A background image featuring a bright blue lightning bolt striking down from the top left towards the center, set against a dark blue sky with lighter blue clouds. The lightning bolt is the most prominent feature, with multiple branches and a bright white core.

Electronic Components  
***KEMET***  
**CHARGED.®**

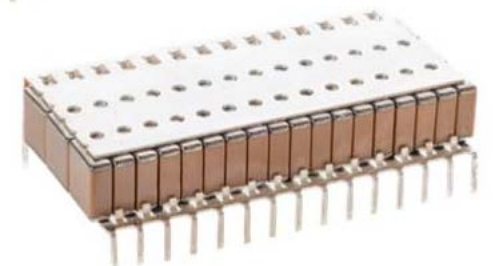
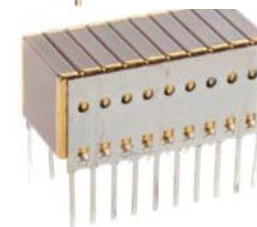
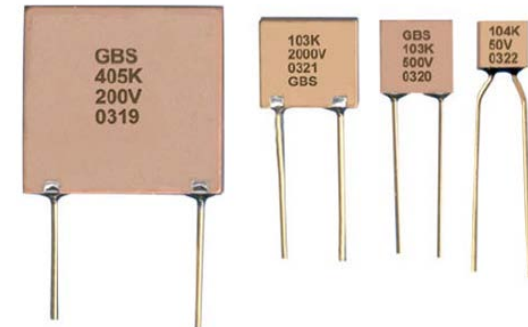
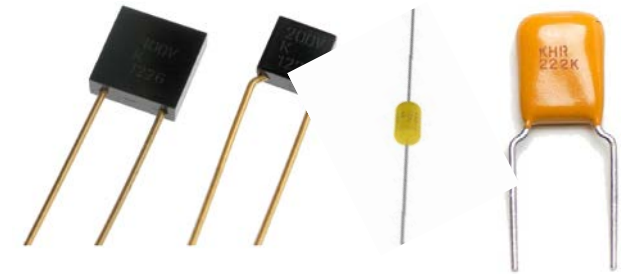
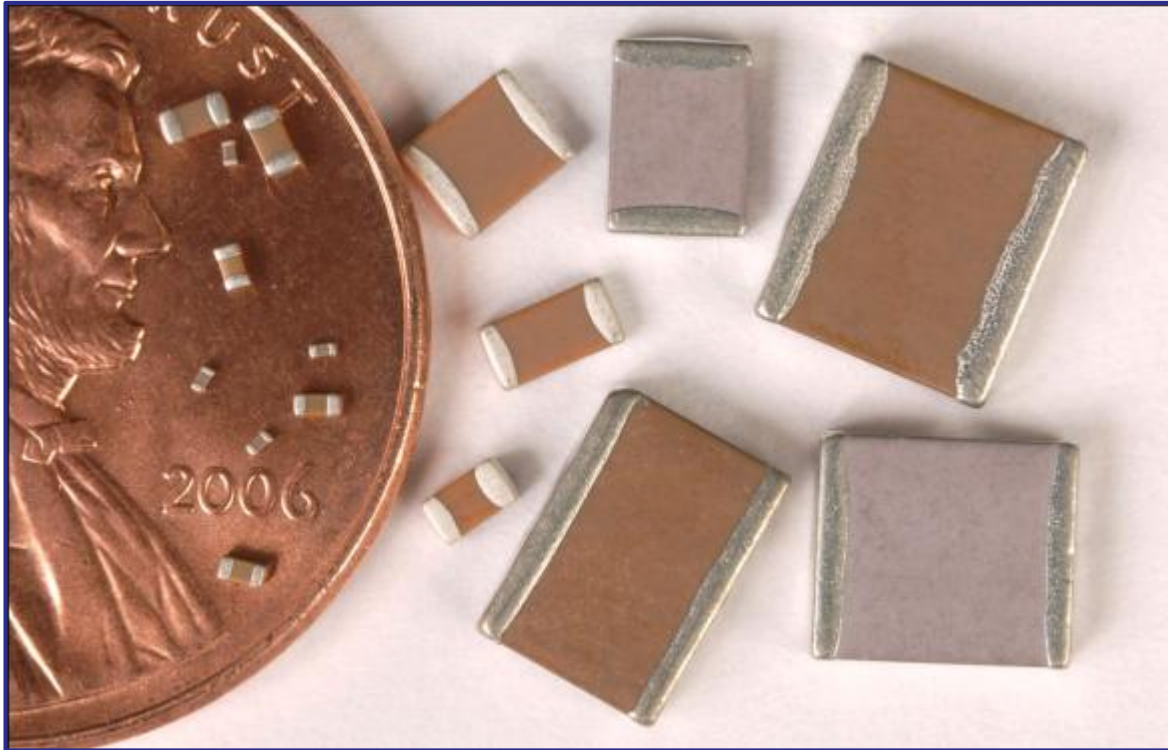
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**Ceramic Capacitors  
(MLCCs)**

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Design and Characteristics

# Ceramic Chip Capacitors



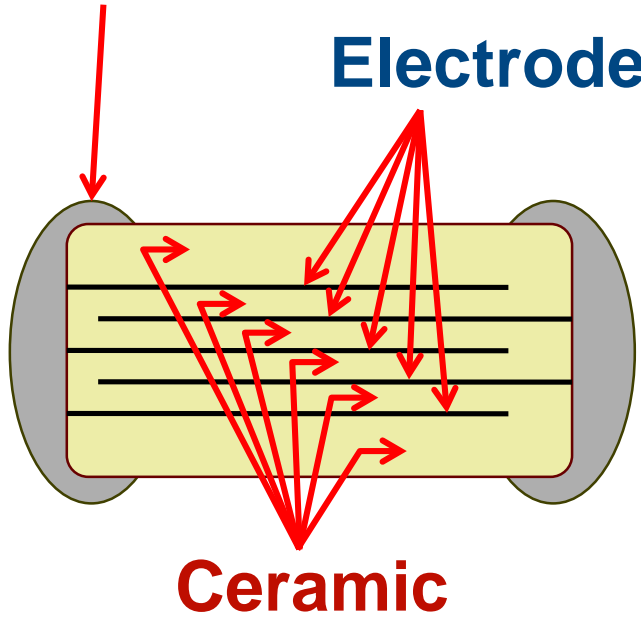


# Design

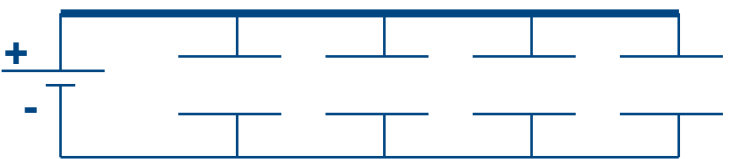
# Ceramic Capacitor Structure

Termination

Electrodes



- C** = Design Capacitance
- K** = Dielectric Constant
- A** = Overlap Area
- d** = Ceramic Thickness
- n** = Number of Electrodes



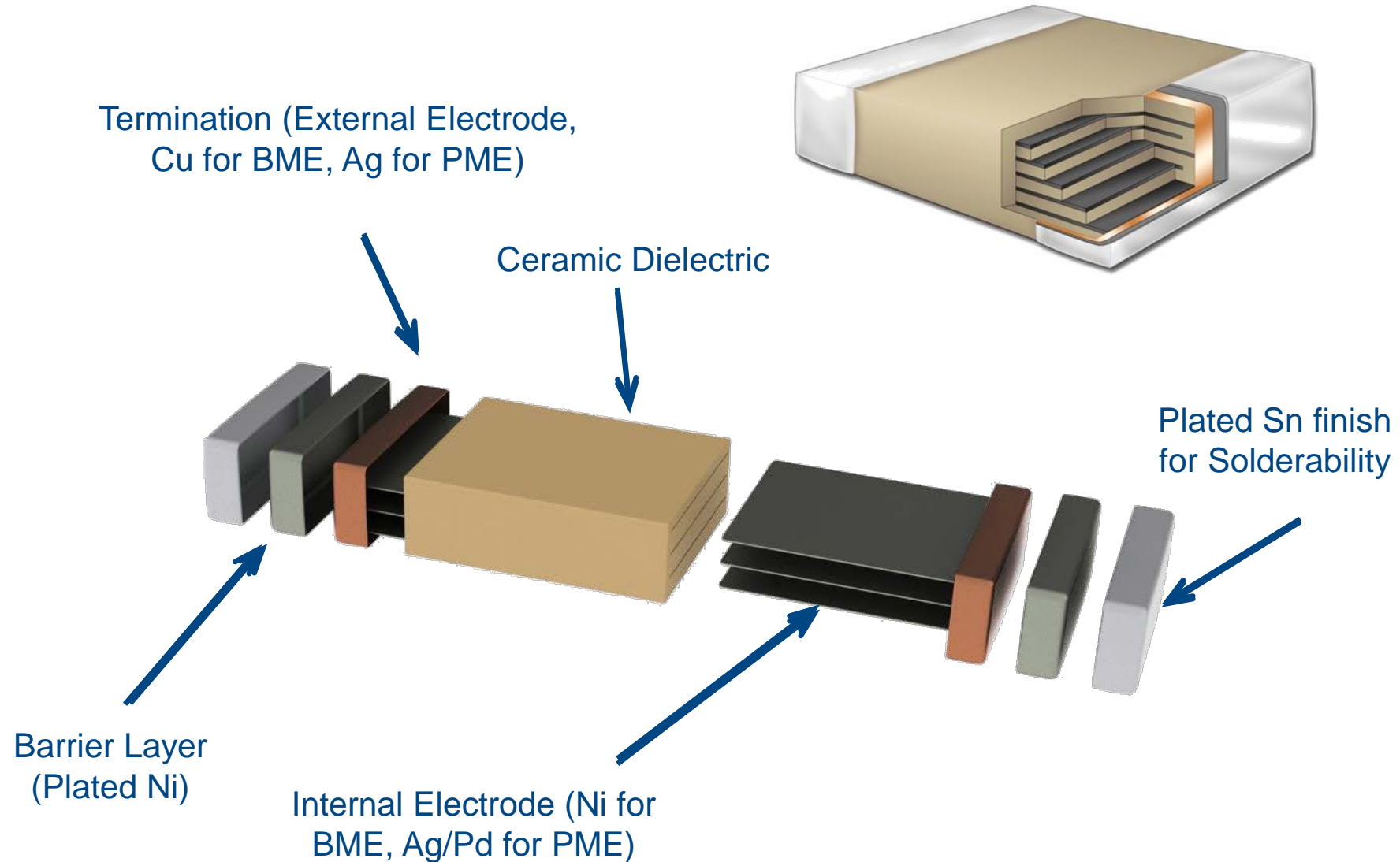
Capacitances in parallel are additive

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

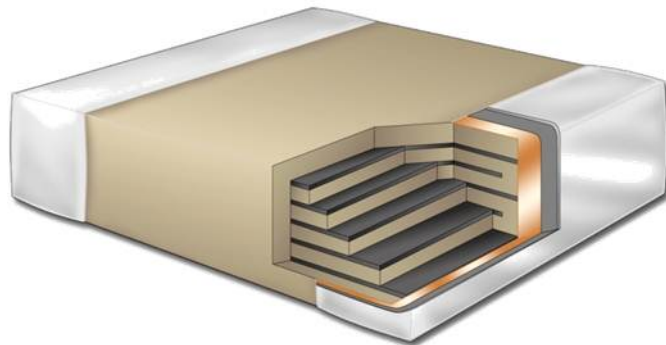
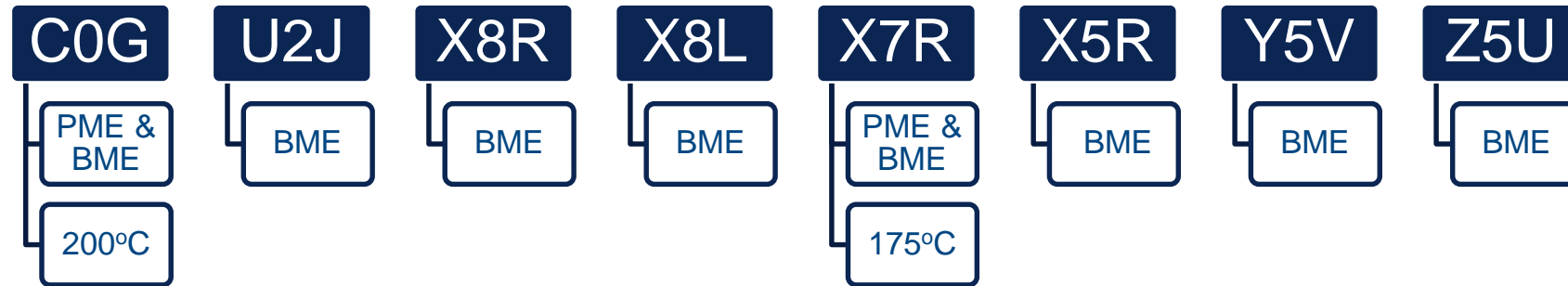
$$C = \frac{\epsilon_0 K A (n-1)}{d}$$

# Multilayer Ceramic Capacitor (MLCC)

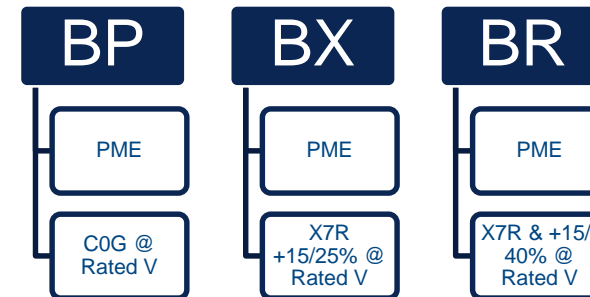
Typical Construction



## Commercial & Automotive Grade Dielectric Materials

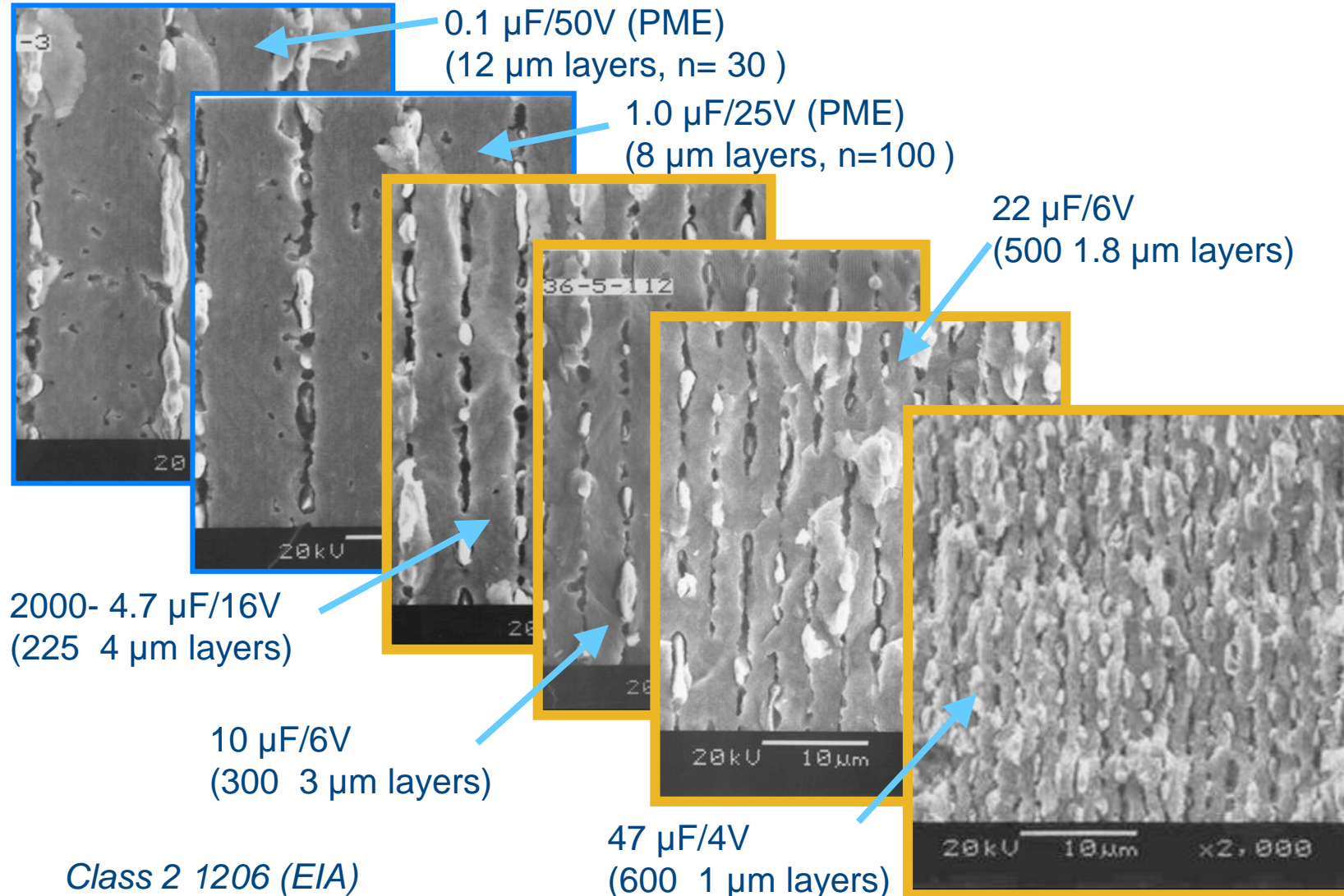


## Military & Hi-Rel Dielectric Materials



# Trend in BME MLCC Technology:

## Dielectric Thickness and Layers Count Progression



1988

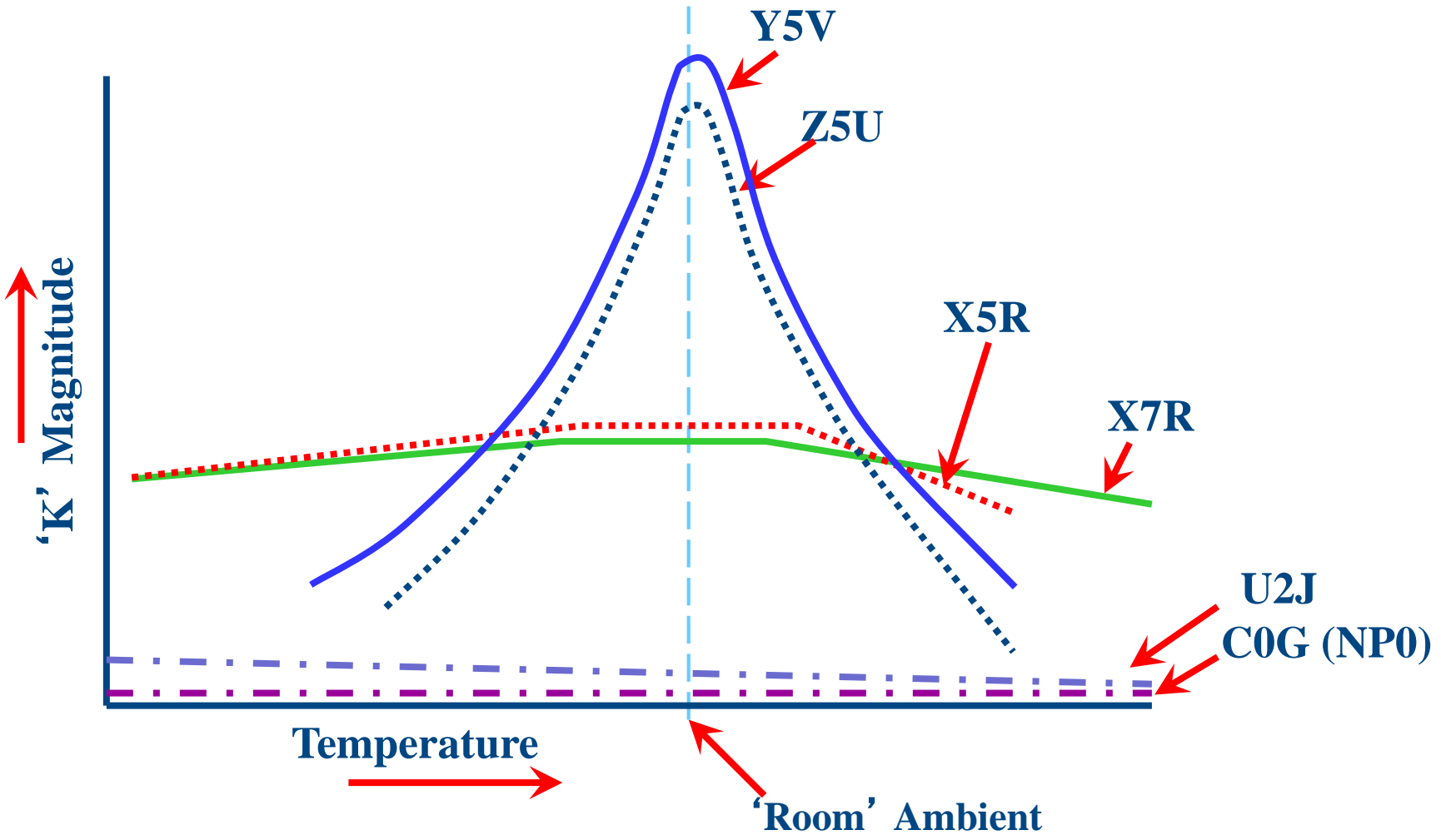
Today

A large, stylized lightning bolt graphic in shades of blue and white, extending from the left side of the slide towards the center. The bolt is composed of multiple jagged, branching lines, creating a sense of energy and power. The background behind the bolt is a gradient of light blue, suggesting a sky or a high-voltage environment.

# Characteristics



# Relative Capacitance vs. Temperature



# Dielectric Classification

Class I (Per EIA – 198)

## Class I Dielectrics: (Example: C0G)

Alpha Symbol	Significant Figure of Temp Coefficient ppm/°C	Numerical Symbol	Multiplier to significant figure	Alpha Symbol	Tolerance of Temp Coefficient ± ppm/°C
C	0	0	-1	G	30
B	0.3	1	-10	H	60
L	0.8	2	-100	J	120
A	0.9	3	-1000	K	250
M	1.0	4	-10000	L	500
P	1.5	5	+1	M	1000
R	2.2	6	+10	N	2500
S	3.3	7	+100		
T	4.7	8	+1000		
U	7.5	9	+10000		

Temperature Range: -55°C to +125°C  
C0G provides highest temperature stability

# Dielectric Classification

Class II and III (per EIA-198)

Alpha Symbol	Low Temperature (°C)	Numerical Symbol	High Temperature (°C)	Alpha Symbol	Max cap change over temp. range (%)
Z	+10	2	+45	A	±1.0
Y	-30	4	+65	B	±1.5
X	-55	5	+85	C	±2.2
		6	+105	D	±3.3
		7	+125	E	±4.7
		8	+150	F	±7.5
		9	+200	P	±10
				R	±15
				S	±22
				* L	+15 to - 40
				T	+22 to - 33
				U	+22 to - 56
				V	+22 to - 82

CLASS II

CLASS III

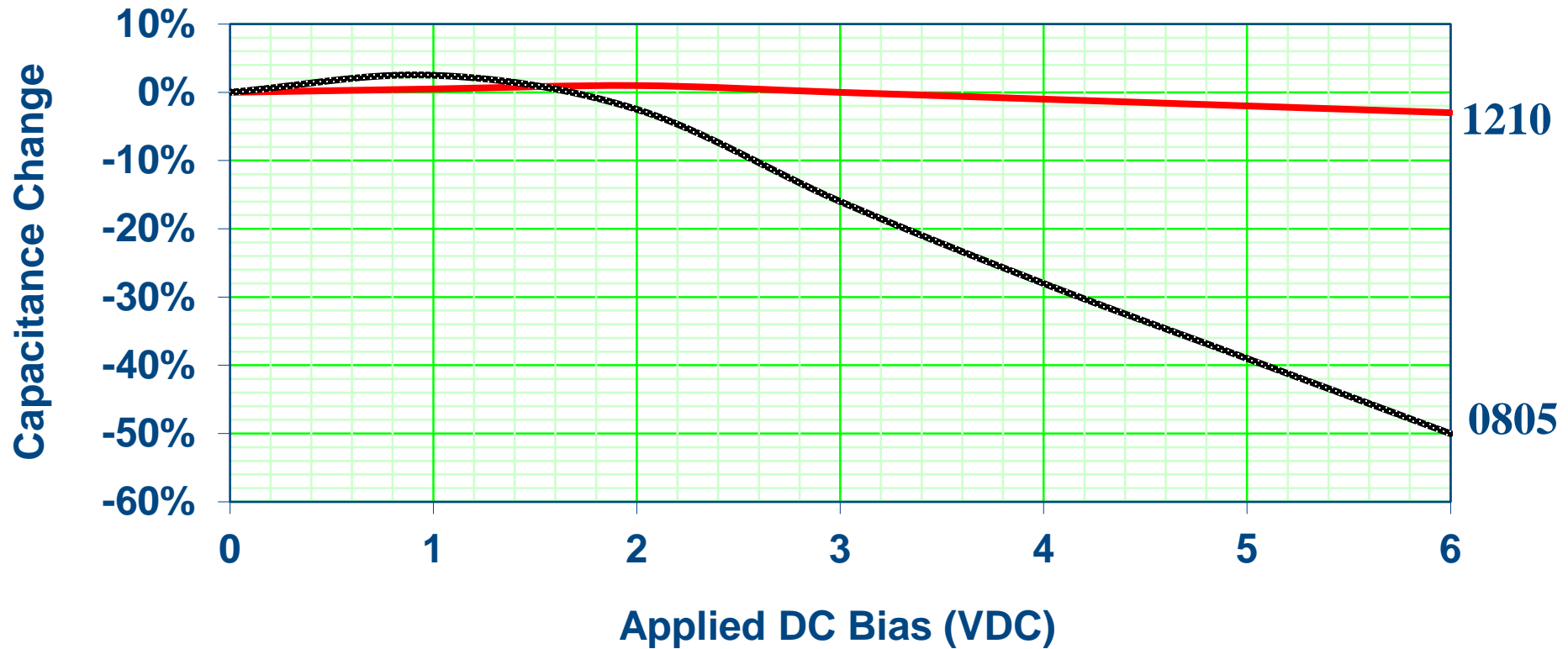
\* Industry Classification (Non EIA-198)

# Voltage Coefficient (Class II and III)

1210 vs 0805, X7R, 10 $\mu$ F, 6.3V

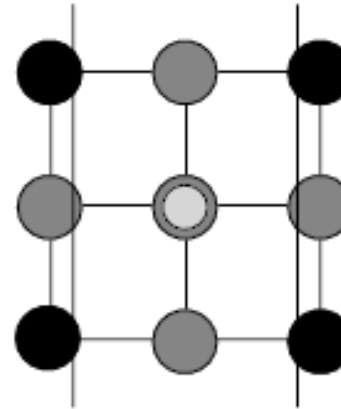
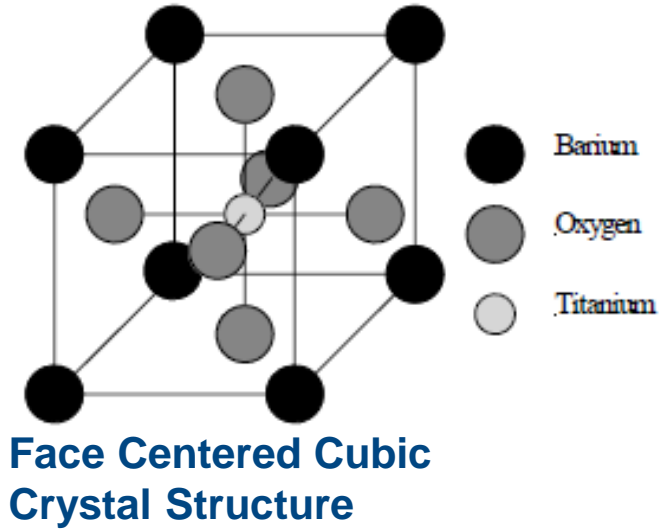
## Capacitance Change vs. DC Bias

Rated 6.3V



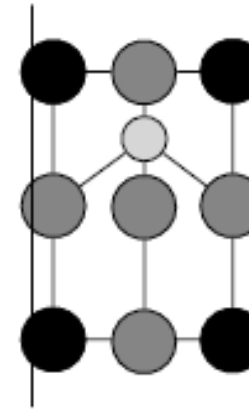
# Voltage Coefficient (Class II and III)

## DC Bias



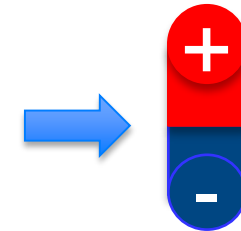
**BaTiO<sub>3</sub> above 130°C**

- Cubic
- No Dipole

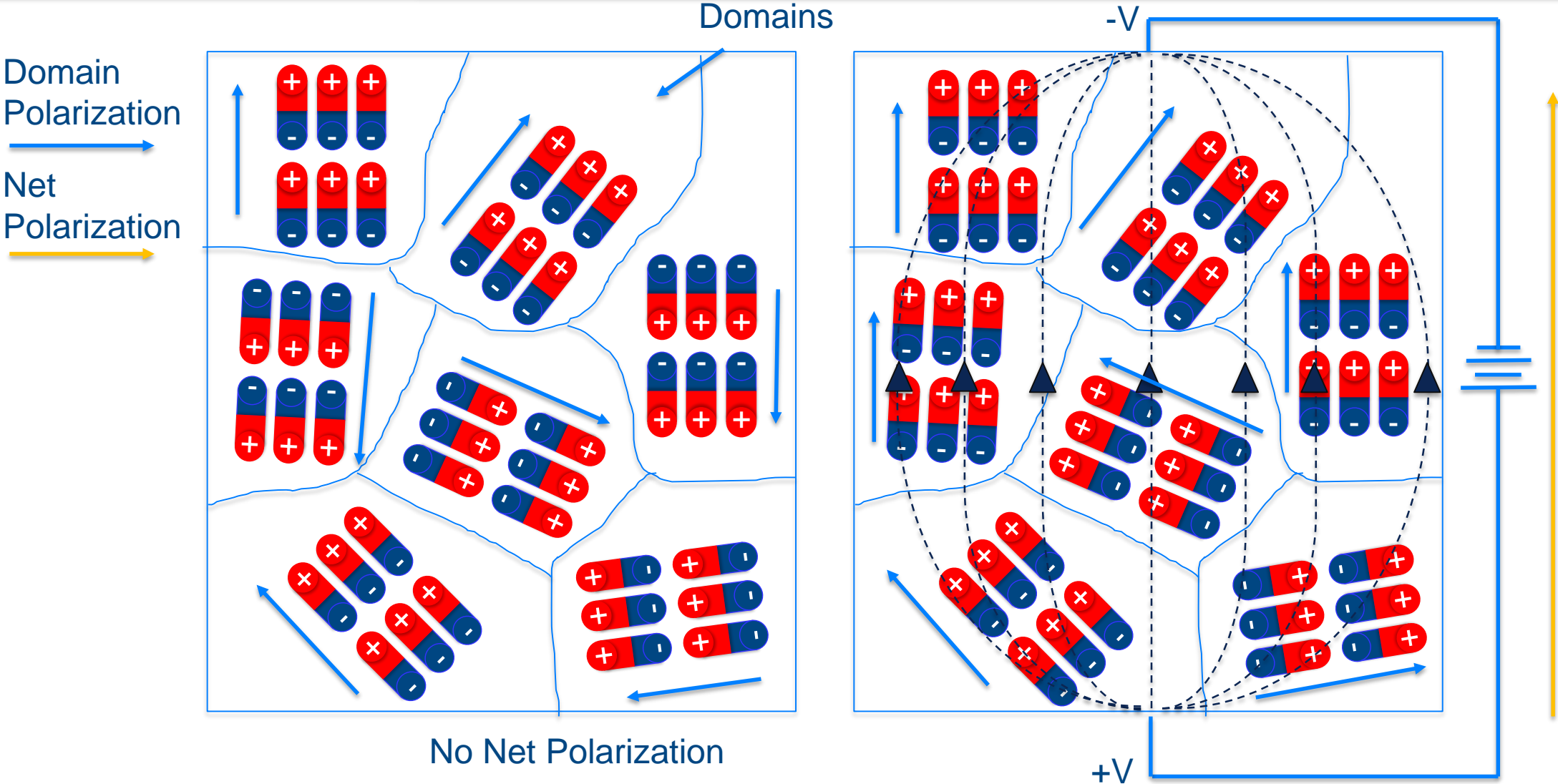


**BaTiO<sub>3</sub> below 130°C**

- Tetragonal
- Creates Dipole

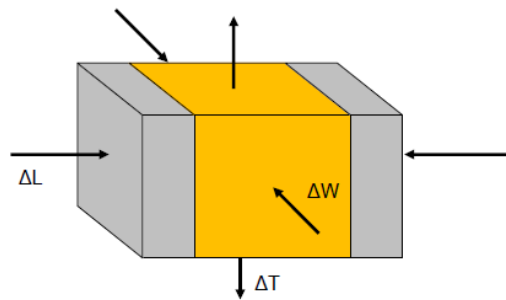
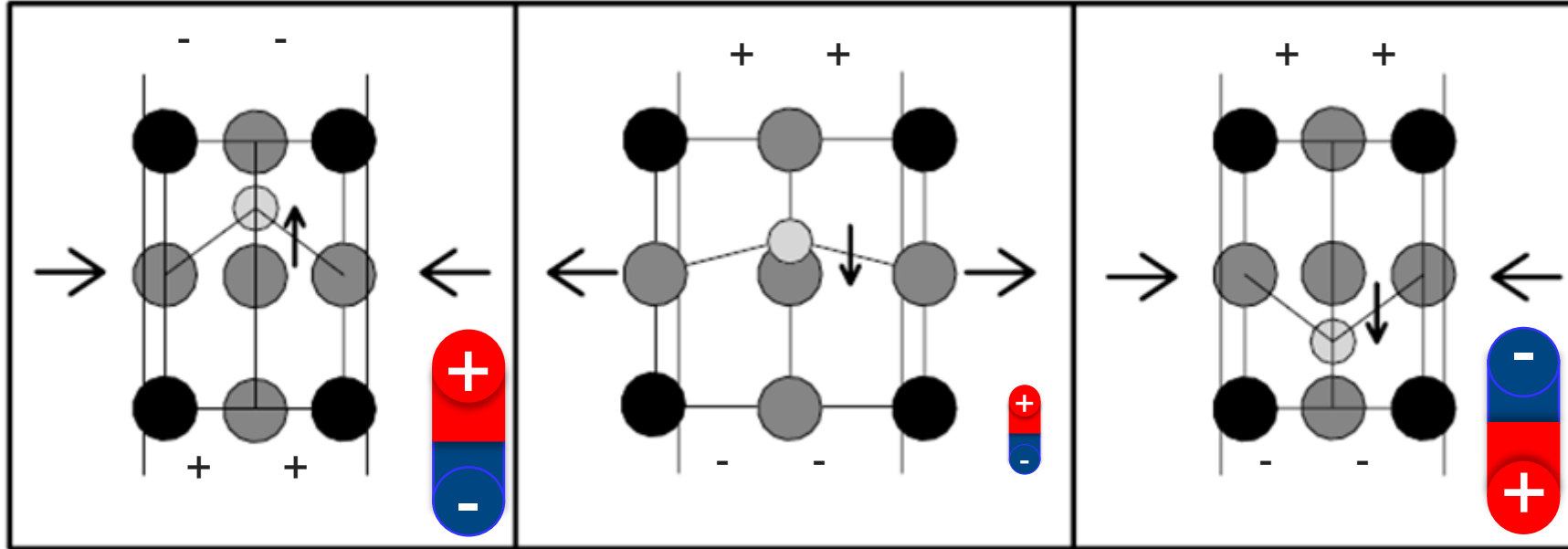


# Voltage Coefficient (Class II and III)



# Voltage Coefficient (Class II and III)

*Piezoelectricity and Electrostriction*



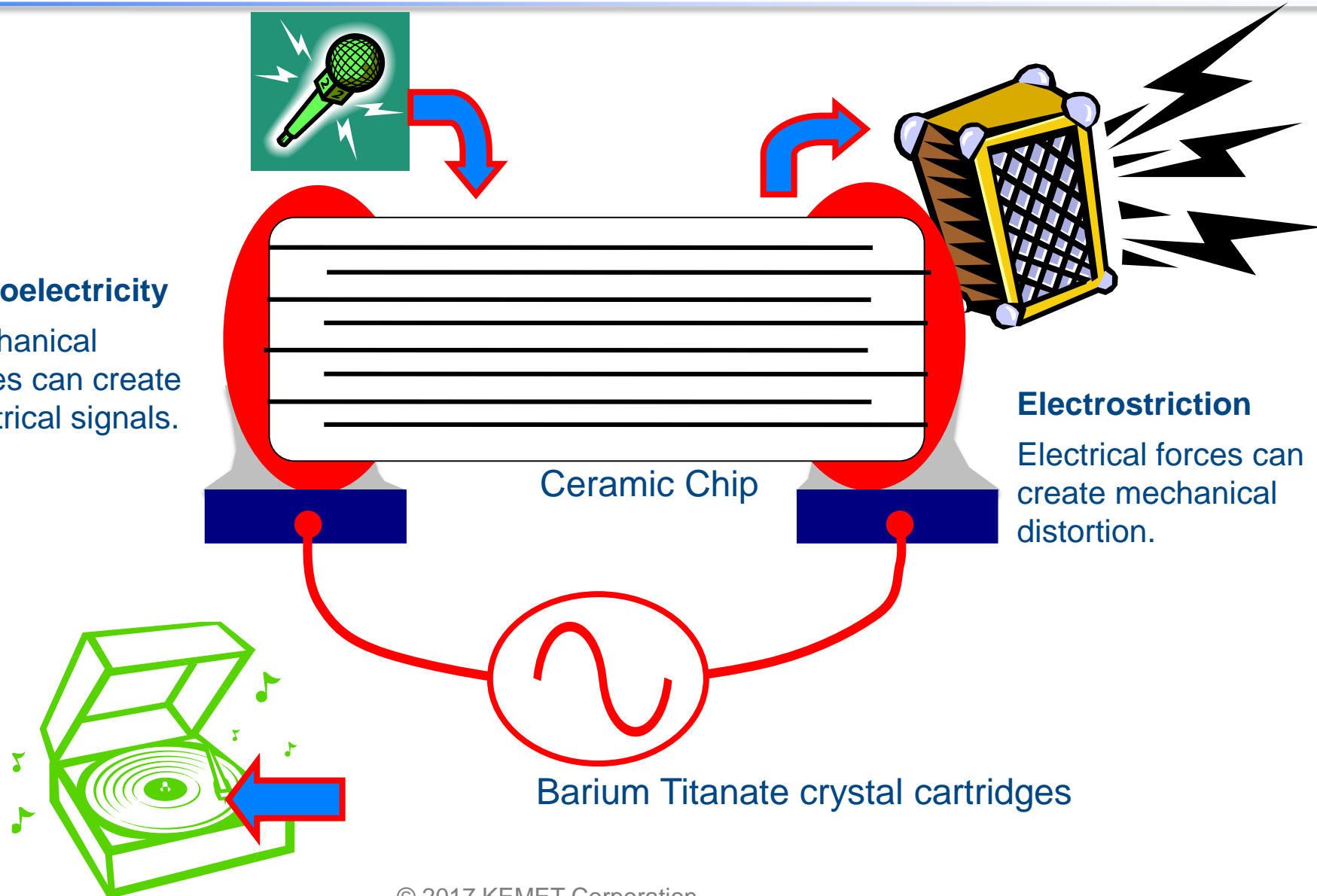
**Mechanical Distortion**

# Piezoelectricity and Electrostriction

Class II and III Only

**Piezoelectricity**  
Mechanical forces can create electrical signals.

**Electrostriction**  
Electrical forces can create mechanical distortion.

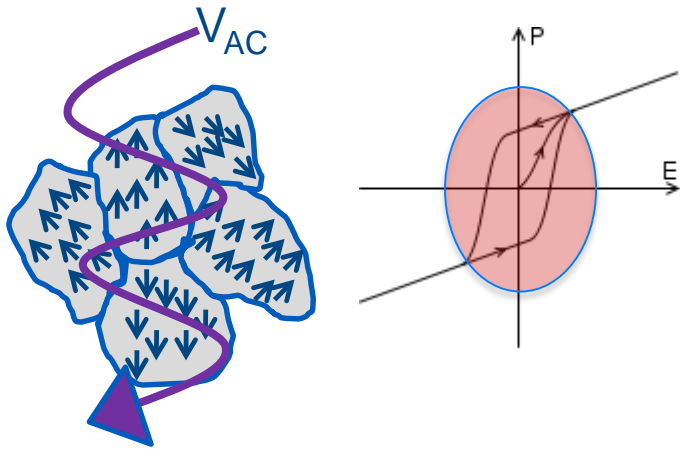




# AC Coupling and Signal Distortion

X7R vs. C0G

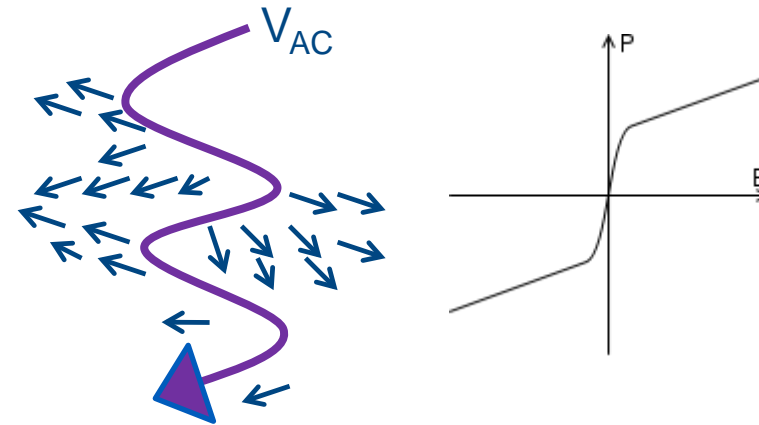
**Class 2 (X7R, X5R, etc) BaTiO<sub>3</sub>**  
Ferroelectric



**Ferroelectric** permanent dipoles in *domains* align with the AC Field

Domain wall heating &  
Signal distortion

**Class 1 (C0G, U2J) CaZrO<sub>3</sub>**  
Paraelectric



**Paraelectric** spontaneously created dipoles align with AC field

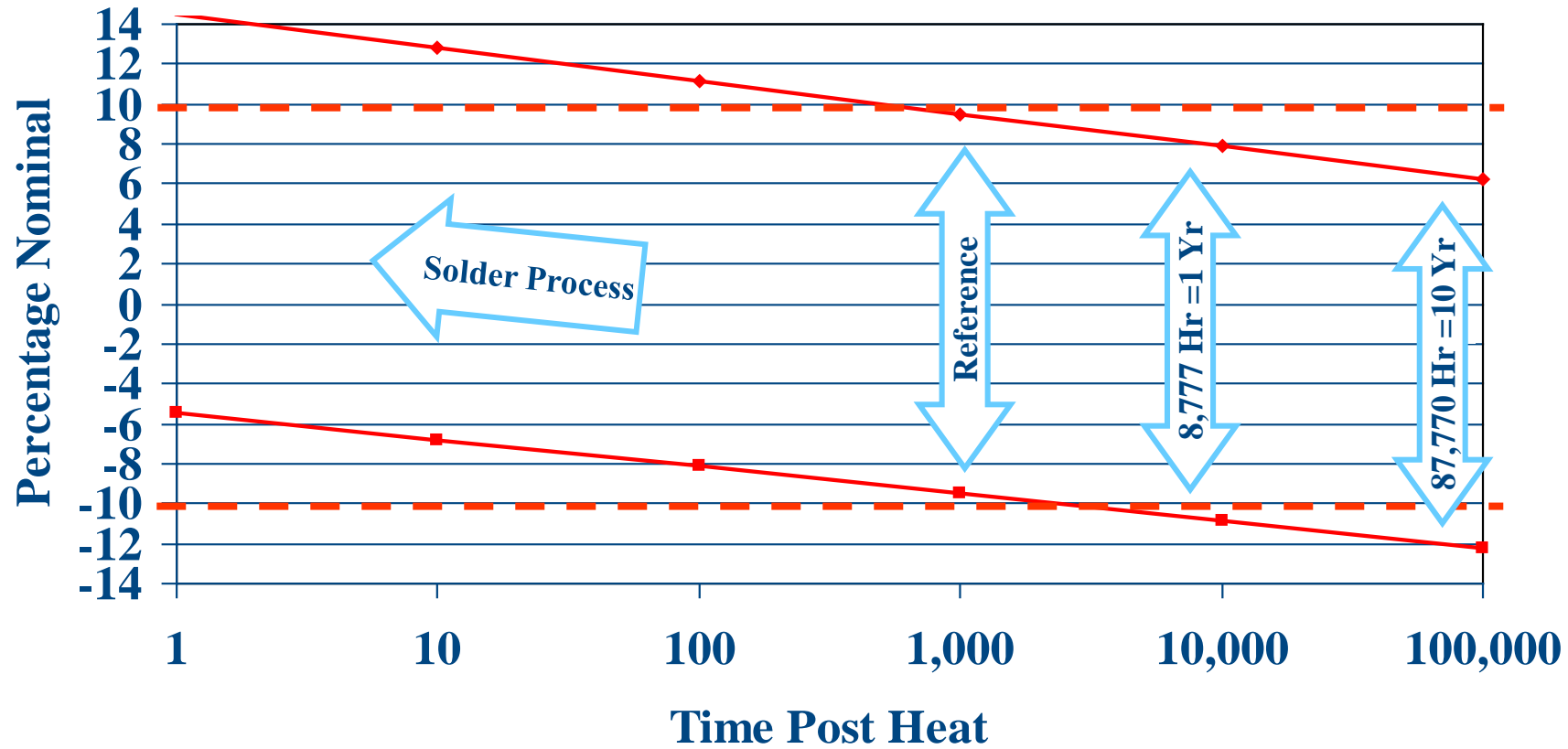
No domains, so  
No Domain wall heating &  
Reduced signal distortion

A large, stylized lightning bolt strikes from the top left, illuminating the scene with a bright blue and white glow. The background is a gradient of light blue, suggesting a sky or a high-tech environment.

## Aging of Class 2 and Class 3 Capacitors

# X7R Aging Rate

1.5% per Decade Hour (Limit)



<https://ec.kemet.com/design-tools/aging-calculator-for-ceramics>



Thank You