

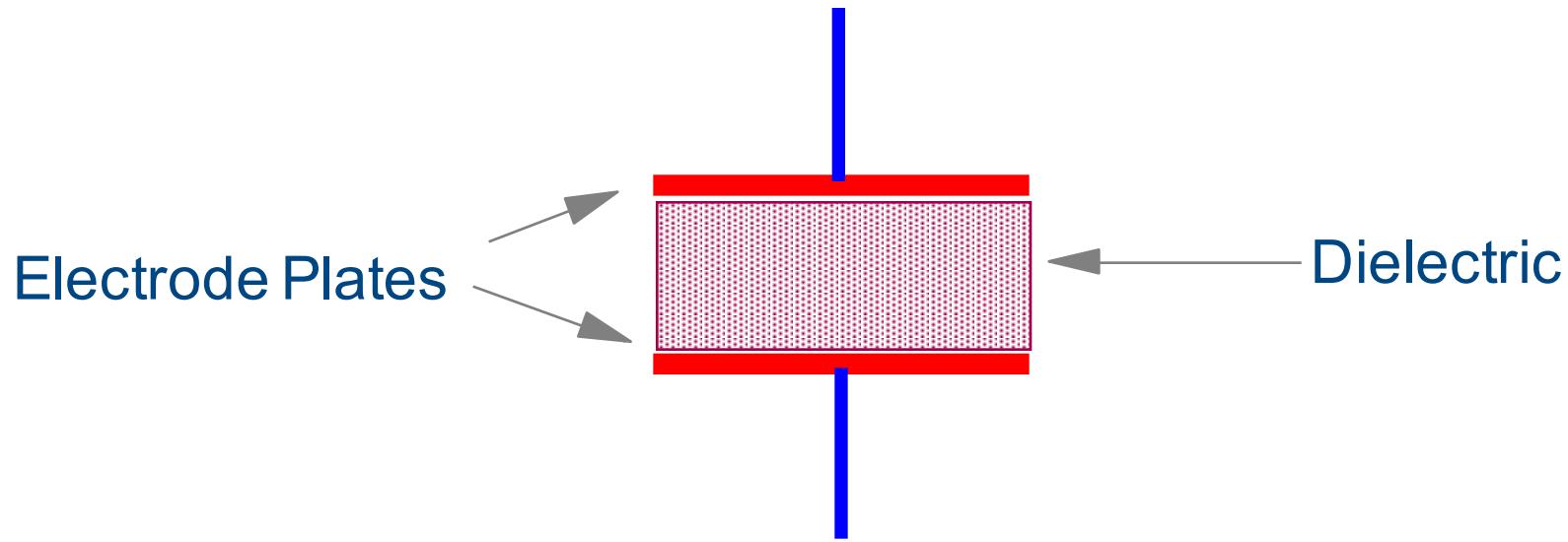


They're JUST capacitors?

James Lewis
Marketing Director
jameslewis@kemet.com



Basic Capacitor

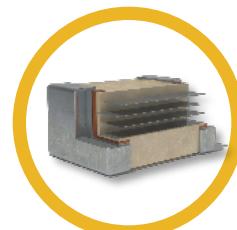


$$C = \frac{\epsilon_0 K A (n-1)}{d}$$

Different materials make different capacitors

Topic List

- Ceramics
 - Why they lose capacitance
- Aluminum
 - Why they don't last forever
- Tantalum
 - Why are they safe to use
- Supercapacitors
 - Why they are called super



We need a context...

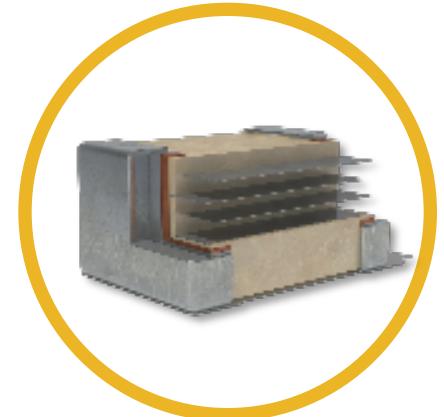
Capacitors should be
voltage derated 50%

True

Or

False

It Depends...

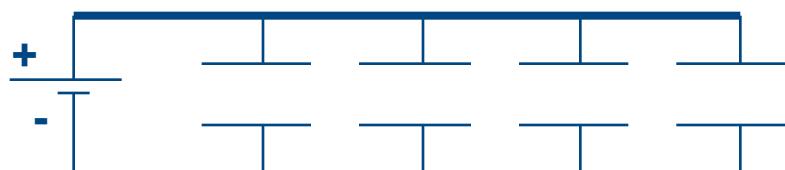
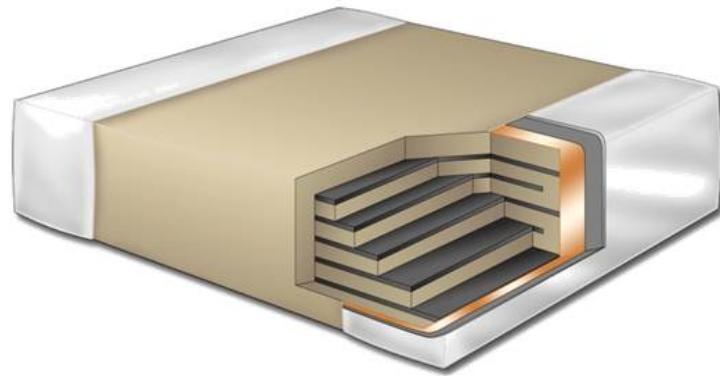
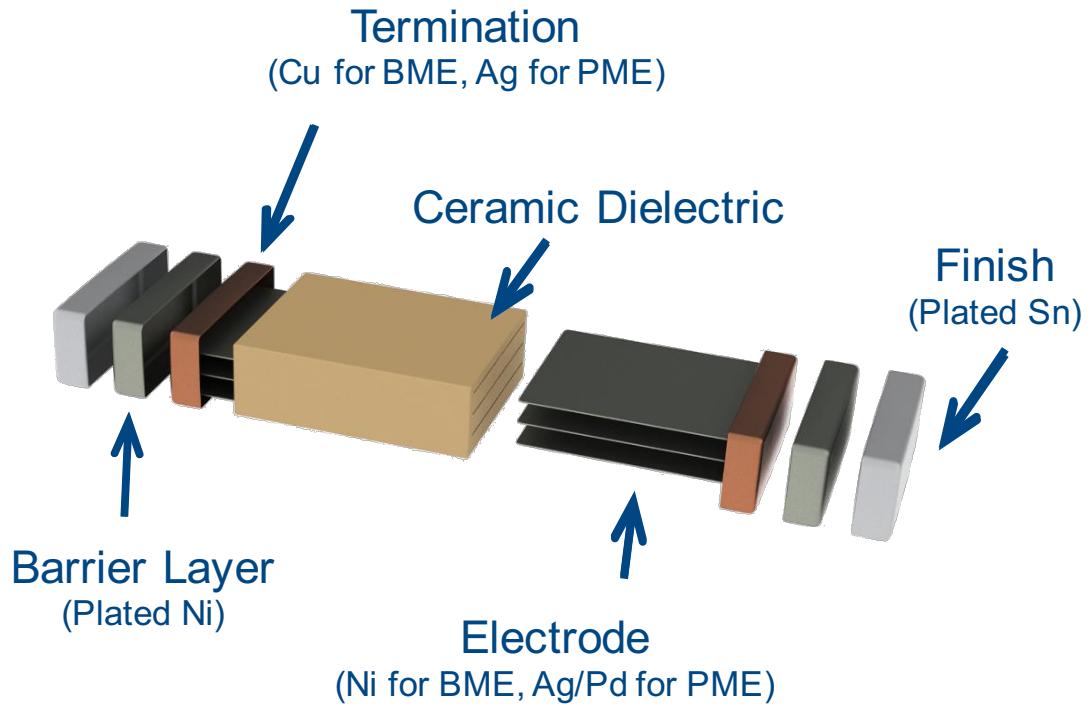


Ceramics

Multilayer Ceramic Capacitor (MLCC)

Typical Construction

Electronic Components
KEMET
CHARGED.



Capacitances in parallel are additive

$$C_T = C_1 + C_2 + C_3 + \dots + C_n$$

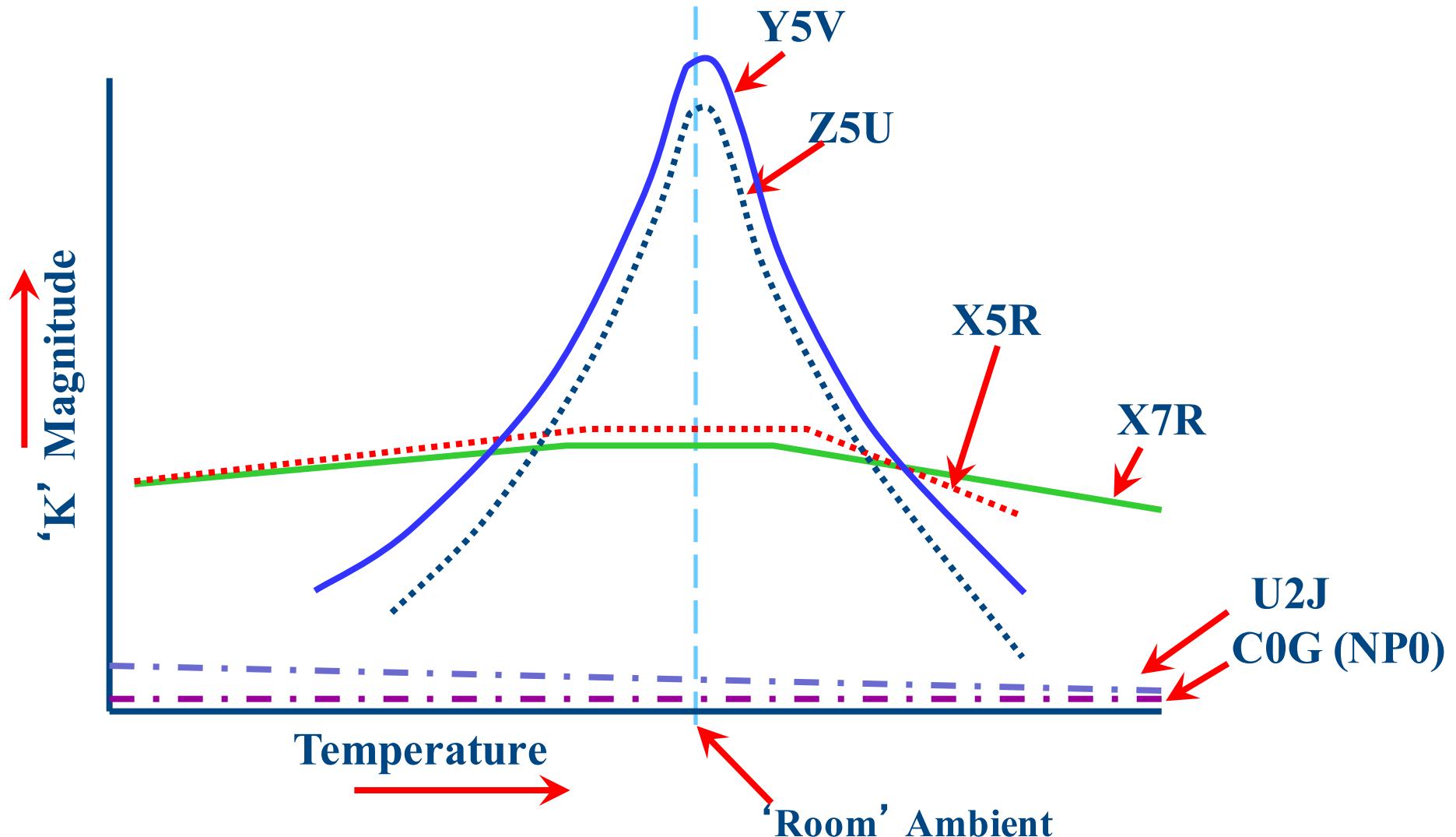
$$C = \frac{\epsilon_0 K A (n-1)}{d}$$

Max Capacitance is limited by “larger” layers

Relative Capacitance vs. Temperature

Temperature Coefficients

Electronic Components
KEMET
CHARGED.



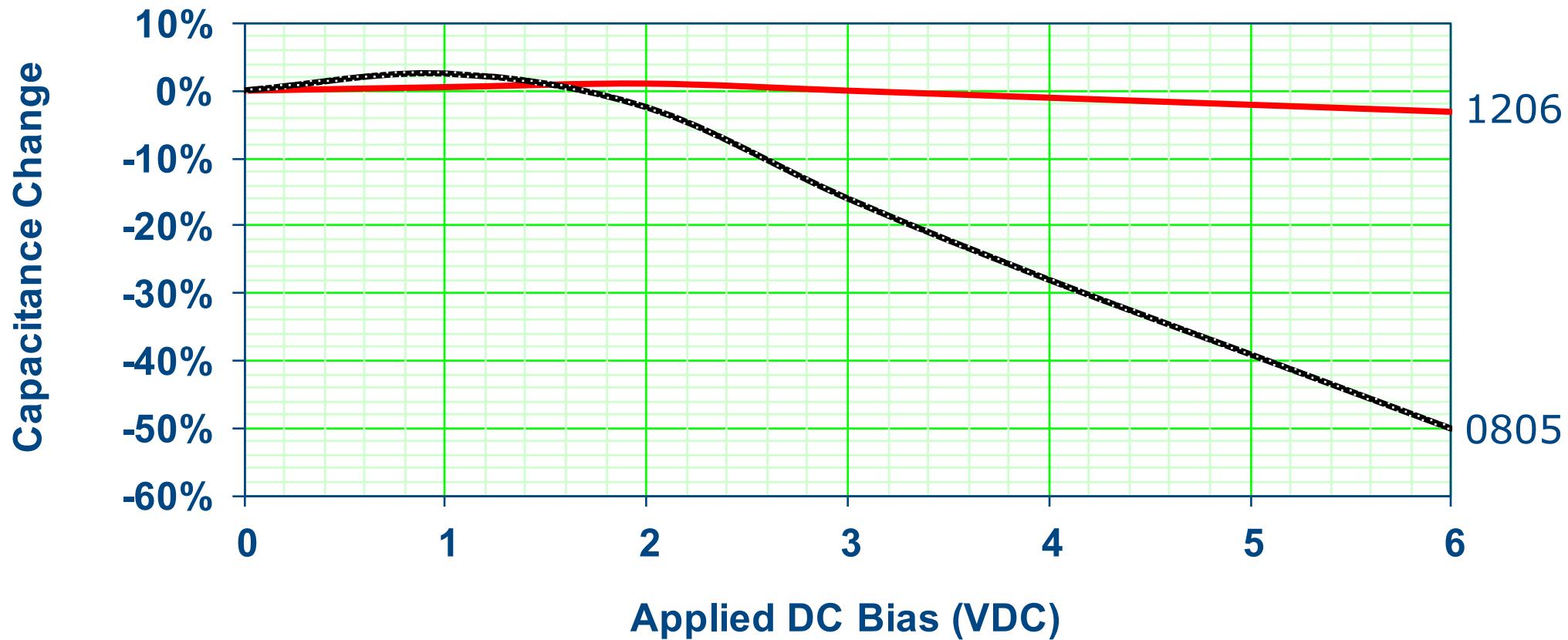
Voltage Coefficient (Class II and III)

1210 vs 0805, X7R, 10uF, 6.3V

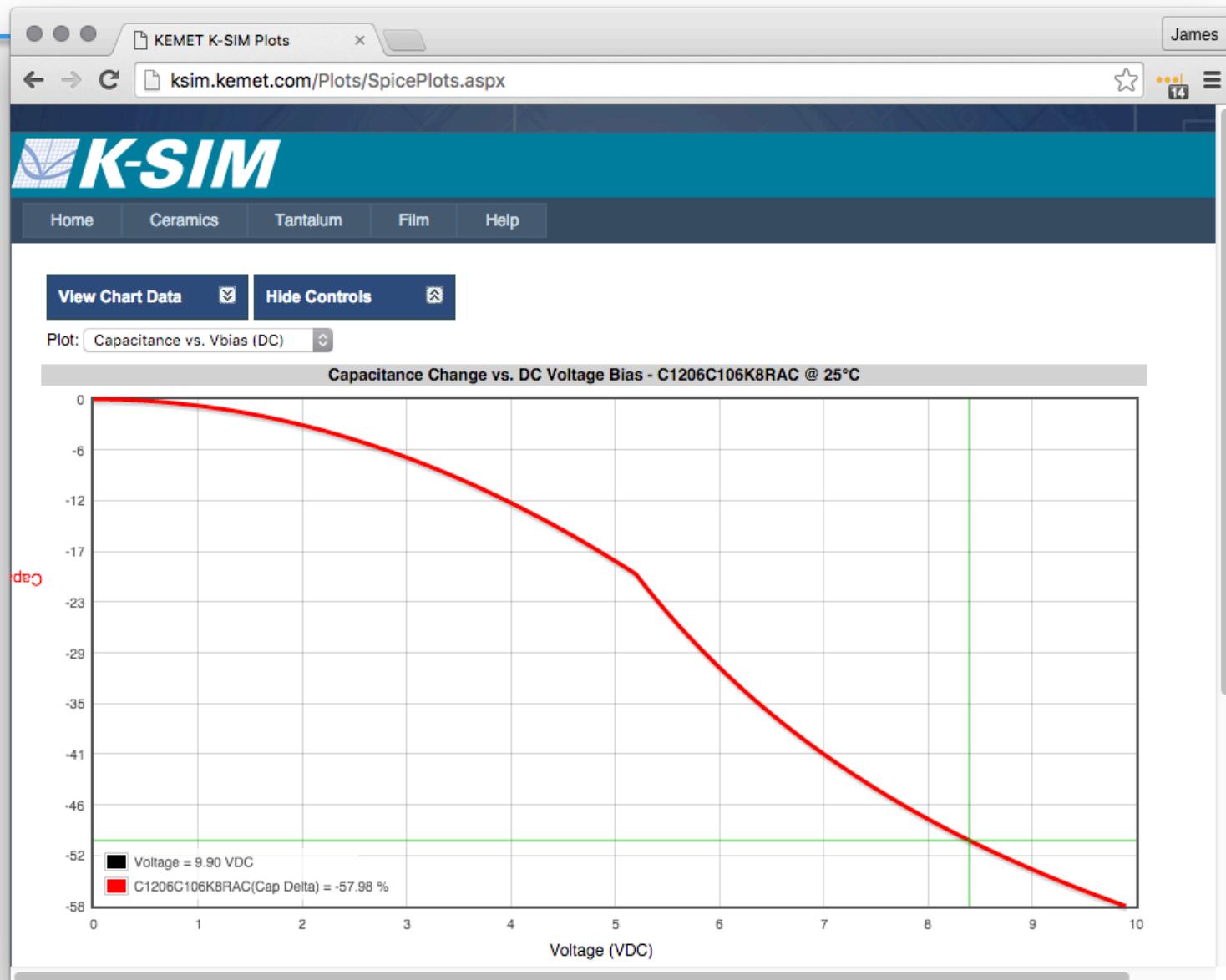
Electronic Components
KEMET
CHARGED.

Capacitance Change vs. DC Bias

Rated 6.3V



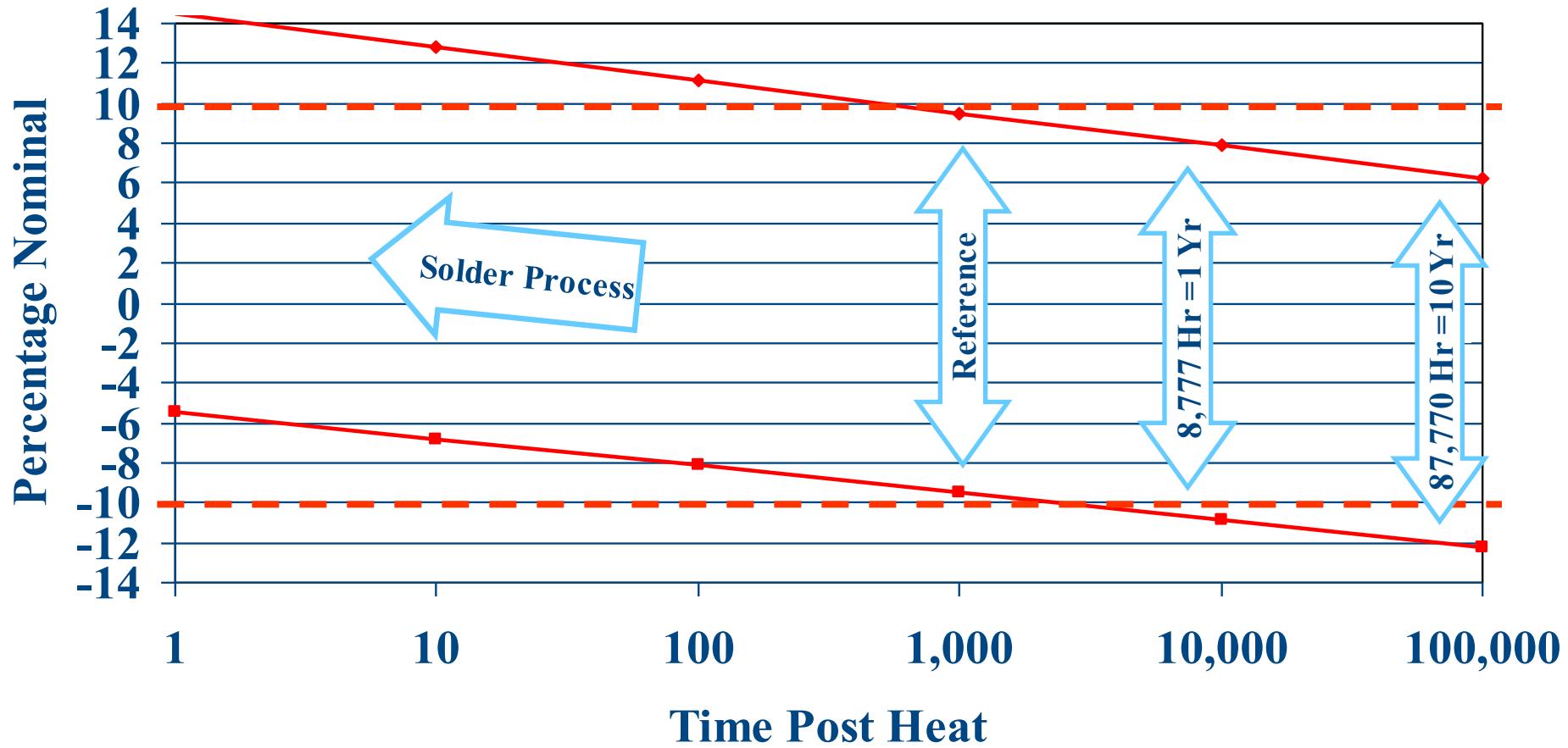
How much capacitance do you really get?



X7R Aging Rate

1.5% per Decade Hour (Limit)

Electronic Components
KEMET
CHARGED.





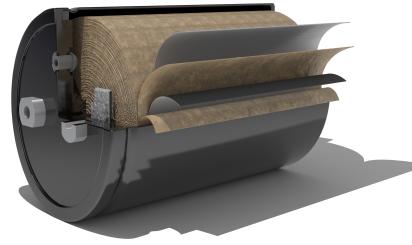
Aluminum Electrolytic

Aluminum Electrolytic Form Factors

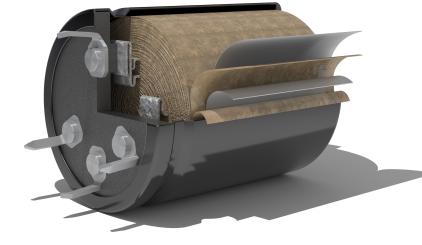
Electronic Components
KEMET
CHARGED.



Axial/Radial



Screw Terminal



Snap-In



Single Ended



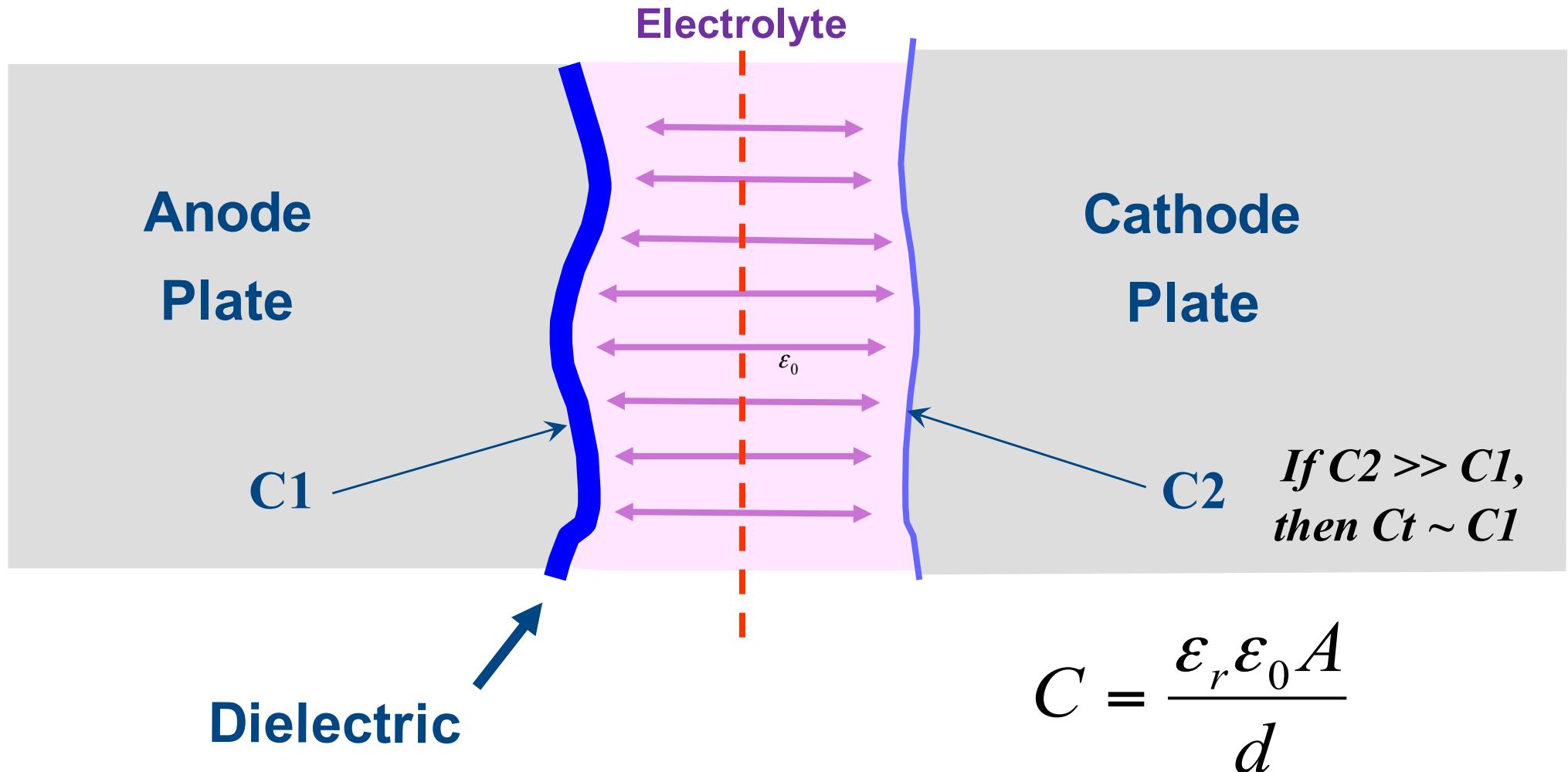
SMD



Motor Start

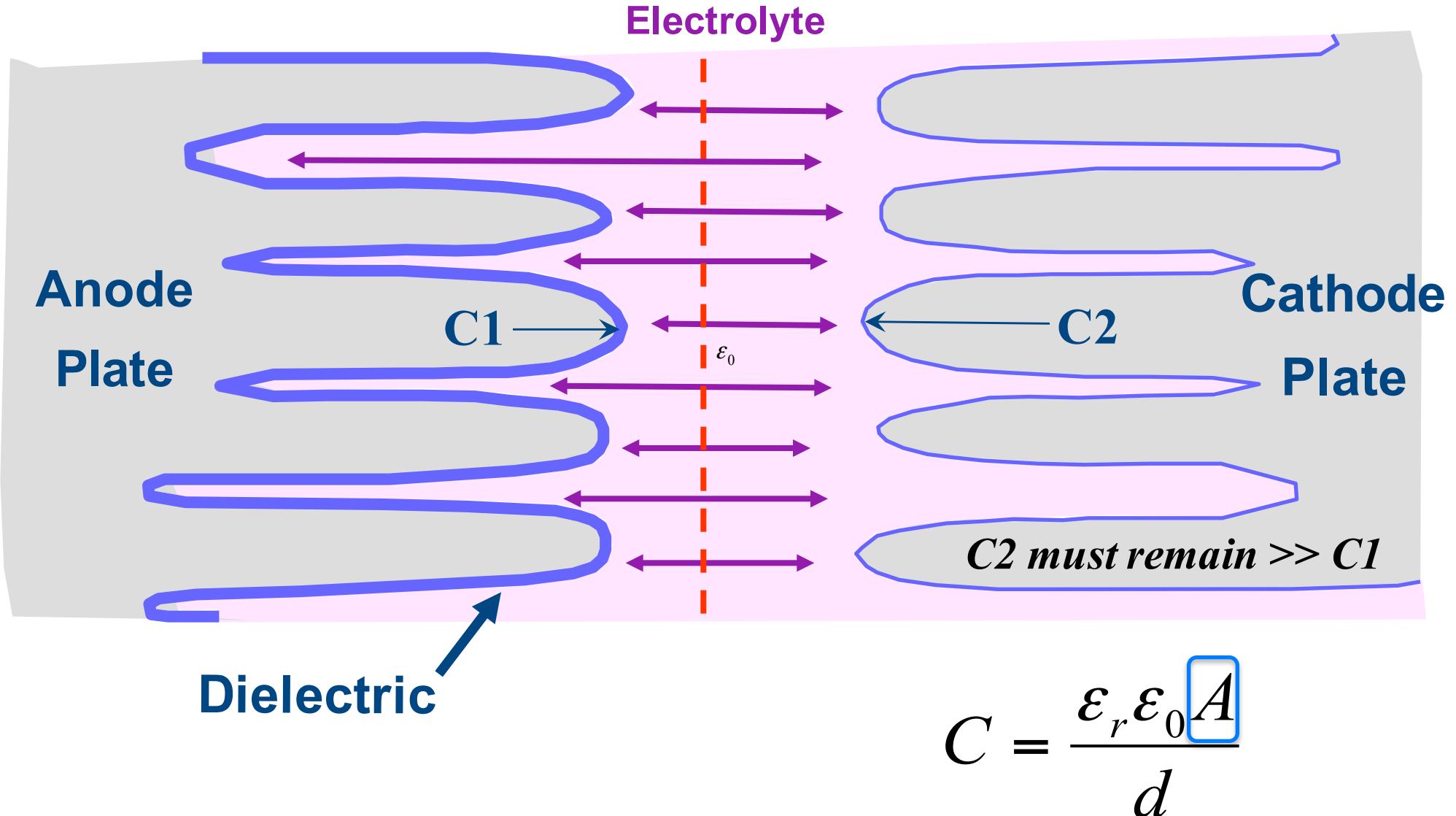
Same construction different form factors

Aluminum Untreated Surface Area



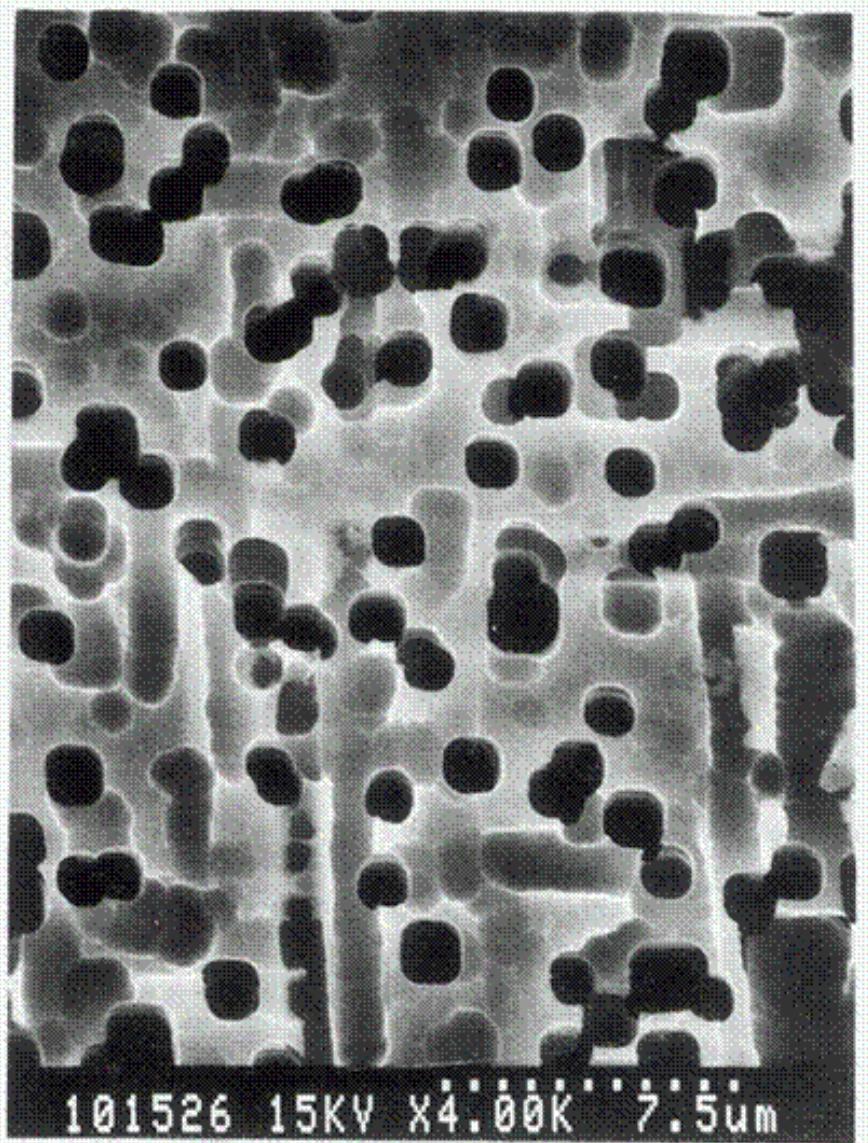
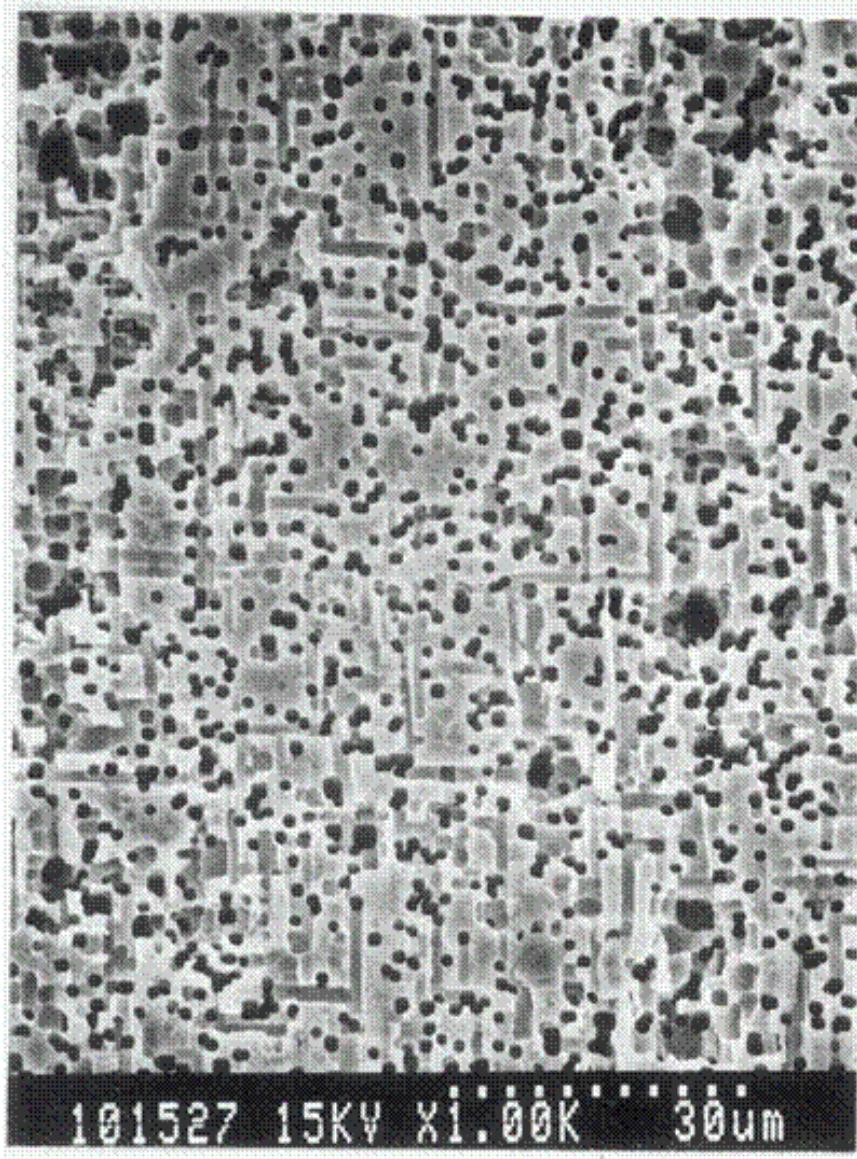
$$\epsilon_r(Al_2O_3) = 9$$

Aluminum Acid-Etched Surface Area



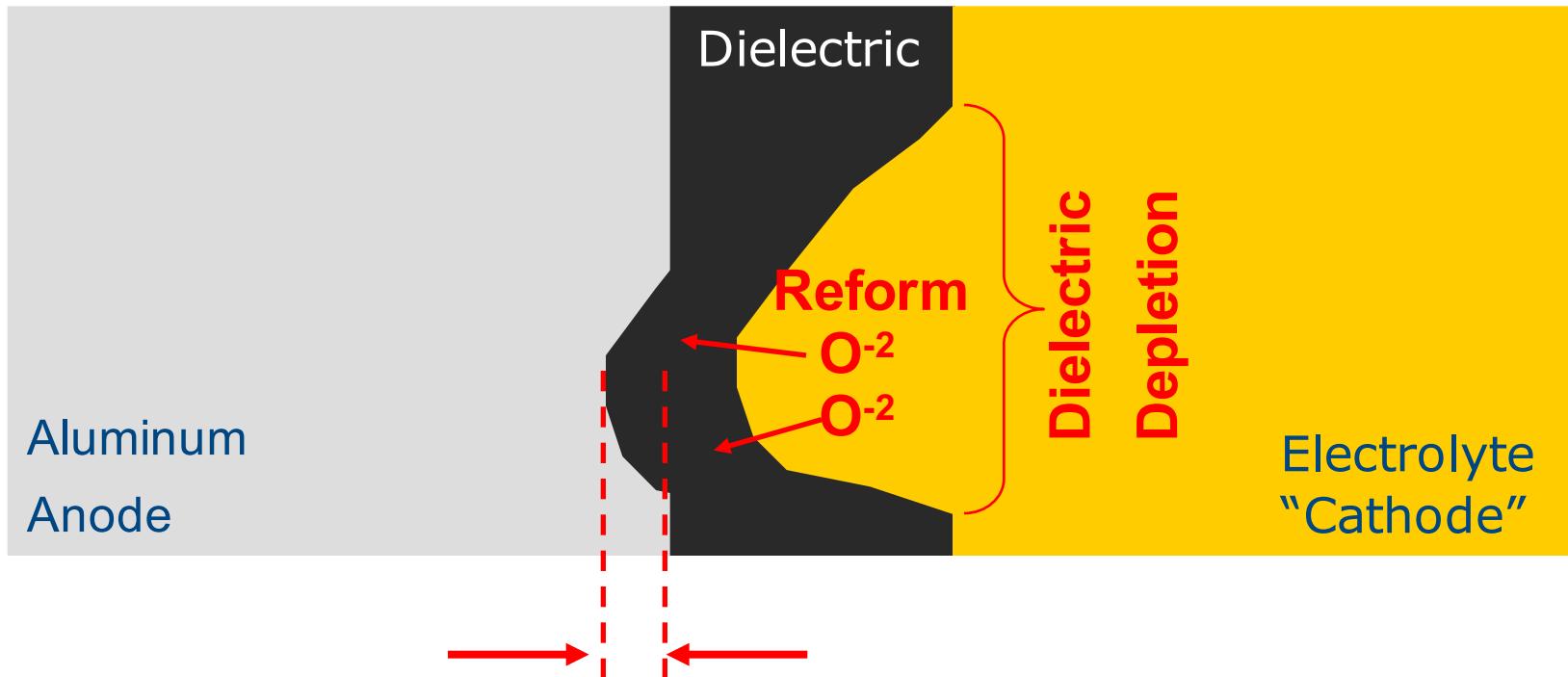
Anode Foil *Etched Surface*

Electronic Components
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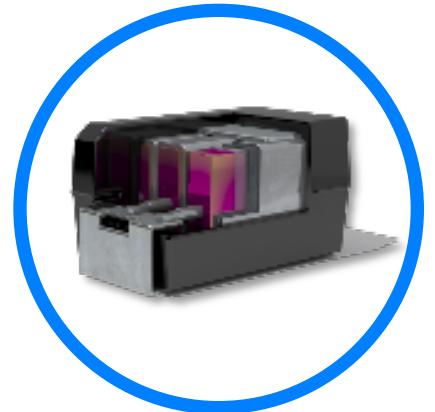
Reforming / Self-Healing Wet Aluminum

$$V_{\text{Formation}} > V_{\text{Rating}} > V_{\text{application}}$$



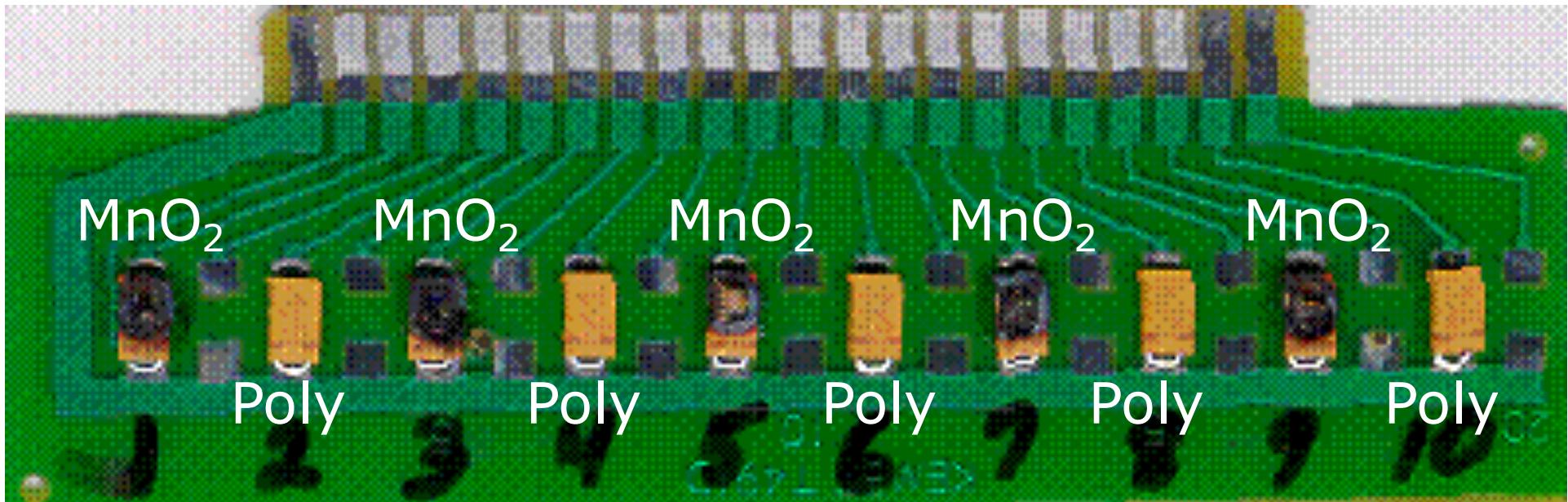
Reformed dielectric region

Voltage contributes to operational lifetime



Tantalum

All Tantalums explode... or do they?



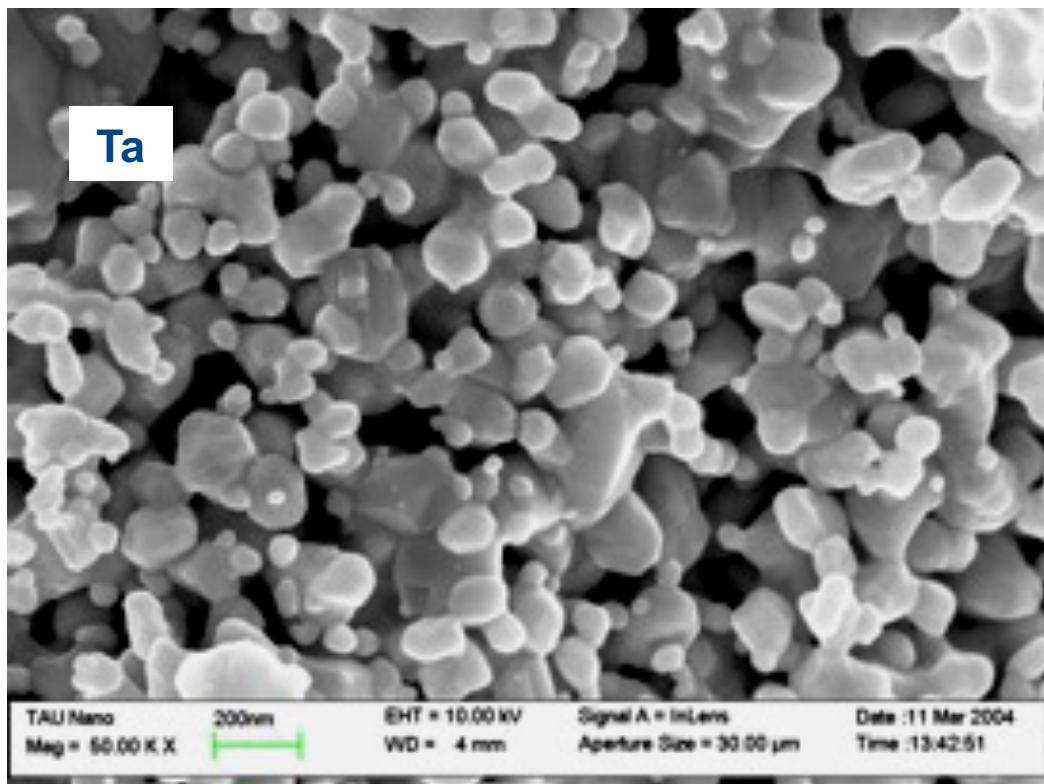
2x Rated Voltage,
applied with **reverse polarity** and
>20 amps of current.

Every capacitor on this board failed as “short”

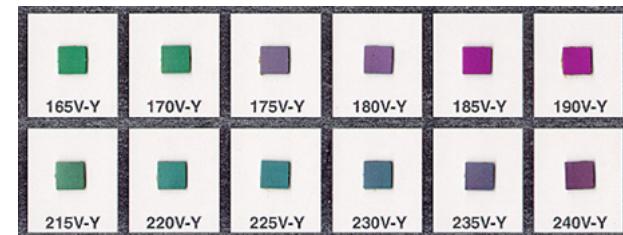
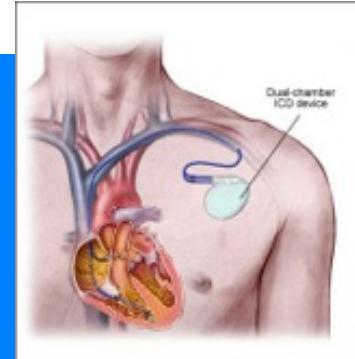
Why use Tantalum?

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

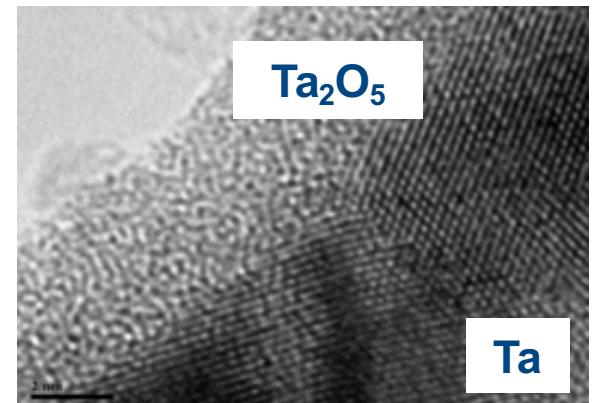
SEM of a Sintered Ta Anode

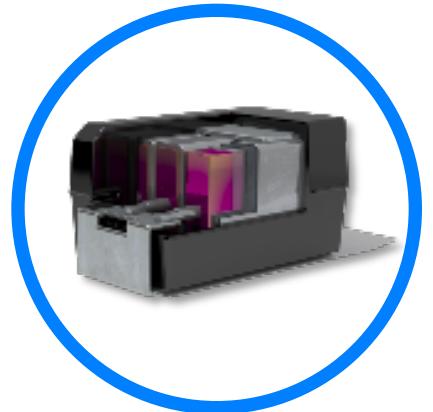


Military
Space
Medical
Automotive
Computers
Telecom



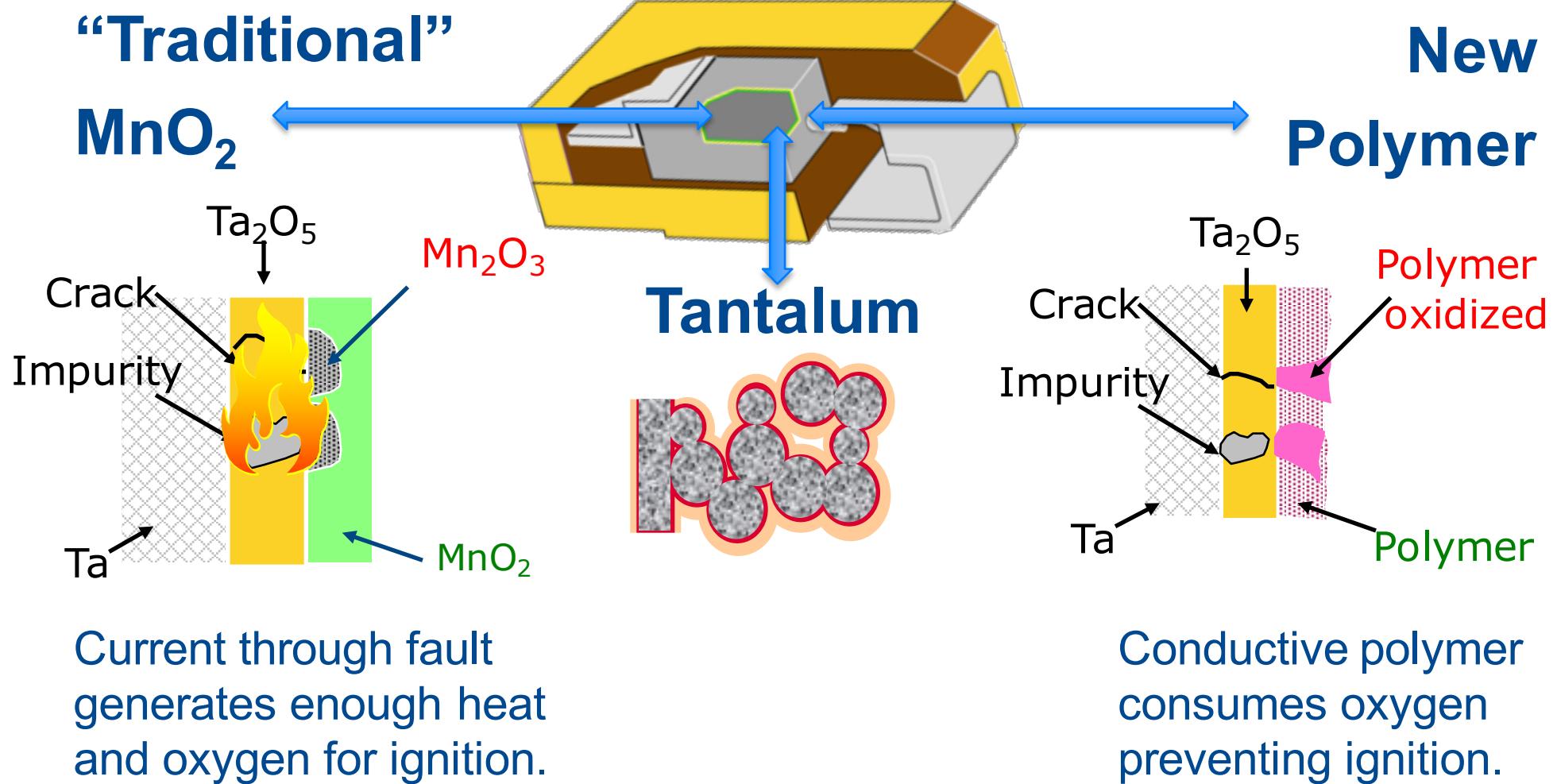
Ta Oxide Dielectric





Polymer Electrolytic: A “new” kind of capacitor

Difference in Self-Healing



If a polymer fails, it fails safely.

Tantalum Voltage Derating

Depend on cathode material

Electronic Components
KEMET
CHARGED.

	Ta-MnO ₂	Ta-Poly KO $V_R > 10\text{VDC}$	Ta-Poly KO $V_R \leq 10\text{VDC}$	Alum-Poly AO
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

- Typical derating guidelines:
 - Tantalum MnO₂: 50%
 - Tantalum Polymer: 20%(>10V), 10% (<=10V)
 - Aluminum Polymer: 0%



Supercapacitors

What Is A “Super” Capacitor?

APowerCap

EVerCAP

Super capacitor

BestCap

DynaCap

SuperCap

Electrostatic Double-Layer Capacitor (EDLC)

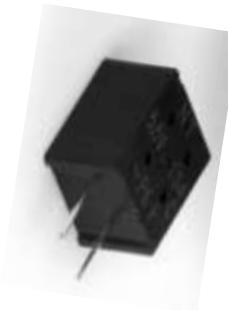
DLCAP



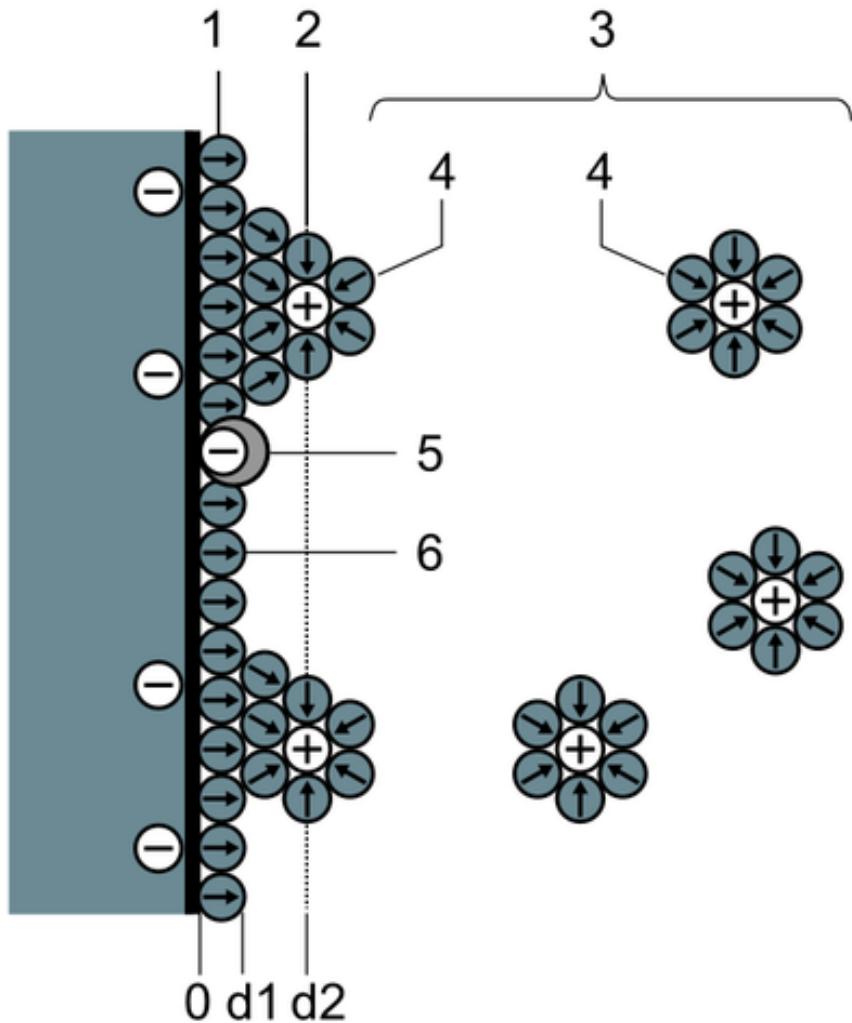
PseudoCap

EneCapTen

Ultracapacitor



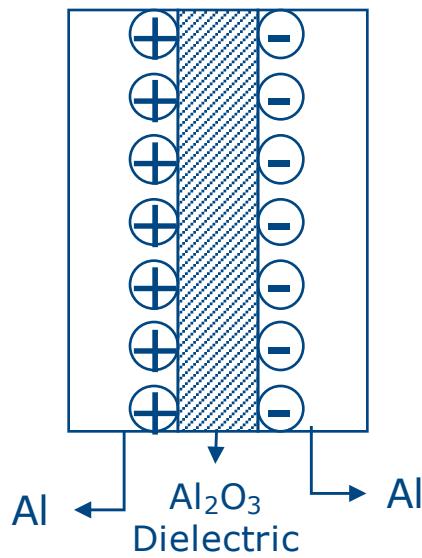
(Electrical) Double Layers



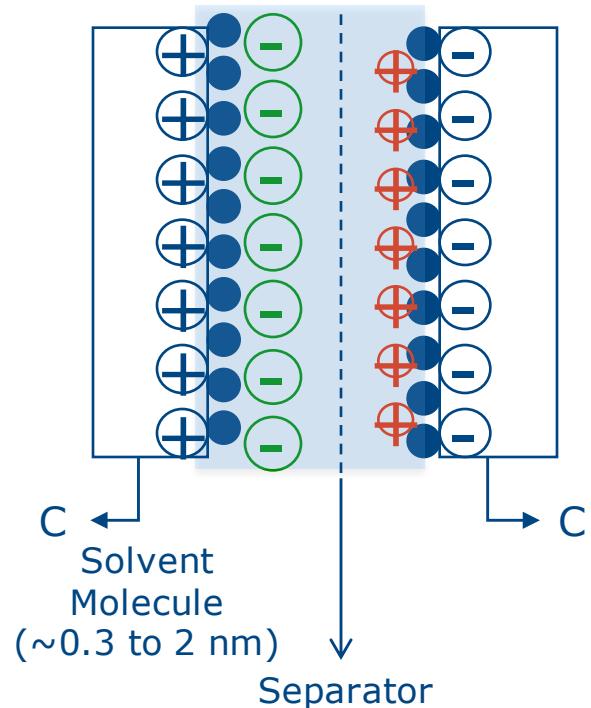
1. IHP Inner Helmholtz Layer
2. OHP Outer Helmholtz Layer
3. Diffuse layer
4. Solvated ions
5. Specifically adsorptive ions
6. Solvent molecule

Traditional and EDLC Comparison

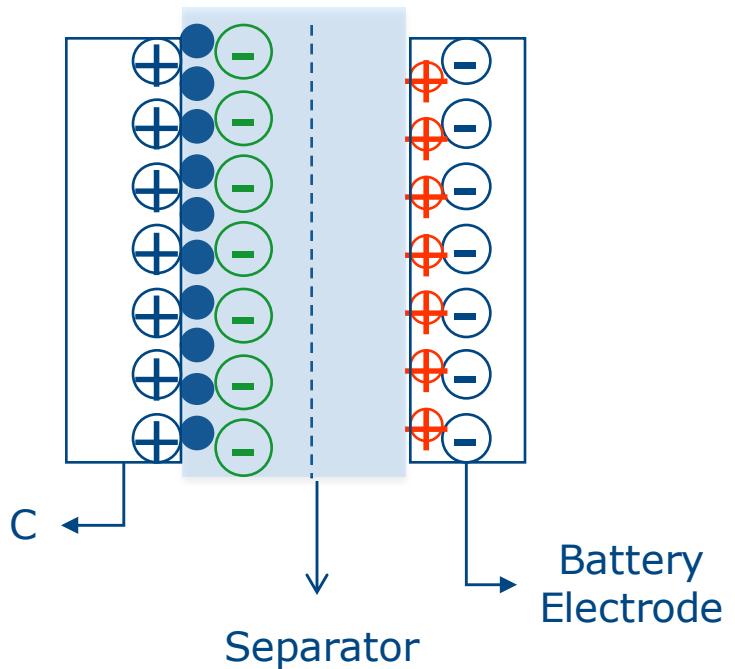
Aluminium Reference



Symmetric "Supercapacitor"



Asymmetric "Hybrid Capacitor"



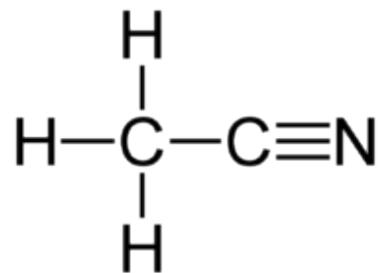
$$C = \frac{Q}{V}$$

$$C = \frac{\epsilon_0 K A}{d}$$

← Surface area of carbon
 ← Inner Helmholtz Layer

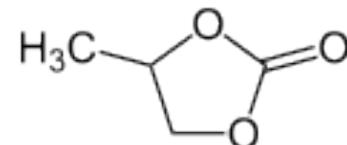
Acetonitrile

- CH₃CN
- Common for SC
- Dielectric constant: 37
- Burns to HCN
- BP: ~80°C



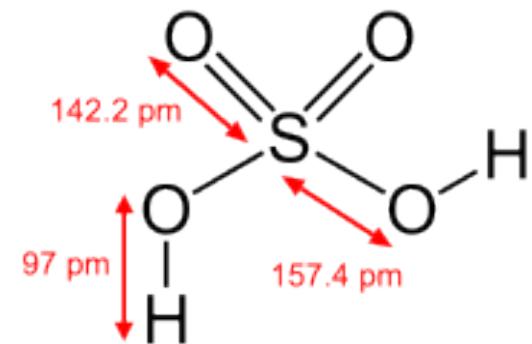
Propylene Carbonate (PC)

- C₄H₆O₃
- Dielectric constant: 64
- Destructive effect on graphite
- BP: ~240°C



Sulfuric Acid

- H₂SO₄
- Used in lead-acid batteries
- Dielectric constant: ~100
- BP: 337°C





Tools

Mobile Catalog Apps



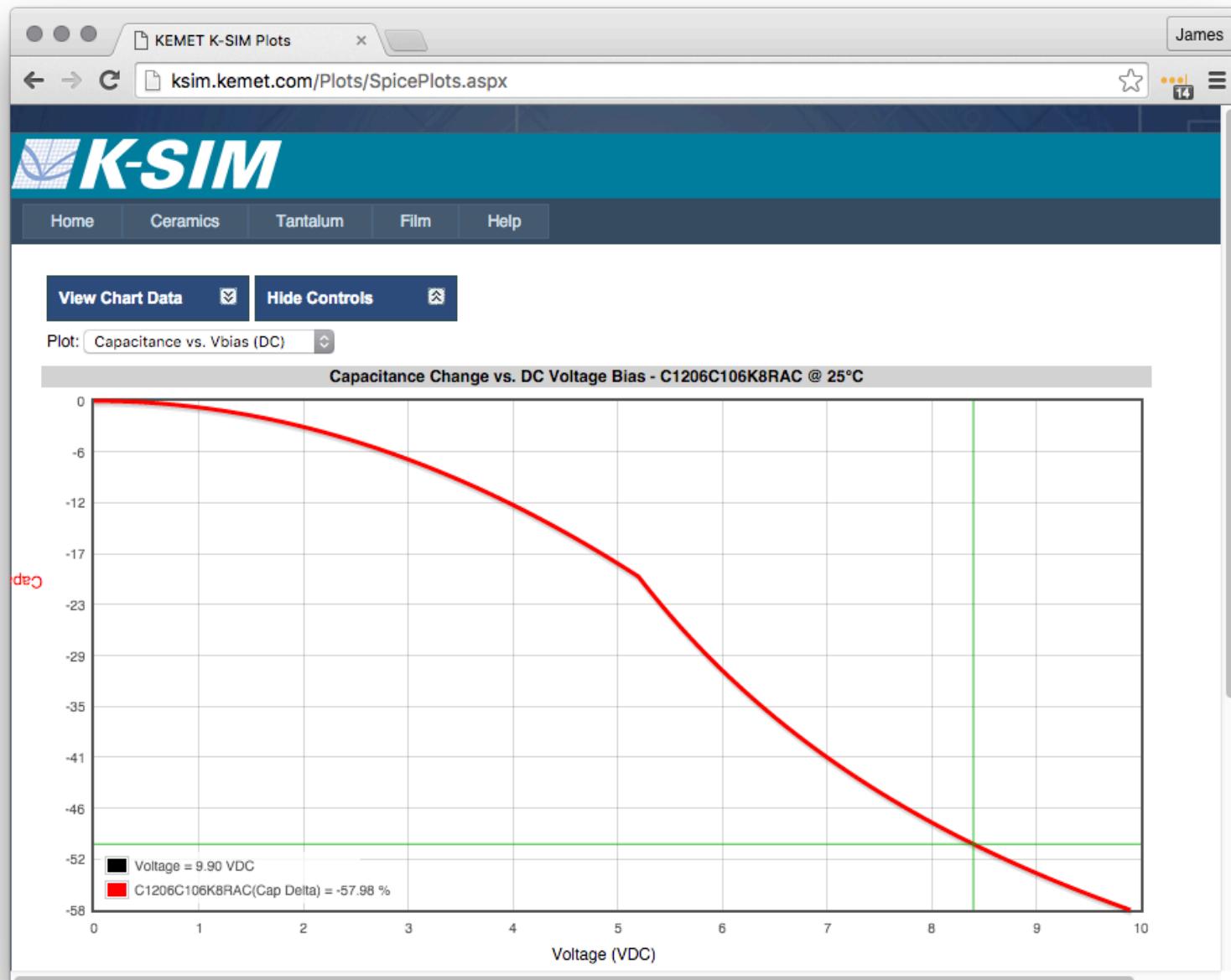
Access to over 350 catalogs and 4.8MM data sheets



Available on the
App Store



www.kemet.com/mobileapps





E2Di EASY TO
DESIGN IN



A screenshot of a web browser displaying a blog post. The header features a video thumbnail of a man working on a CNC machine, with the text "Electronics Stuff for Enginerrs". Below the video, the date "WEDNESDAY, FEBRUARY 17, 2016" is shown, followed by the title "MQTT Introduction and Tutorial Part One" and a subtitle "Message Brokers and why your IoT device should use them.". The author is listed as "by James Lewis". Below the text is a social sharing bar with icons for Comment, Facebook, Twitter, LinkedIn, Pinterest, and Google+. At the bottom is a diagram illustrating MQTT connectivity between various IoT devices like a Raspberry Pi, Python, and MQTT Broker. A blue button at the bottom says "Send James A Question (Offline)". The URL "https://www.baldengineer.com/mqtt-introduction.html" is visible at the bottom of the page.



A screenshot of a web browser displaying a video page. The header shows a video thumbnail of a hand pointing to a MOSFET component with labels for Drain, Gate, Source, and Body. The text "#11 MOSFETs" is displayed above the component. The video title "Video" is shown above the thumbnail. Below the video, the section title "Description – Transistors Part 2" is displayed. A paragraph of text explains that MOSFETs are common switches used with Arduino, BeagleBone, or Raspberry Pi. It notes that this is part 2 of a 2-part series on transistors, with part 1 covering BJTs. It also mentions that MOSFETs are complex devices. At the bottom, there is a call to action: "Don't forget to subscribe to the AddOhms YouTube channel or to our Email Newsletter to know when more". The URL "https://addohms.com/ep11" is visible at the top of the page.

Capacitors should be voltage derated 50%

True

Or

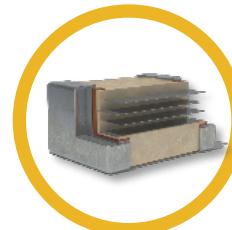
False

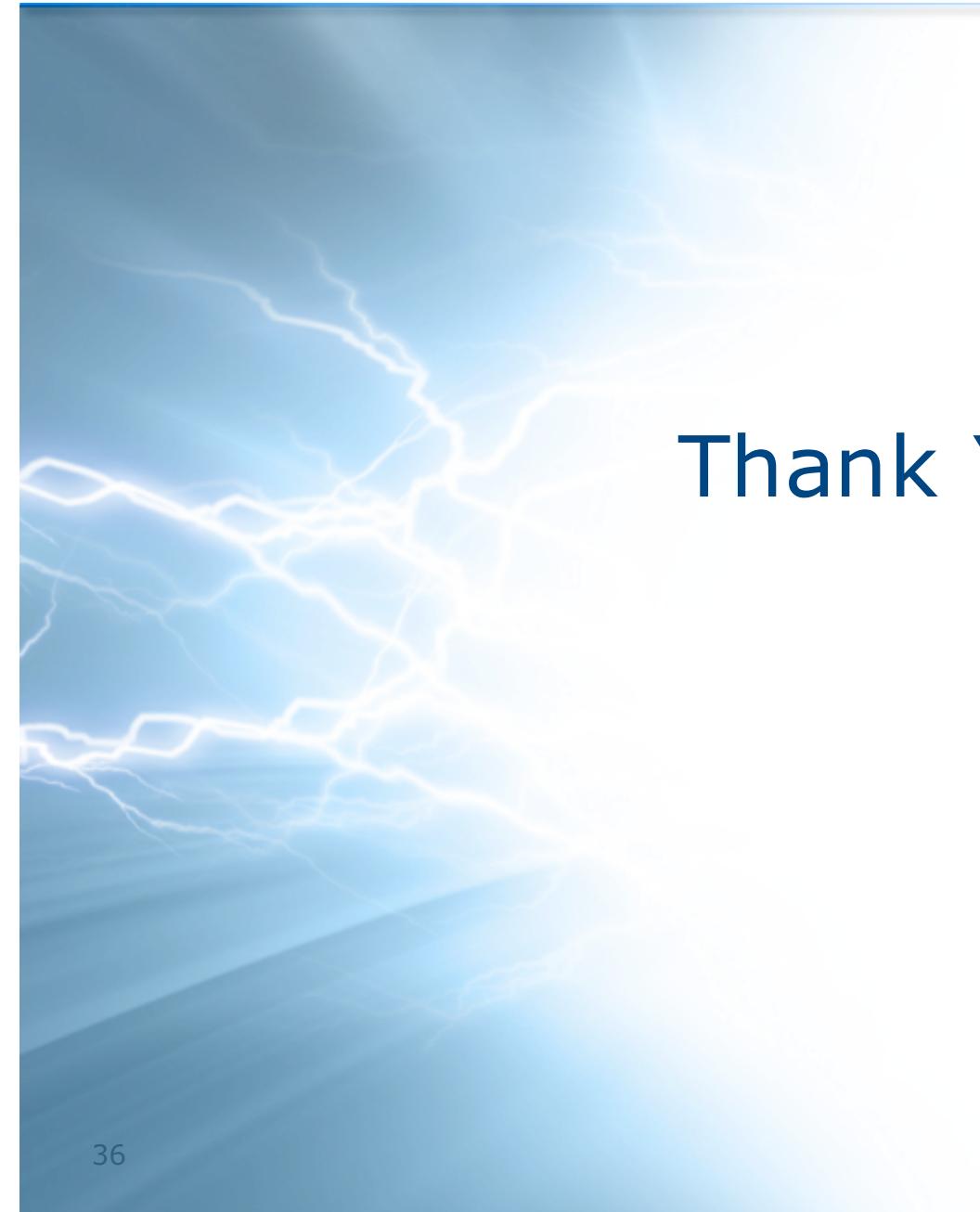
It Depends...

Summary

Why do you voltage de-rate a capacitor?

- Ceramic
 - More capacitance
- Aluminum Electrolytic
 - Longer operational life
- Tantalum
 - Power-On Reliability
- Supercapacitors
 - Operational Life





A large, stylized lightning bolt graphic is positioned on the left side of the slide, extending from the bottom left towards the center. The bolt is white against a blue gradient background.

Thank You!