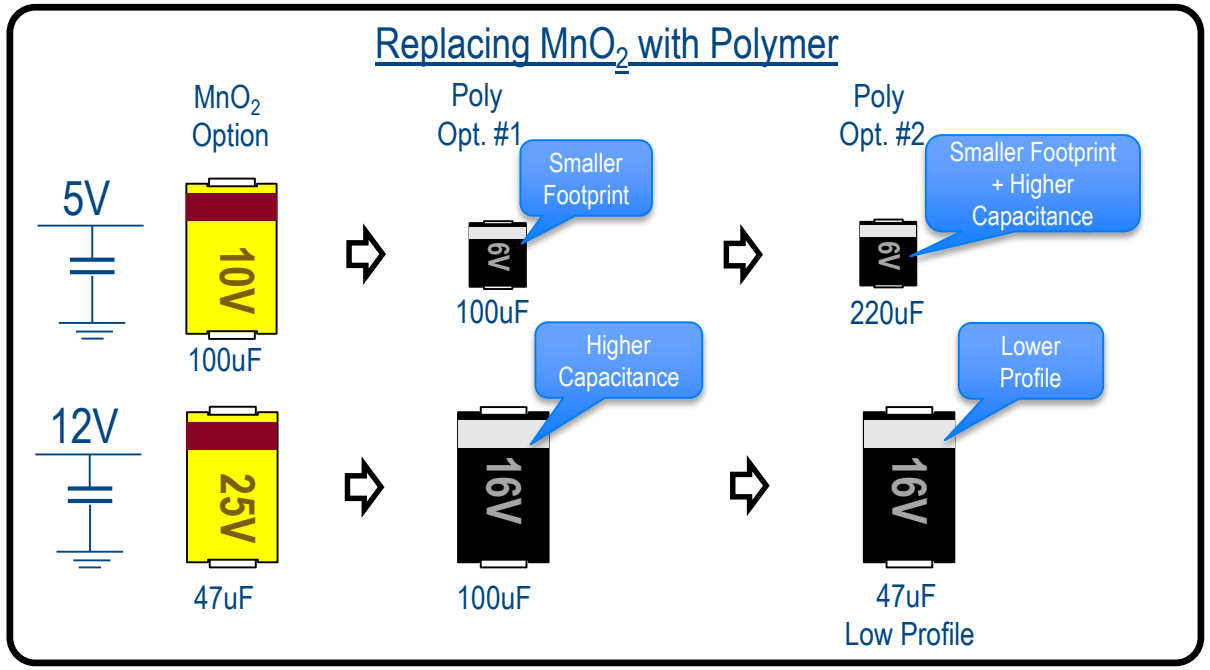


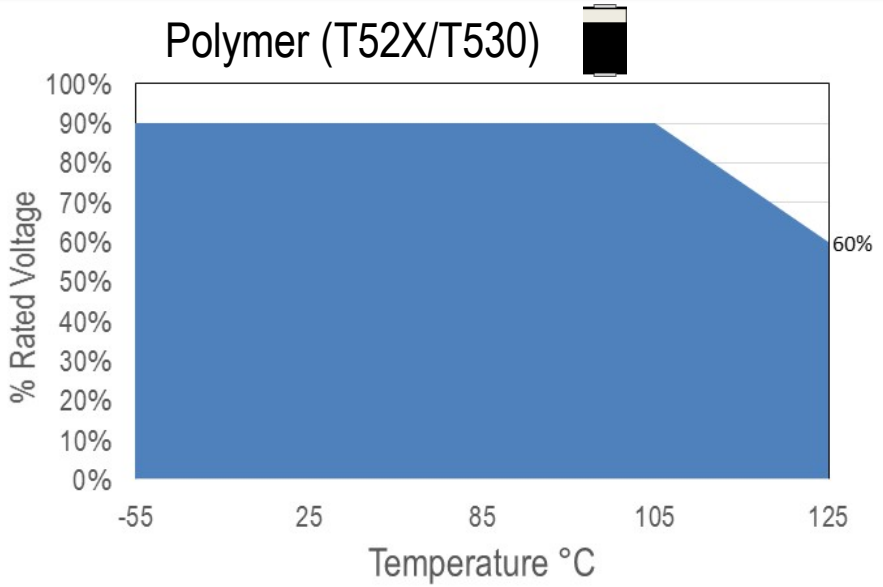
Low Profile

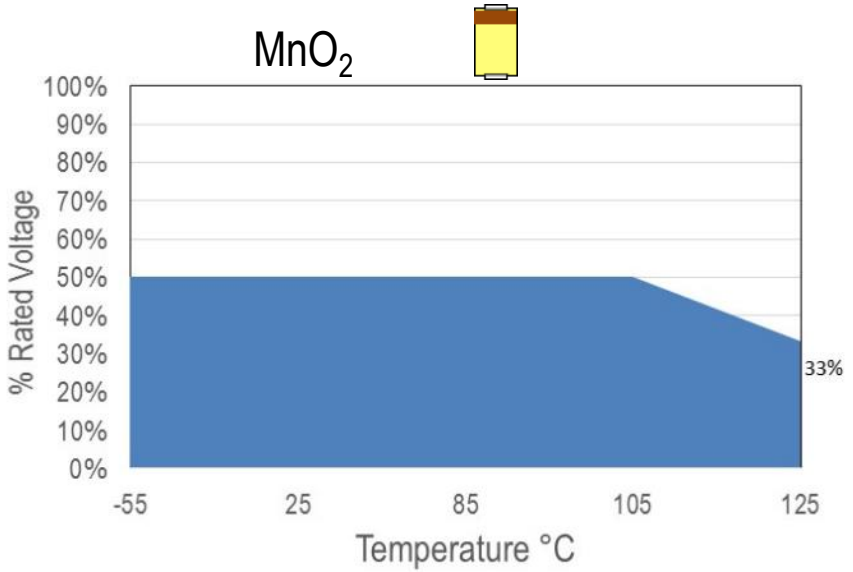
No Flex Cracks

MnO_2 vs. Polymer

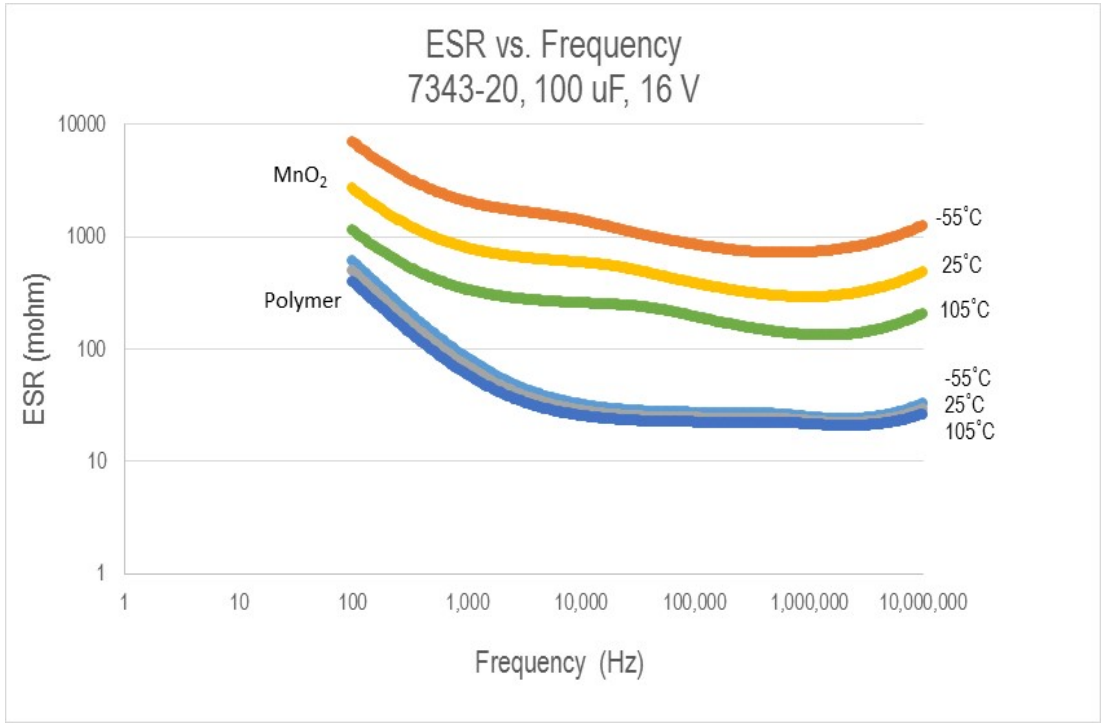
Application Voltage	MnO2 Voltage Rating	Polymer Voltage Rating
1.0 -1.5	4.0	2.5
3.3	6.3	4.0
5.0	10	6.3
12	25	16
24	50	35
28	50(?)	35 & 50
36	N/A	50
48	N/A	63 & 75

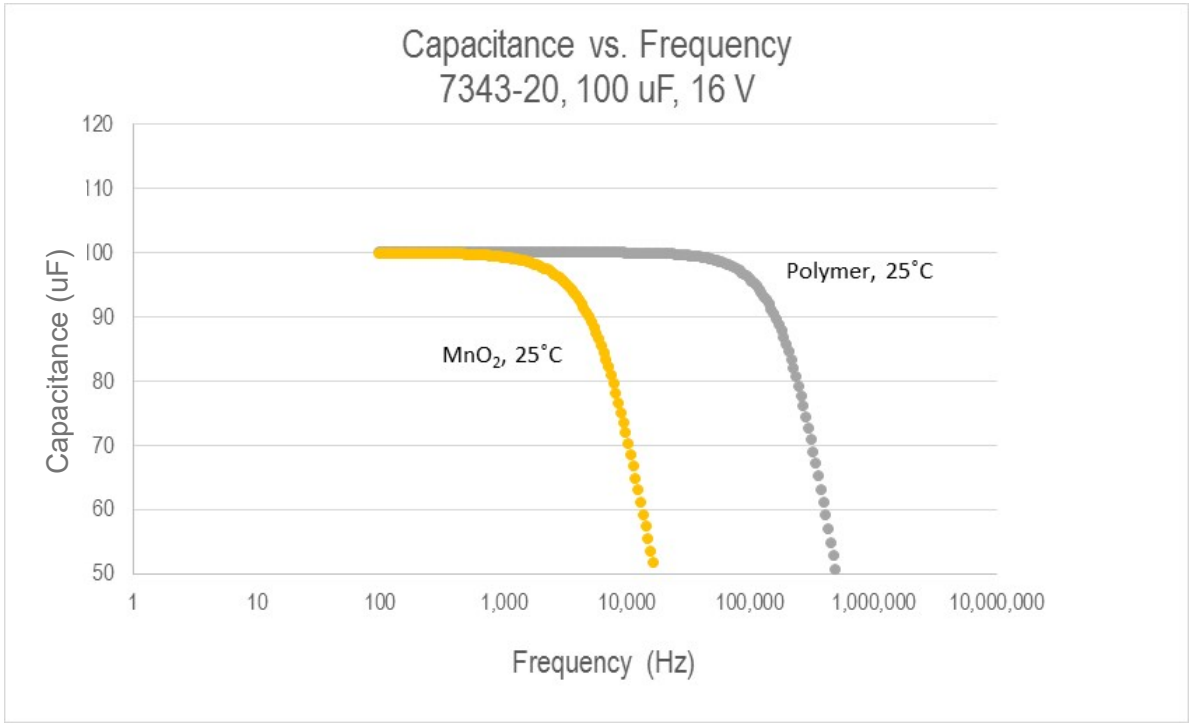






MnO_2 vs. Polymer

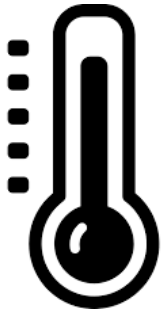




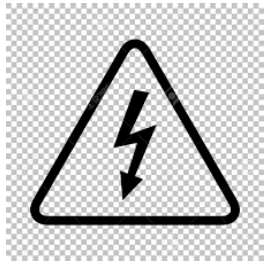
- Polymers are much lower in ESR which result in a more efficient circuit.
- Polymer capacitors retain more actual capacitance than MnO_2.

When Polymer Is Not the Ideal Choice

Frequencies approach or exceed 1 MHz

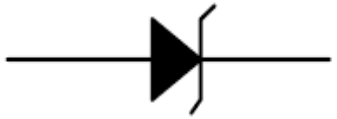


Temperatures exceed 150°C unless expected life time is short (within days).

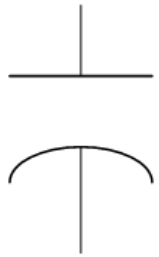


Voltage rails exceed 48 Volts.

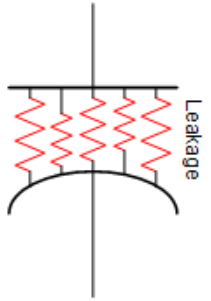
Ultra low ESR (<< 4 mΩ) is needed.



Reverse bias occurs.



Low cap (< 0.68 µF) is needed.



Low leakage is needed for maximum battery life.

MLCC to Polymer Considerations

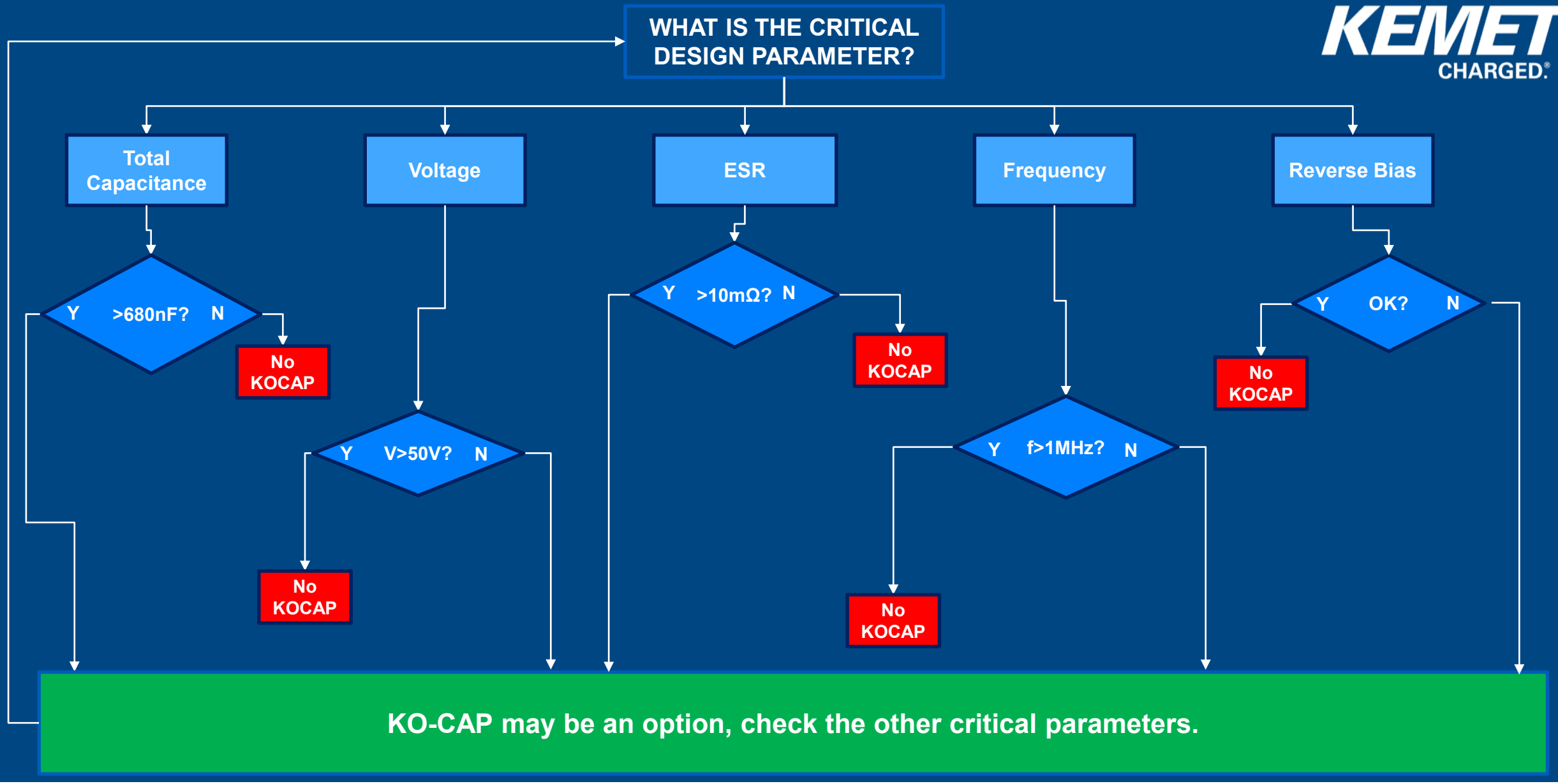
Leakage

Application Voltage

Switching Frequency

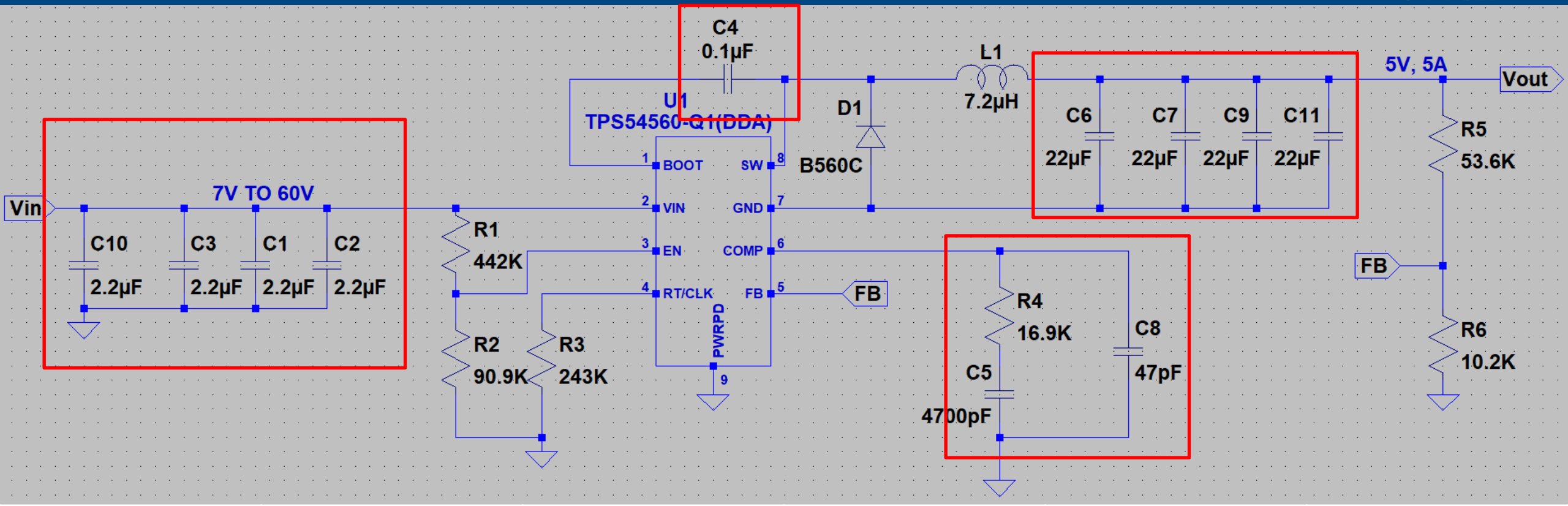
Total Capacitance

ESR



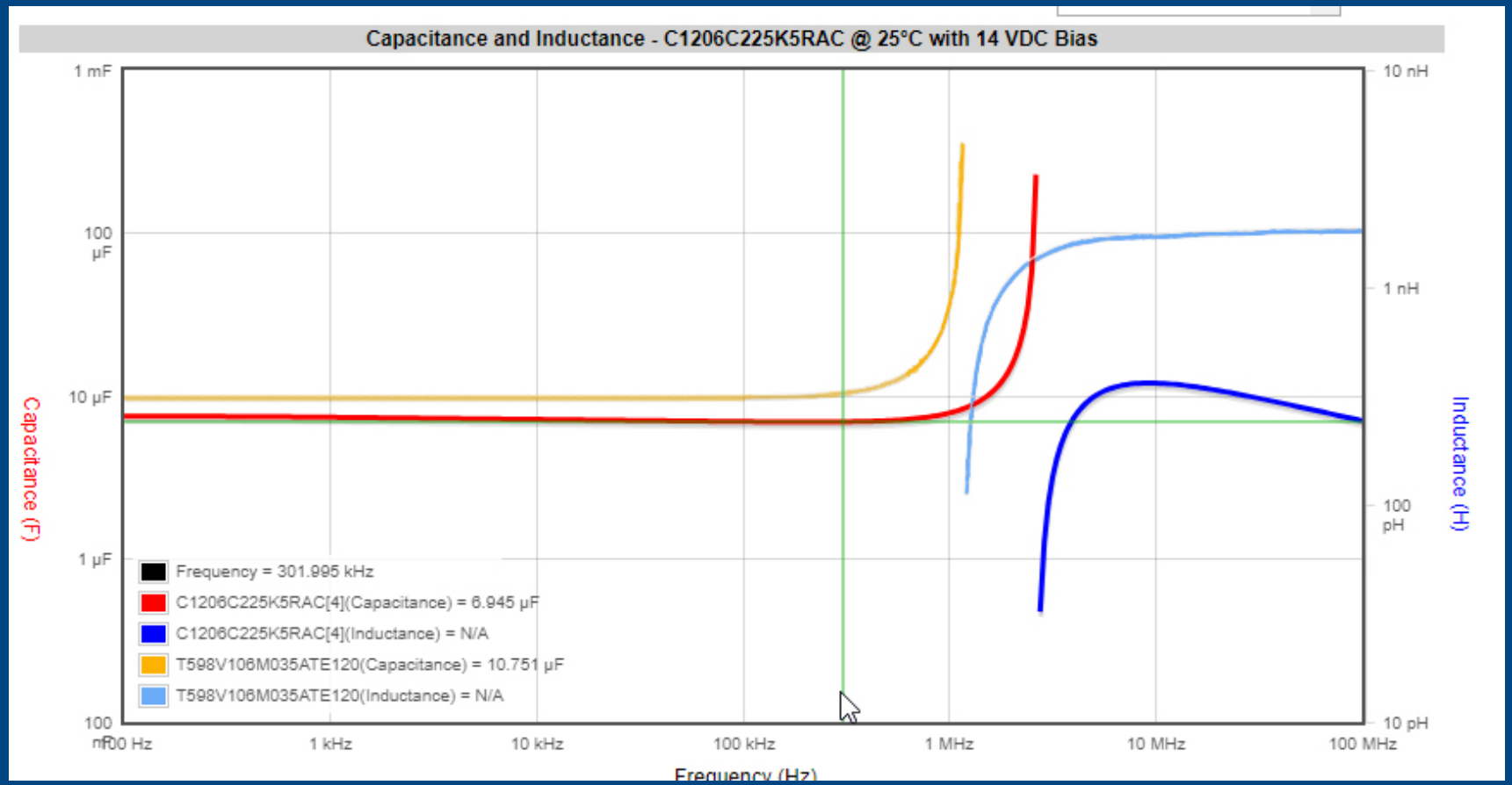
If you pass all the checks then you are in good shape for KO-CAP

A Common Buck



Location (Ref Des)	Original MLCC	Description	KO-Cap Replacement	Description	Result
Input (C1, C2, C3, C10)	C1206C225K5RAC	50V X7R 2.2uF 10%	T598V106M035ATE120	35V KO 10uF 20%	Layout change: 4 to 1
Support (C4)	C0402C104K4RAC	16V X7R 0.1uF 10%	None		DQ: Size
Support (C5)	C0603C472K3GAC	25V C0G 4.7nF 10%	None		DQ: Size
Support (C8)	C0402C470K3GAC	10V C0G 47pF 10%	None		DQ: Size
Output(C6, C7, C9, C11)	C1206C226K8RAC	10V X7R 22uF 10%	T520A226M006ATE100	6.3V KO 22uF 20%	Drop-in replacement

Input Side – Does it work as well?



K-SIM

ON

MOUSER ELECTRONICS

KO-CAP has more effective delivered cap @ given conditions

Input Side – What‘s this going to cost me?

MOUSER ELECTRONICS

C1206C225K5RACTU

Enlarge

Images are for reference only
See Product Specifications

Share

Mouser #:	80-C1206C225K5R
Mfr. #:	C1206C225K5RACTU
Mfr.:	KEMET
Customer #:	
Description:	Multilayer Ceramic Capacitors MLCC - SMD/SMT 50volts 2.2uF X7R 10%
	View Simulation and SPICE Model in K-SIM
Datasheet:	C1206C225K5RACTU Datasheet
More Information:	Learn more about KEMET C1206C225K5RACTU

Compare Product | Add To Project | Add Notes

Availability

Stock:	0
On Order:	131483 View Delivery Dates
Factory Lead-Time:	38 Weeks
Enter Quantity:	Minimum: 1 Multiples: 1 Buy

Pricing (USD)

Qty.	Unit Price	Ext. Price
1	$1.04	$1.04
10	$0.729	$7.29
100	$0.46	$46.00
500	$0.415	$207.50
1,000	$0.378	$378.00

Full Reel (Order in multiples of 2000)

T598V106M035ATE120

Enlarge

Images are for reference only
See Product Specifications

Share

Mouser #:	80-T598V106M035E120
Mfr. #:	T598V106M035ATE120
Mfr.:	KEMET
Customer #:	
Description:	Tantalum Capacitors - Polymer SMD 35V 10uF 2917 20% ESR=120mOhm AEC-Q200
	View Simulation and SPICE Model in K-SIM
Lifecycle:	New Product: New from this manufacturer.
Datasheet:	T598V106M035ATE120 Datasheet
More Information:	Learn more about KEMET T598V106M035ATE120

Compare Product | Add To Project | Add Notes

In Stock: 686

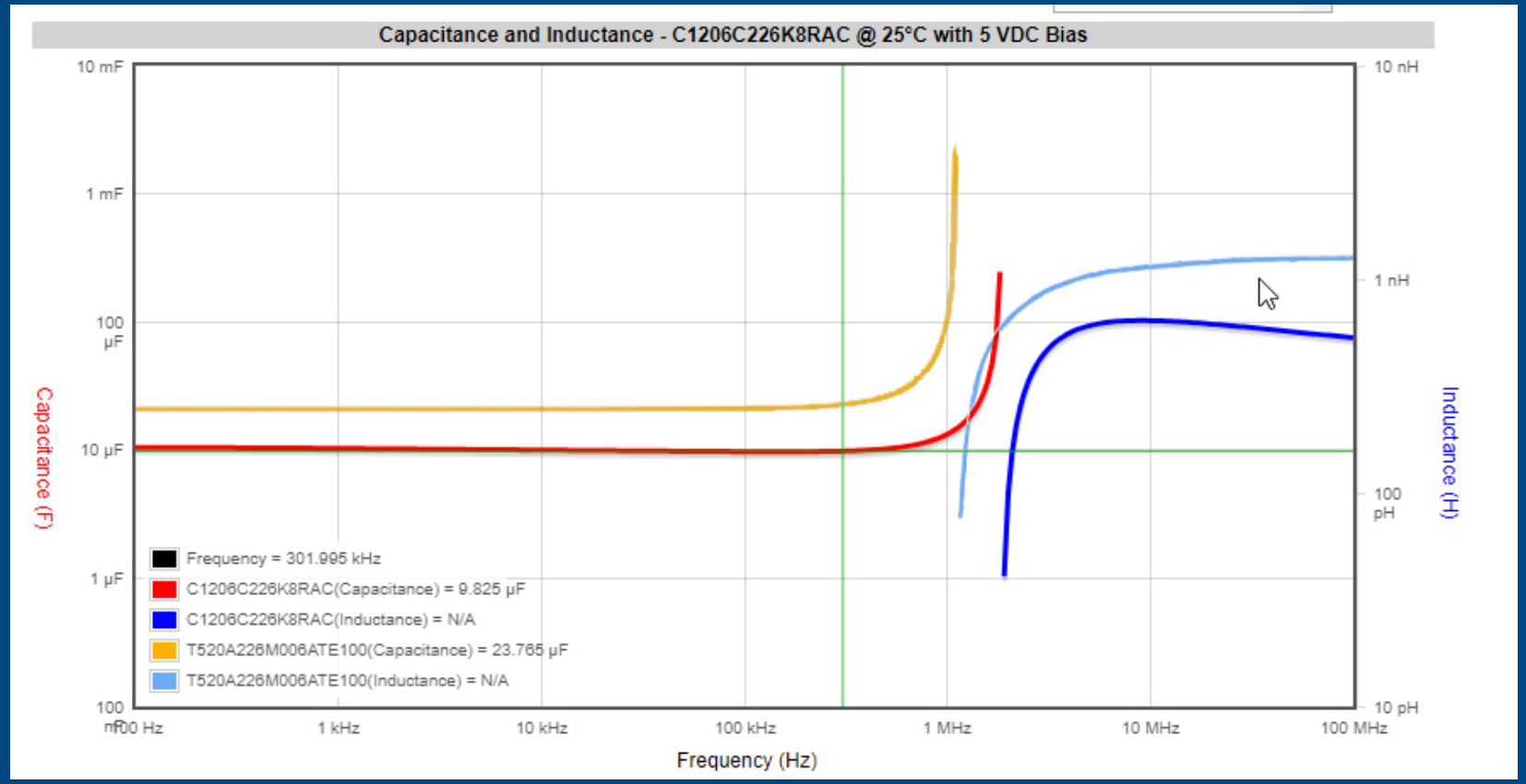
Stock:	686 Can Ship Immediately
On Order:	0
Factory Lead-Time:	23 Weeks
Enter Quantity:	Minimum: 1 Multiples: 1 Buy

Pricing (USD)

Qty.	Unit Price	Ext. Price
1	$3.10	$3.10
10	$2.47	$24.70
100	$1.78	$178.00
500	$1.59	$795.00
Full Reel (Order in multiples of 1000)		
1,000	$1.06	$1,060.00
2,000	$0.982	$1,964.00
10,000	$0.963	$9,630.00

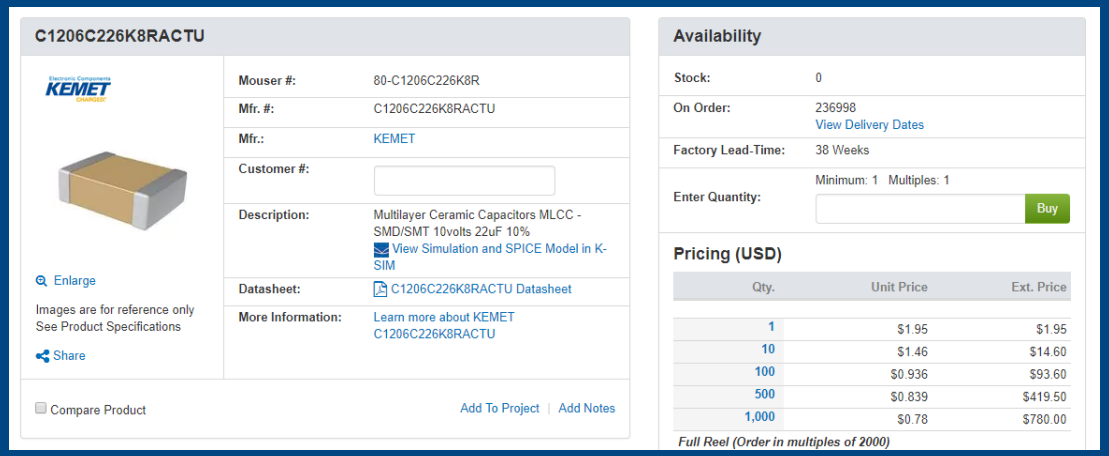
Capacitor Part Number	No of Caps	Cap/pc (µF) @ 14V	Effective Cap (µF)	ASP/pc (Mouser)	ASP/Total Cap (Mouser)	Difference
C1206C225K5RAC	4	1.75	7	$1.04	$4.16	
T598V106M035ATE120	1	10	10	$3.10	$3.10	25%

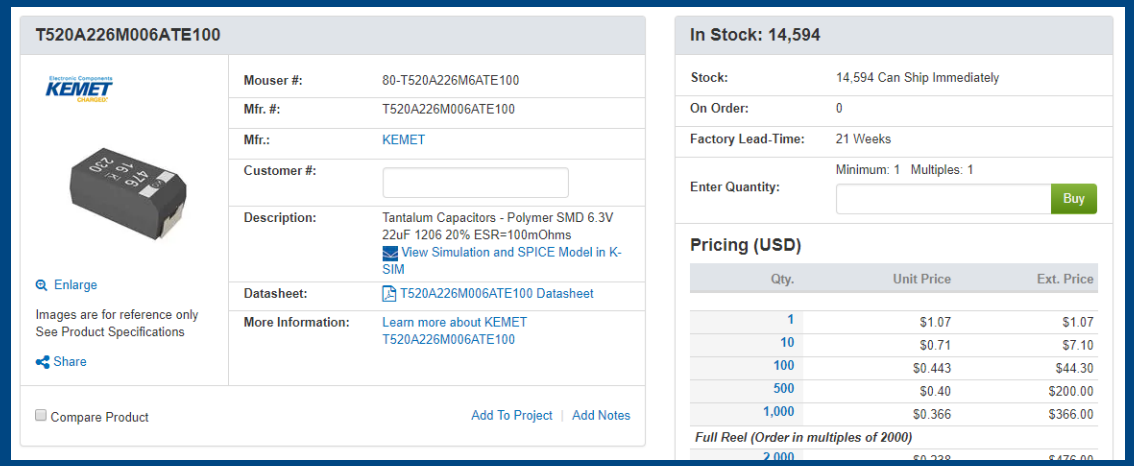
Output Side – Does it work as well?



KO-CAP has more effective delivered cap @ given conditions

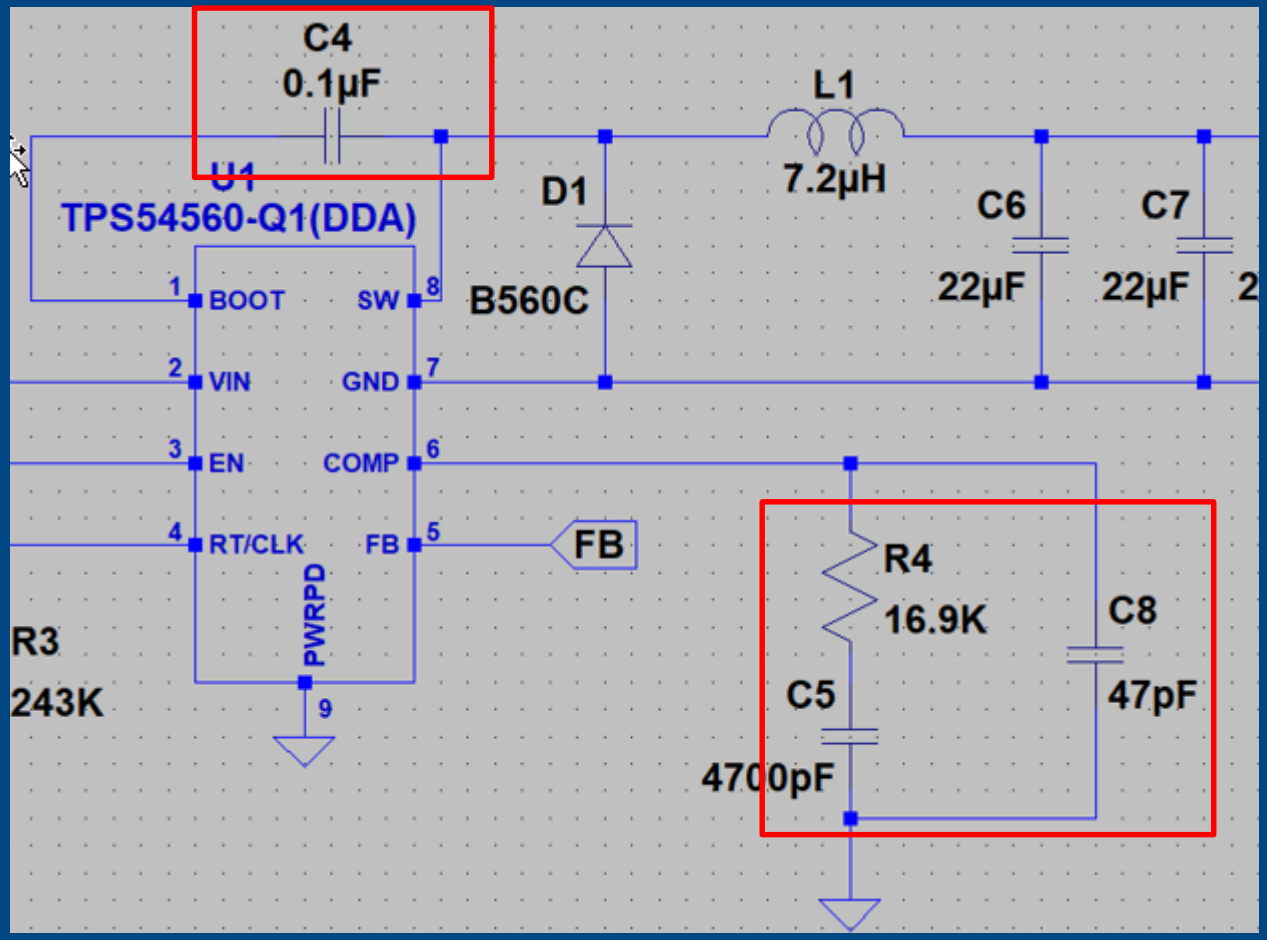
Output Side – What‘s this going to cost me?





Capacitor Part Number	No of Caps	Cap/pc (µF) @ 5V	Effective Cap (µF)	ASP/pc (Mouser)	ASP/Total Cap (Mouser)	Difference
C1206C226K8RAC	4	9.825	36.3	$1.95	$7.80	
T520A226M006ATE100	4	22	88	$1.07	$4.28	45%

Support Capacitors



C4, C5, C8 have no KO-CAP equivalent options. Their cap values are below the range of KO-CAP.

Operating Parameters of Support Caps May Yield Other Options

Other Considerations

- ESR
  - KO-CAP ESR is generally higher than ceramics, but the additional capacitance helps to mitigate the additional ripple.
  - Some series have ESR lower than 10mOhms, contact FAE if close to limit.
- Voltage
  - Derating rules may need to apply to extend life, if necessary.
- Leakage
  - Leakage mostly a major consideration with fixed, non-chargeable direct battery voltage is applied
- Robustness
  - KO-CAP will NOT tolerate reverse bias.
- Supply
  - KO-CAP supply chain is stable and KEMET capacity to be increased by 25%
  - KO-CAP capacity is currently below maximum for most series
  - KO-CAP can offer immediate and sustainable relief
- Design
  - The best value proposition is to replace banks of ceramics with fewer KO-CAPs
  - Drop-in replacements are possible but less likely

Contact a KEMET FAE for further support (www.kemet.com/ask)

Thank You!