

# **CAPACITOR WEBINAR 101**

**Offered by the PSMA Capacitor Committee**

## **Presenters**

**Fred Weber – Future Technology Worldwide / Richardson Electronics & Polycharge**

**Scott Franco – Cornell Dubilier**

**Stephan Menzel – Wurth Elektronik**

**Wilmer Companioni - KEMET**



*CUTTING EDGE POWER  
PRODUCTS & SERVICES*

# What else is the PSMA Capacitor Committee Offering?

- **Capacitor 201 Webinar**
- **Road Map Webinar – Newest Technologies & Trends**
- **2019 APEC Capacitor Workshop**  
**Capacitors – Broadband technologies and it's requirements on Caps + Capacitor Technology and an Application Deep Dive**
- **2019 APEC Capacitor Industry Session**  
**Designing a New Application? Which Cap Technology should you use?**  
**A deep dive into capacitor technology, including Broadband requirements.**

# What else is the PSMA Capacitor Committee Offering?

- **PSMA Capacitor Committee Website**

[www.pasma.com/technical-forums/capacitor/purpose](http://www.pasma.com/technical-forums/capacitor/purpose)

There will be a tab for reference material which include this presentation and several others that you may find interesting.

Be sure to view all of the old Industry presentations, and Workshop Detail.

# **CAPACITOR BASICS**

**Intro to Capacitors Sponsored  
by**

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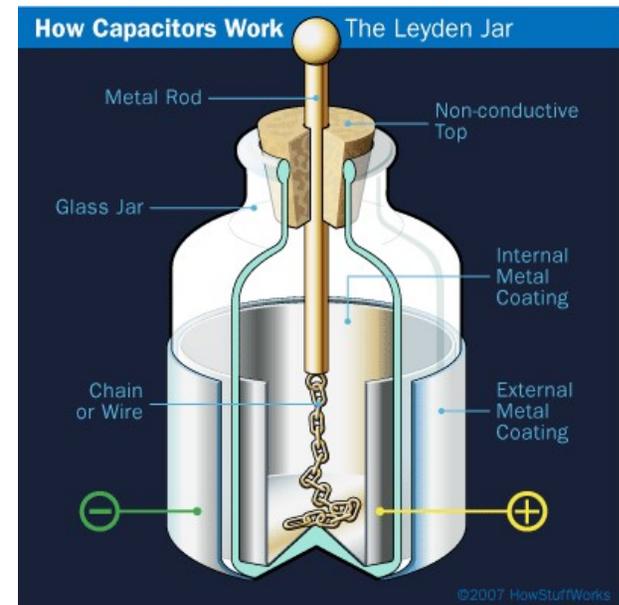
Presented by Scott Franco, Director of Market Development

## **TOPICS COVERED**

- History of Capacitors
- Capacitor Theory
  - Basic Construction
  - Energy Storage
  - Capacitors in Series & Parallel
- Applications for Capacitors
- Terms to Know

# History

- 1745 Ewald Georg von Kleist of Pomerania invented the first recorded capacitor.
- Early capacitors, were known as Leyden Jars. These devices consisted of a glass (insulator) jar with metal foil (electrodes) on the outside and inside of the jar.
  - Early jars were filled with impure water that conducted to a wire or metal chain that passed through a cork (insulator) at the top of the jar. Later jars had an inside foil that replaced the water.
  - The inside foil (electrode) and outside foil (electrode) were electrically isolated from one another.
  - Leyden jars were charged using frictional static generators, e.g. the Electrophorus developed in 1764.
- Early capacitors were primarily used for electrical experiments.



*The earliest unit of capacitance was called the "jar"*

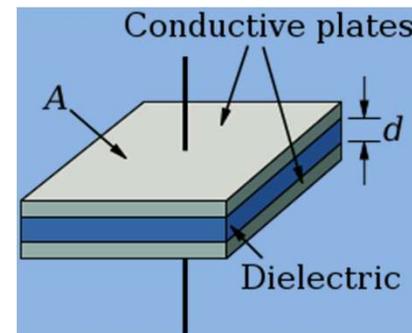
# HISTORY

- Michael Faraday pioneered the use of capacitors and the unit of measure for capacitance "Farad" was named after him.
- Capacitors also known as condensers in that time were first used commercially in wireless-telegraphy, i.e. radio.

# What is a Capacitor?

- A device that stores electric energy, consisting of two metal plates (electrodes) separated by an insulator (dielectric).
- The equation for capacitance is given by:

$$C = Ak/d$$



*A = Area of the plates  
d = distance between plates  
K = dielectric constant of insulating material. Vacuum = 1*

# Dielectric Constant of Common Capacitor Dielectrics

Material	Dielectric Constant (k)
Vacuum	1.0
Aluminum Oxide	9–10.0
Mica	5–7.5
Polypropylene	2.2
Polyester	3.2
Tantalum Pentoxide	26
Ceramic	NPO: 15-100 X7R: 2,000-4,000 Y5V: >16,000

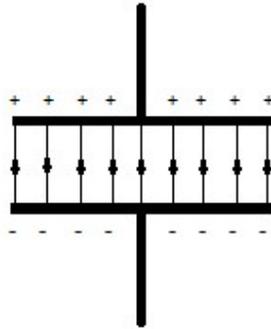
# HOW DO DIELECTRICS INCREASE CAPACITANCE?

$$C = Q/V$$

C = Capacitance,

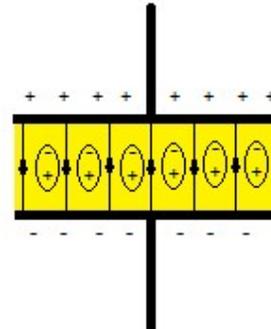
Q = Quantity of charge

V = Voltage.



Starting with a vacuum capacitor charged to voltage  $V_1$  after which the voltage source is removed.

$$C_1 = Q_1/V_1$$



A dielectric material of constant  $k$  is then placed between the electrodes.

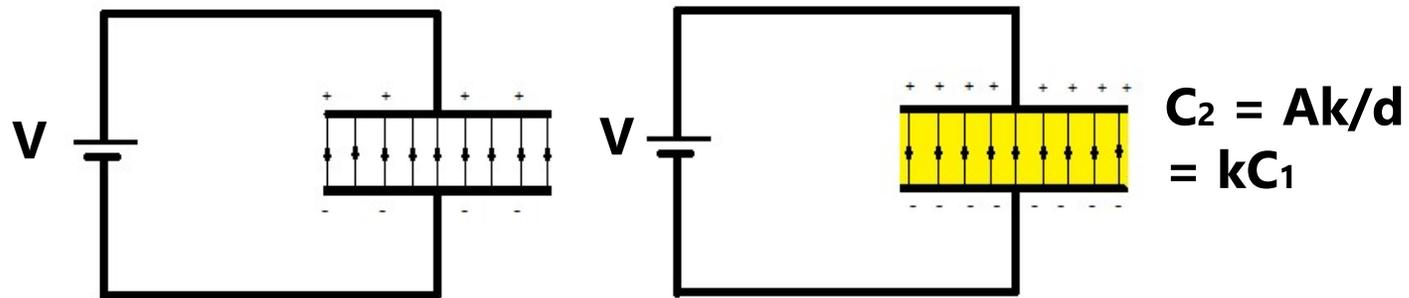
$$C_2 = kC_1$$

$$Q_1 = Q_2 \text{ (Conservation of charge)}$$

$$V_2 = V_1/k$$

$$C_2 = Ak/d \\ = kC_1$$

# HOW DO DIELECTRICS INCREASE CAPACITANCE?



Now consider a case where a vacuum capacitor is hooked up to a constant voltage source.

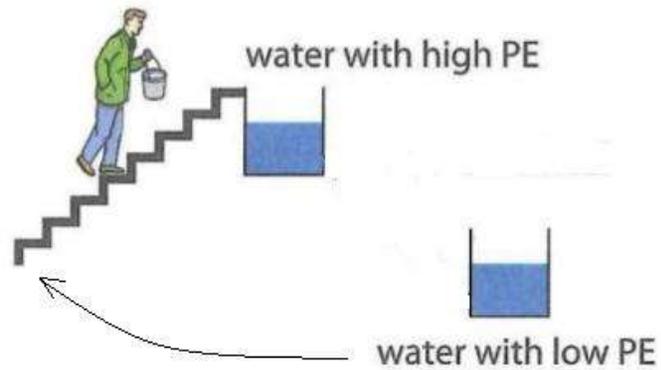
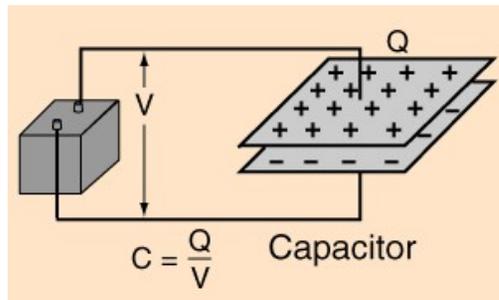
$$C_1 = Q_1/V$$
$$C_1 V = Q_1$$

A dielectric material of constant  $k$  is then placed between the electrodes.

$$kC_1 = Q_2/V$$
$$kC_1 V = Q_2$$
$$Q_2 = kQ_1$$

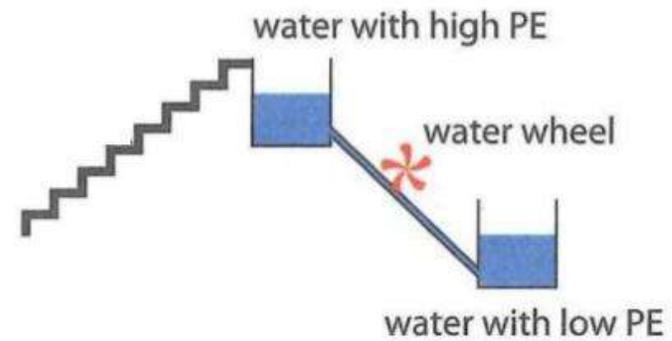
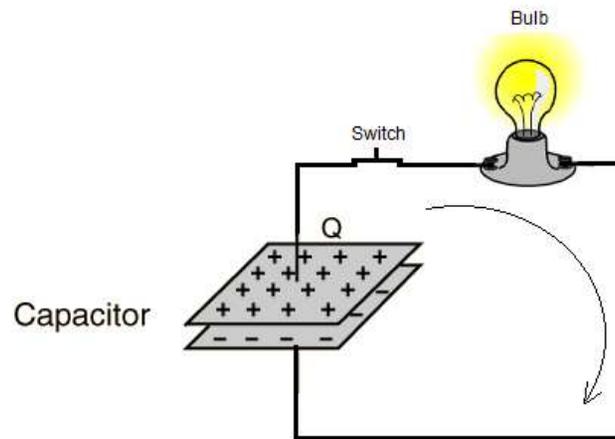
# What do capacitors do?

Store Electrical Energy



# What do capacitors do?

Release Energy



# Capacitance

- Capacitance: Ability of the capacitor to store electrical charge

## Units

**Farad (F):** is a basic unit of capacitance storage given by:

$$C = Q/V$$

**1 F** = 1 Coulomb per volt, wherein C = Capacitance, Q = Quantity of charge as measured in Coulombs and V = Voltage.

**Microfarad ( $\mu\text{F}$ )**     **$1\mu\text{F} = 1 \times 10^{-6} \text{ F}$**

**Nanofarad (nF)**     **$1\text{nF} = 1 \times 10^{-9} \text{ F}$**

**Picofarad (pF)**     **$1\text{pF} = 1 \times 10^{-12} \text{ F}$**

# Uses for Capacitors

- **Store Electrical Energy**
  - Capacitors store electrical energy when disconnected from its charging circuit so it can be used like a temporary battery.
  - Energy stored in a capacitor can be delivered to a device that requires pulses of power such as a flash lamp or devices as large as particle accelerators.
- **Bulk Storage and Filtering**
  - Capacitor reservoirs are used in power supplies to smooth the DC output .
  - Capacitors applied on an AC output are used to smooth out the AC waveform to “clean” the voltage signal of harmonics before it is supplied to the grid or load.
- **Snubber**
  - Snubbers are used to reduce voltage spikes or noise across a switch by creating a path for the impulse to bypass the contact points or semiconductor junction.
- **Power Factor Correction**
  - In industrial applications where large inductive loads, such as motors, are used capacitors are used to counteract the effect of the inductive load to make load look more resistive or at unity power factor, improving efficiency.

# USES FOR CAPACITORS

## ➤ **Signal Coupling**

- Because capacitors allow AC signals to pass but block DC when charged to the applied DC voltage, they are often used to separate the AC and DC components of a signal.

## ➤ **Decoupling**

- A decoupling capacitor is used to protect one part of circuit from the effects of another. For instance, noise caused by other circuit elements is shunted through the capacitor, reducing the effect they have on the rest of the circuit.

## ➤ **Motor Starters**

- Some single phase motors require a start winding that develops a magnetic field that is out of phase with the main winding to start the motor's rotation.

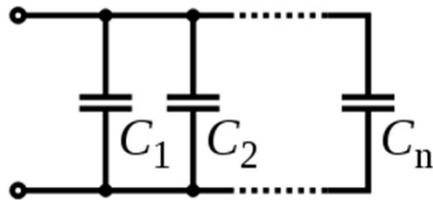
## ➤ **Tuned Circuits**

- Capacitors and inductors are applied together in tune or resonance to select or receive information in certain frequency bands. Radio circuits and MRI used tuned circuits.

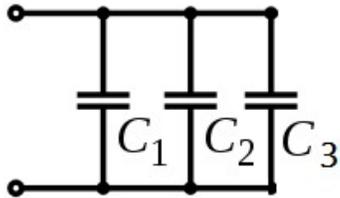
# Capacitors Connected in Series, Parallel

## PARALLEL CONNECTION

When capacitors are placed in parallel, the resulting capacitance is the sum of all capacitors. The maximum permissible voltage across the "bank" of capacitors is equal to voltage rating of the capacitor with the lowest permissible voltage.

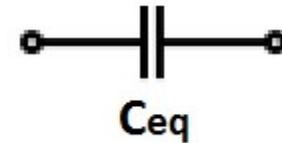


$$C_{eq} = C_1 + C_2 + \dots + C_n$$



## Example

**$C_1 = 5 \mu\text{F} @ 50 \text{ V}$**   
 **$C_2 = 10 \mu\text{F} @ 100 \text{ V}$**   
 **$C_3 = 2 \mu\text{F} @ 75 \text{ V}$**

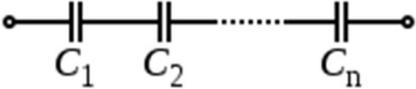


$$C_{eq} = 17 \mu\text{F}, \quad V_{eq} = 50 \text{ V}$$

# Capacitors Connected in Series, Parallel

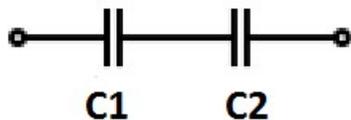
## **SERIES CONNECTION**

When capacitors are placed in series, the resulting capacitance is given by the following equation. Series connected capacitors result in higher voltage capability.

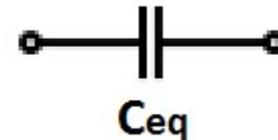

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}$$

## **A SPECIAL CASE FOR CAPACITORS IN SERIES**

When two or more capacitors of equal capacitance value and voltage rating are placed in series, the resulting capacitance  $C_{eq}$  is equal to the capacitance value of each capacitor divided by the number of capacitors placed in series. The resulting voltage withstand  $V_{eq}$  is the voltage of each capacitor times the number of capacitors in series.



**Example**



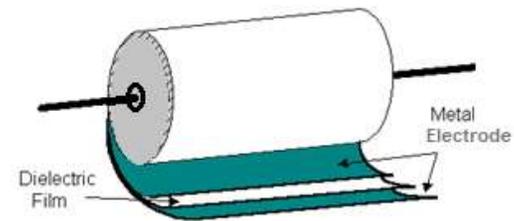
$$C_1 = C_2 = 10 \mu\text{F} @ 50\text{V}$$

$$C_{eq} = 5 \mu\text{F}, \quad V_{eq} = 100\text{V}$$

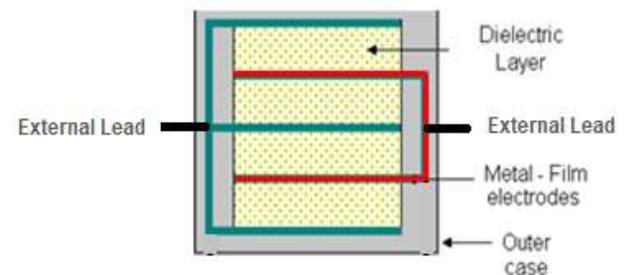
# Basic Capacitor Construction

While there are many capacitor construction types, all capacitors share some common elements:

- **Section:** Wound or stacked construction. The basic capacitor element is known as the "section".
- **Leads:** wire leads, ribbon leads or screw terminals that connect to each electrode.
- **Case:** or encapsulation to electrically insulate the section and protect it from the elements.

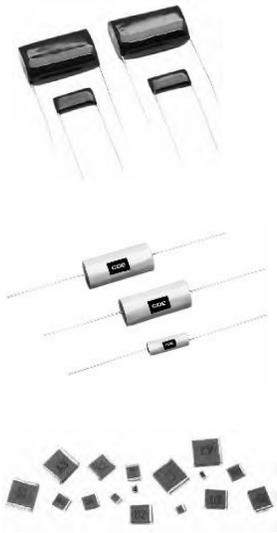


**Wound Construction**



**Stacked or Wound Construction**

# Capacitor Terminations



**Radial:** Leads exit from the radius. Soldered to PCB.

**Axial:** Leads exit from the axis. Soldered to PCB.

**Surface Mount:** Auto inserted and reflow soldered onto PCB.



**Bus Mount:** Use screw terminals or threaded studs for mounting to bus bars.

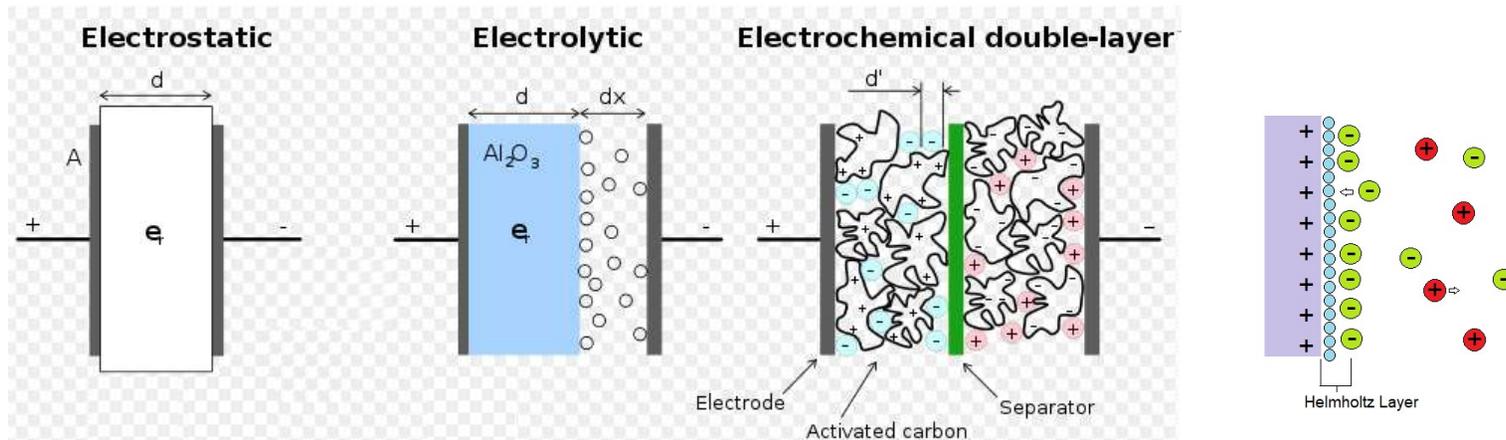
# Terms to Know

- **Rated Capacitance:** Capacitance value usually measured at room temperature of  $20^{\circ}\text{C} - 25^{\circ}\text{C}$ .
- **Rated Voltage:** Maximum continuous voltage that may be applied at rated temperature to ensure full life. Capacitors are either rated for AC or DC or sometimes both.
- **Leakage Current:** The dielectrics used are not perfect insulators and results in a small current "leaking" through the dielectric.
- **Temperature Range:** The safe minimum and maximum ambient temperatures under which the capacitor may operate.
- **ESR: Equivalent Series Resistance:** is the combined effect of all the resistive elements that form the resistive path in series with the capacitor, measured in ohms.
- **Dissipation Factor:** or DF is a measure of a capacitor's loss. It is the ratio of ESR/ $X_c$ . Dissipated energy typically turns into heat. The higher the DF, the greater the loss and heat generated.

# Terms to Know

- **ESL: Equivalent Series Inductance:** A measure of a capacitor's series inductance. Includes resistance of leads, connections, electrodes, etc.
- **Peak Current Rating:** The pulse rating of a capacitor or its ability to handle repetitive peak current as determined by the product of C and dV/dt (the rate in change of voltage with time)  $I_{pk} = C \times dV/dt$ .
- **Ripple Current:** The RMS value of AC current flowing through a capacitor.
- **Ripple Current Rating:** The maximum permissible ripple current is dependent on the case style and surface area, the heat dissipation (ESR), the AC frequency, the maximum allowed core temperature and the ambient temperature.

# Capacitor Types



## Electrostatic

Capacitors use insulating material placed between two metal electrodes. The electrodes may be foil or metal deposited onto the dielectric. Dielectrics include: Paper, mica, plastic and ceramic capacitors.

## Electrolytic Capacitors

use insulating oxides that are formed on a metal anode (+ electrode) and immersed in an electrolytic solution that forms the (-) cathode. Types include aluminum electrolytic and tantalum. Solid cathode types replace the electrolyte with  $MnO_3$  or conductive polymer.

## Carbon Double Layer

Electric double-layer capacitors don't have a dielectric insulator. It is replaced by an ionic barrier with about a 2 V standoff voltage. Since the ionic barrier is only a molecule thick EDLC capacitors have farads of capacitance. The standoff voltage is the voltage needed to start conduction between the liquid electrolyte and the activated carbon anode.

# A Discussion of Major Dielectric Types

In the following section we explore various capacitor technologies, their construction, advantages, disadvantages and applications.

- **Film**
- **Electrolytic**
- **Aluminum Polymer**
- **Ceramic**

# Film Capacitors



**DC Film  
Capacitors**

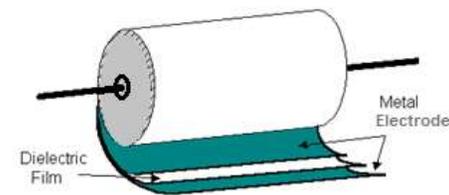
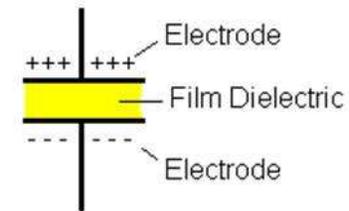


**AC Film  
Capacitors**

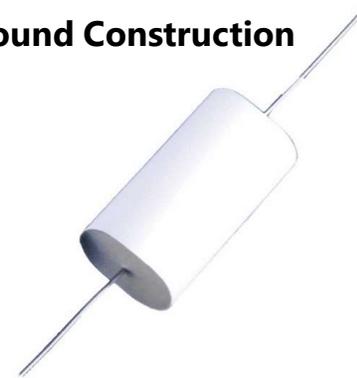
# Film Capacitor Construction

- A film capacitor is made by winding plastic film between two electrodes.
- Polypropylene and Polyester are the two most widely used film dielectric materials.
- Each end is sprayed with a metal coating "endspray" to lower the resistance and acts as a base to solder or weld wire leads to.
- The winding may be placed in a can or box or tape wrapped and end filled with epoxy.

Film Capacitors



**Wound Construction**



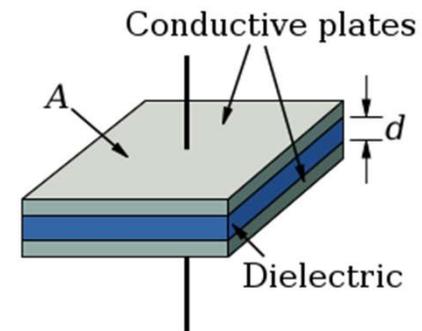
# Common Film Dielectrics

## POLYESTER

- Higher loss than polypropylene
- Lower Cost per CV rating
- Smaller size
- Higher temperature up to 125°C with voltage derating
- Best suited for DC applications.

## POLYPROPYLENE

- Lower loss than polyester. Lower ESR
- Used in high frequency, snubber and pulse applications.
- Cost more per CV rating than polyester.
- Rated to 85°C without derating.
- Best suited for application requiring high ripple current.



# Film Capacitor Construction

## Electrode Types

- Metal deposited electrodes (metallized capacitors) are used when self healing capability is required.
  - When a short occurs in the dielectric, the metallization evaporates in the fault area, creating a "clearing" that allows the capacitor to continue to operate with minimal capacitance loss.
- Most AC applications require the use of metallized film for protection.
- Foil electrodes are used in DC applications for high pulse current or high ripple current.



# Film Capacitors

## Advantages and Disadvantages of Film Caps

- .001 $\mu$ F to 3000  $\mu$ F
- Voltage Range: 50 Vdc to 3000 Vdc
- AC Ratings up to 2000 Vac
- Low loss results in less heating than other types
- Higher ripple and pulse current ratings
- High voltage capability reducing the need to place them in series
- Stability over wide temperature range
- Metallized types are self healing
- Disadvantages
- Lower energy density compared with aluminum electrolytics.  
Less capacitance in the same size case.

# Film Capacitor Applications

- **DC Link for Power Inverter**
- **DC Filtering**
- **Snubber**
- **DC Pulse Discharge**
- **AC Power Factor Correction**
- **AC Motor Run**
- **AC Harmonic Filter**

# E-Cap Capacitors

Aluminum Electrolytic Capacitors

Aluminum Polymer Capacitors

also known as Lytics

## Short Introduction of Today's Presenter



### Stephan Menzel

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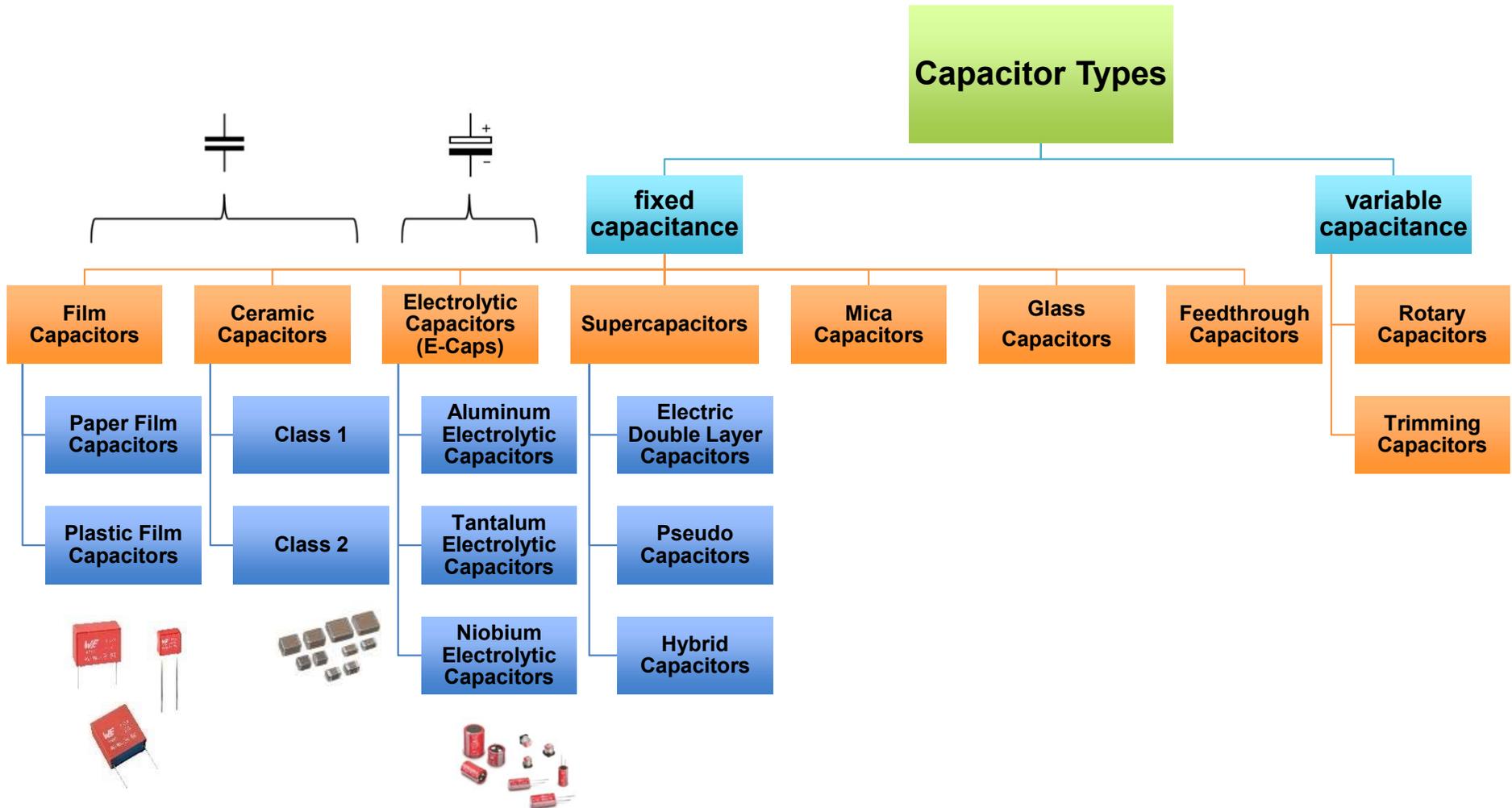
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### Background:

- More than 10 years of work experience in electronics industry
- Background in Global Sales & Marketing, Industrial Engineering and Quality Management
- In charge for strategic sales conception and global market penetration of capacitor division at WE

# Capacitor Types



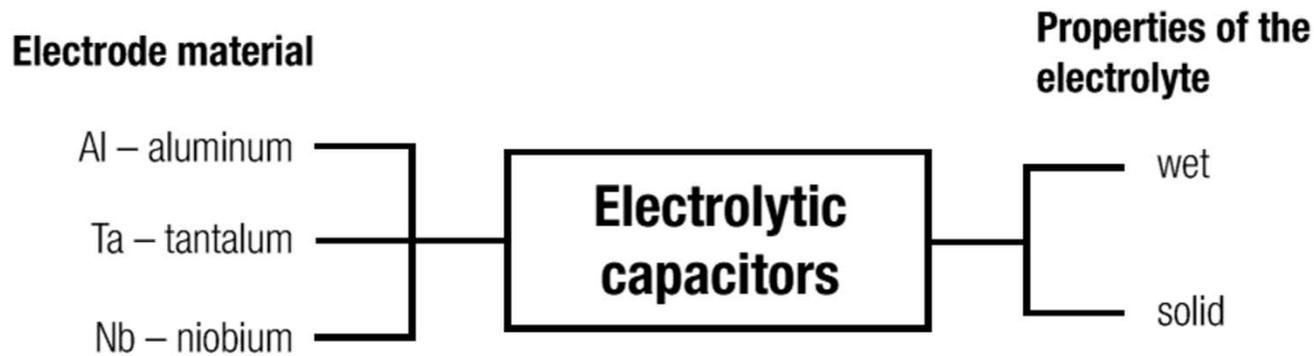
## Most Common Capacitor Types in Comparison

capacitor type	max. possible capacitance	voltage range	max. permissible current	max. operating temperature	Applications
<b>Aluminum Electrolytic Capacitors</b>	> 1F 	ca. 650 V 	ca. 0,05 A/ $\mu$ F 	85°C up to 150°C 	smoothing, buffering, DC Link
<b>Film Capacitors</b>	> 8mF 	ca. 3kV 	ca. 3 A/ $\mu$ F 	max. 110°C 	DC Link, EMI suppression, filtering
<b>MLCC's</b>	> 100 $\mu$ F 	ca. 10 kV 	ca. 10 A/ $\mu$ F 	85°C up to 200°C 	EMI suppression, buffering, coupling

# Electrolytic Capacitor Types



Differentiation of Electrolytic Capacitors:

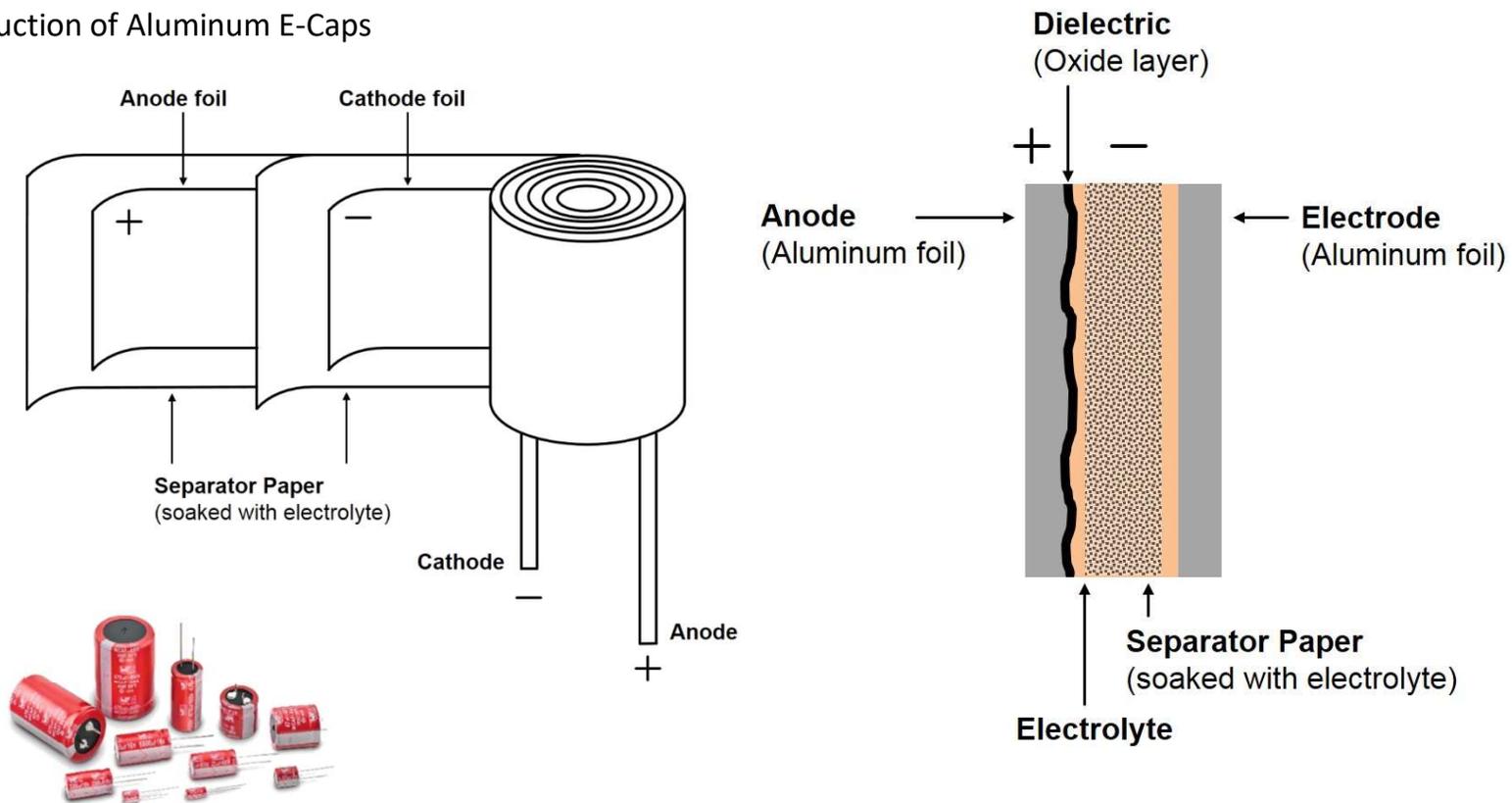


Anode electrode material	Dielectric	Relative permittivity ( $\epsilon_r$ ) at +20 °C
Al – aluminum	$\text{Al}_2\text{O}_3$ – aluminum oxide	9.3
Ta – tantalum	$\text{Ta}_2\text{O}_5$ – tantalum pentoxide	26
Nb – niobium	$\text{Nb}_2\text{O}_5$ – niobium pentoxide	42



# Construction of Aluminum-Electrolytic-Capacitors (E-Caps)

- Construction of Aluminum E-Caps



# Comparison: Aluminum Polymer / Aluminum Electrolytic Capacitors

## • Aluminum Electrolytic Capacitors

- Higher voltage ratings available (up to 600V)
- cheaper pricing (@ same capacitance and voltage rating)
- Better leakage current behavior than Polymer
- Load life will be calculated as following:

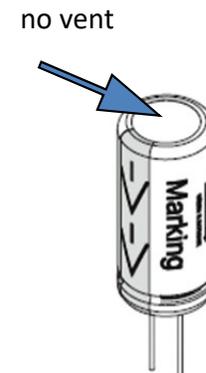
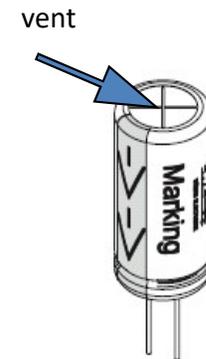
$$L_x = L_{nom} * 2^{\frac{T_0 - T_a}{10}}$$

## • Aluminum Polymer Capacitors

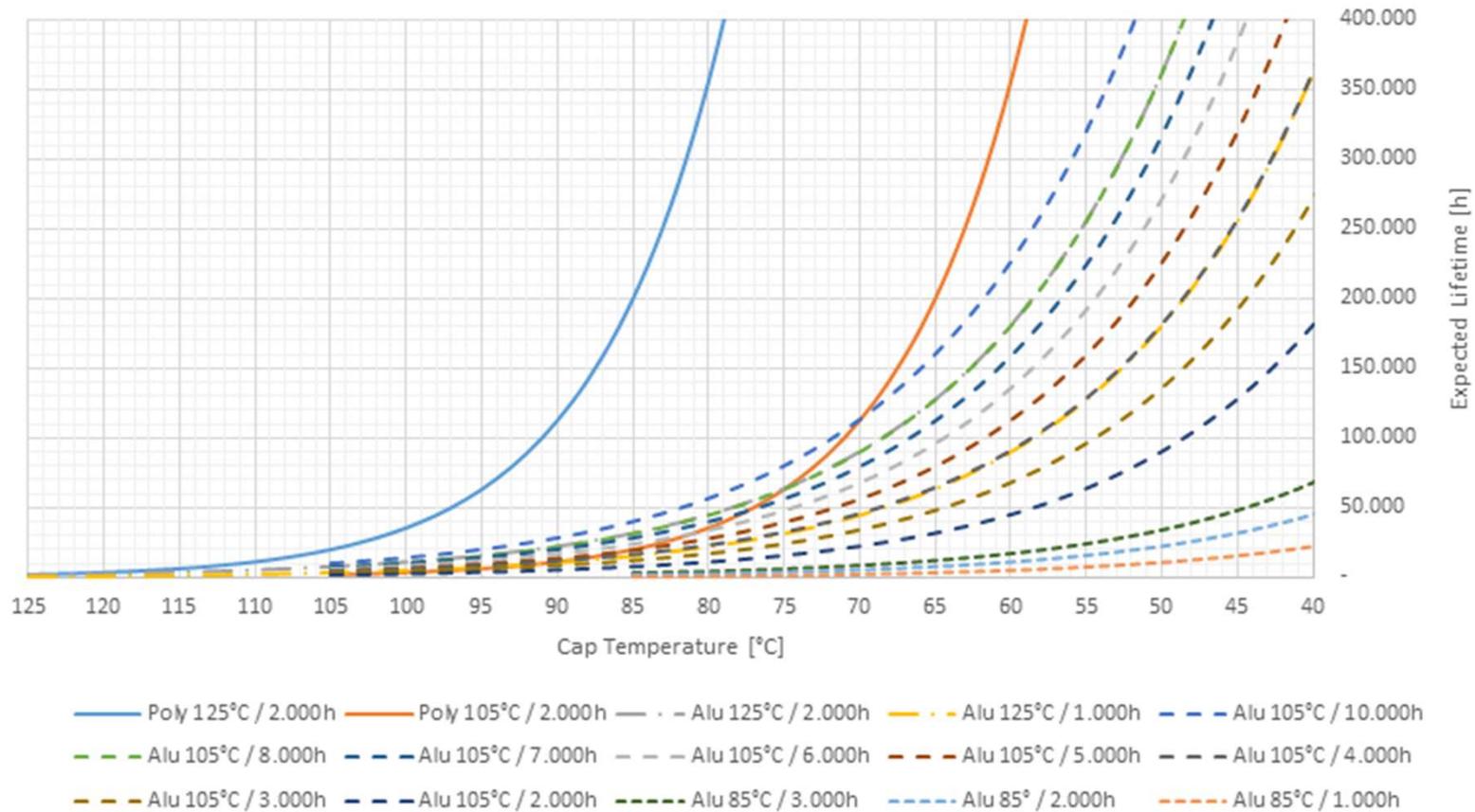
- Smaller ESR than Aluminum-Cap >> higher allowable ripple current
- No dry-out behavior like Aluminum-Cap (solid electrolytic)
- Higher expected lifetime / load life
- Limited in size (max. 10 x12 mm cans) and voltage (max. 200V)
- Load life will be calculated as following:

$$L_x = L_{nom} * 10^{\frac{T_0 - T_a}{20}}$$

$L_x$  = expected lifetime;  $T_0$  = upper temperature limit ;  $T_a$  =temperature of capacitor



# Comparison of expected life: Aluminum Electrolytic vs. Aluminum Polymer Capacitor



# Electrical Values – Who's Best in Class?

## Aluminum Electrolytic Cap

- ESR approx. 85mΩ
- Ripple Current rating approx. **630mA**



10 X 10

## Aluminum Polymer Cap

- ESR approx. 11mΩ
- Ripple Current rating approx. **5,500mA**

## Tantalum Polymer Cap

- ESR approx. 200mΩ
- Ripple Current rating approx. **1,900mA**

# What changes at switching from standard e-caps to polymer e-caps?

- Permanent applied voltage up to 80-90% of rated voltage
  - standard e-caps max. 70% recommended
- Resistant to temperatures down to  $-55^{\circ}\text{C}$   
>> due to solid polymer
  - usage in low temperature applications possible
- Higher leakage current
  - watch out in battery powered applications



## General-Comparison: Aluminum-Electrolytic vs. Aluminum-Polymer



Property	Aluminum Electrolytic Capacitors (wet electrolyte)	Aluminum Polymer Capacitors (solid electrolyte)
<b>ESR</b>	Much higher - > 10times and more	Lowest values, even below 10mOhm
<b>ESL</b>	Depending on form factor, windings	Depending on form factor, windings
<b>Leakage current</b>	Advantage, getting even better over time	Good in the beginning, but getting bigger over time
<b>Self healing</b>	Possible, due to liquid electrolyte	No self healing over usage possible
<b>Low temperature</b>	Worse performance due to liquid electrolyte, conductivity decreases	Better performance due to solid polymer, steady high conductivity
<b>Vibration</b>	With additional, mechanical fixation very high vibration G-forces possible	Theoretically not that good like liquid electrolyte
<b>High voltage</b>	Up to 650V possible	Solid polymer up to 150V, hybrid polymer up to 300V
<b>Endurance</b>	Dry out phenomenon shortens the lifetime dramatically with higher ambient temperature	No dry out phenomenon due to solid polymer element, much higher endurance

What describes Endurance, Load Life and Useful Life?



# Endurance and Useful Life - Example

Life	Endurance	Useful life
Time	2000 h	4000 h
Test condition	85°C, $V_R$ , $I_R$	85°C, $V_R$ , $I_R$
Requirements	1. $\Delta C/C \leq \pm 20\%$ ; 2. $DF \leq 2$ times of the specified value; 3. $LC \leq$ specified value; 4. Capacitor without visible damage.	1. $\Delta C/C \leq \pm 40\%$ ; 2. $DF \leq 4$ times of the specified value; 3. $LC \leq$ specified value; 4. Capacitor without visible damage.

- It is necessary to check this for each manufacturer because it is not standardized!
- Not the specification of the manufacturer finally determines the lifetime, it will be the dimensioning and selection of the proper capacitor for your design

>> How much capacitance drift is acceptable and still the application running properly? <<

# Major Factors for Aging of E-Caps

- The following factors mainly accelerate the aging behavior of an e-cap:

- **Temperature**

- electrolyte loss / dry out
- leakage current >> oxide degradation



- **Ripple Current**

- self heating >> electrolyte loss / dry out



- **Voltage**

- leakage current >> oxide degradation



These effects result in:

- >> capacitance decrease
- >> increase of ESR

# E-Cap Capacitors

## Advantages and Disadvantages of E-Caps

### ➤ *Advantages:*

- *Capacitance Range up to > 1F.*
- *Voltage Range: 2,5Vdc to 650 Vdc*
- *High Ripple Currents especially for large can and solid polymer types*
- *Higher energy density as film capacitors in the same size case*
- *Available in various sizes and mounting styles (SMT, THT, Snap In, Screw)*

### ➤ *Disadvantages:*

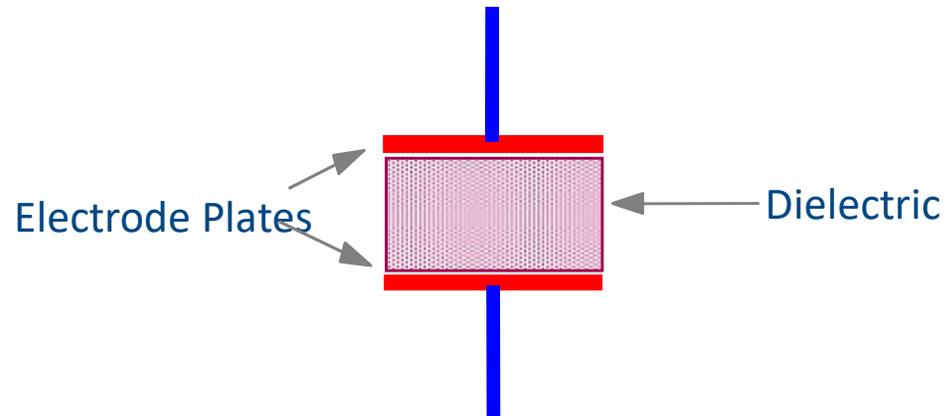
- *Aging behavior and Low Temperature Capabilities of wet electrolyte types*
- *Polarized Types and not meant for AC applications*
- *Lower energy density for Aluminum E-Caps compared with MLCC's and Tantalum Capacitors, Less capacitance in the same size case.*

# E-cap Applications

- ***Buffering***
- ***Filtering and Noise Suppression***
- ***DC Link for Power Inverters like***
  - ***Wind & Solar Inverters***
  - ***Electric Drives***
- ***Audio Applications***
- ***Photo Flash Applications***

# Multilayer Ceramic Capacitors aka: MLCCs or Ceramics

# Common Structure

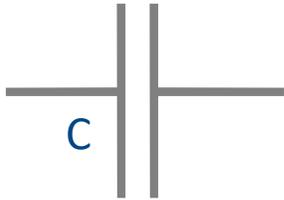


The value of a capacitor is measured in farads. For 1 farad of capacitance, 1 coulomb of charge is stored on the plates, when 1 volt of force is applied.

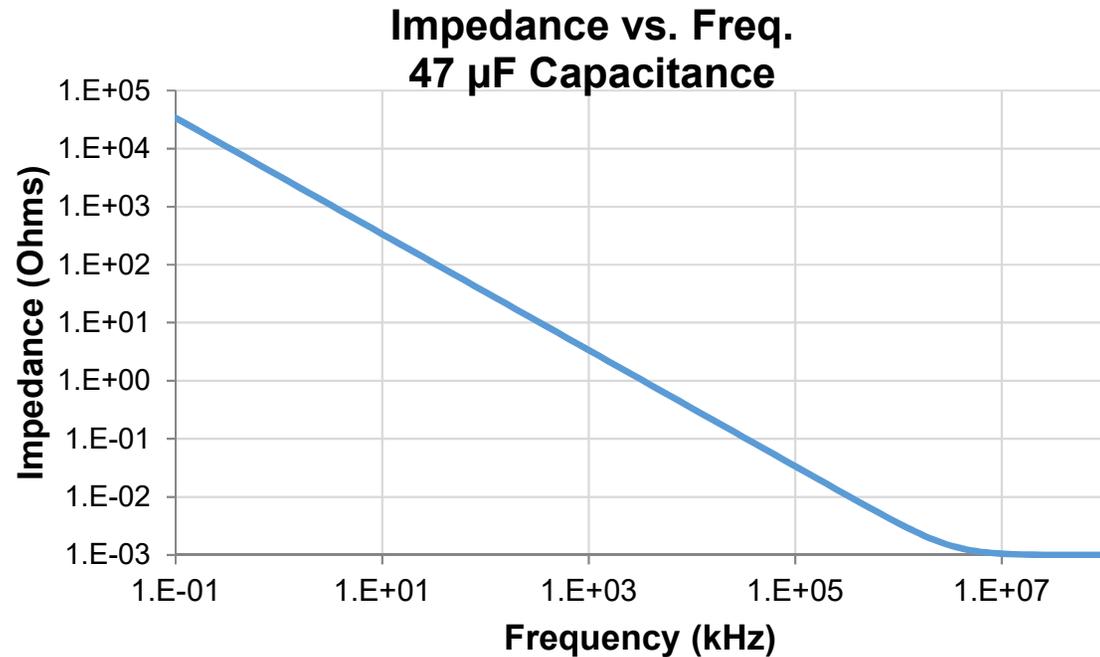
$$1 \text{ farad} = 1 \text{ coulomb} / 1 \text{ volt}$$

1 coulomb represents  $\sim 6 \times 10^{19}$  electrons

# “Ideal” Capacitor



$$Z = X_C = \frac{1}{2\pi f C}$$

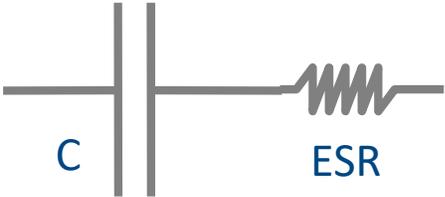


Where:

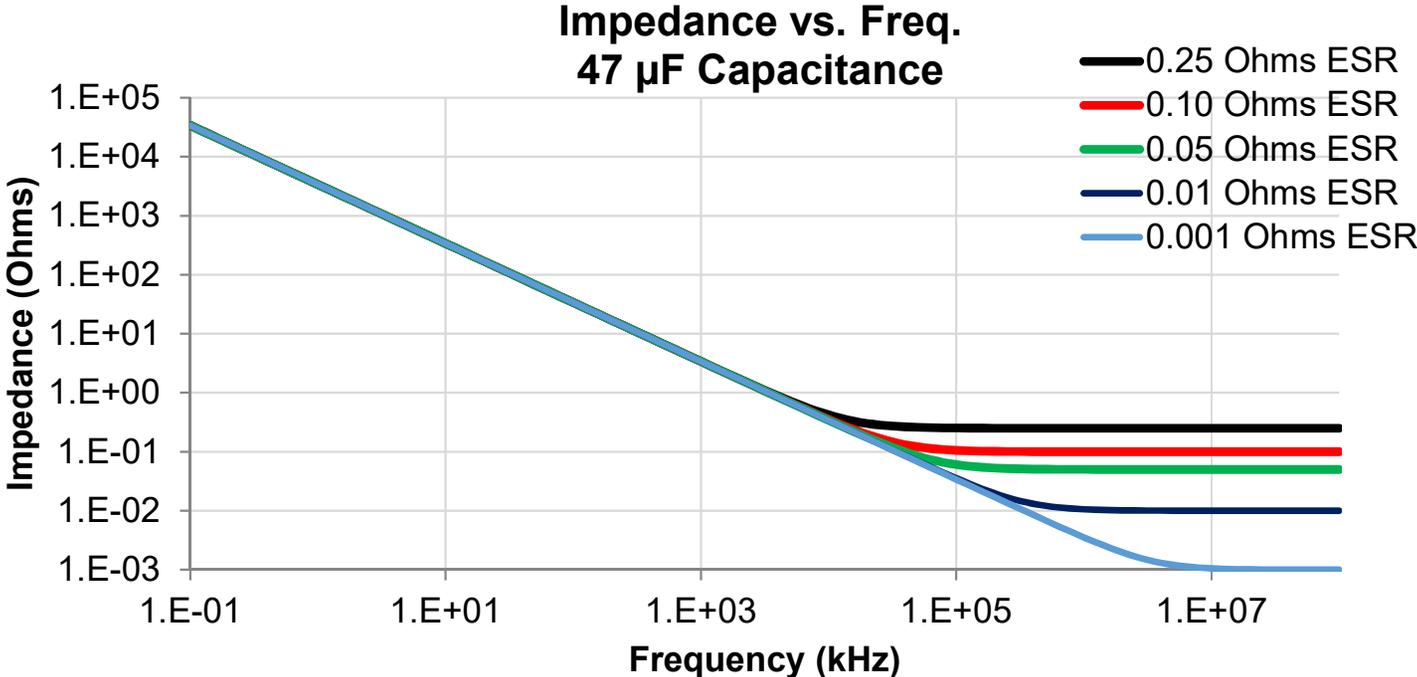
*f* is frequency (Hertz)

*C* is capacitance (Farads)

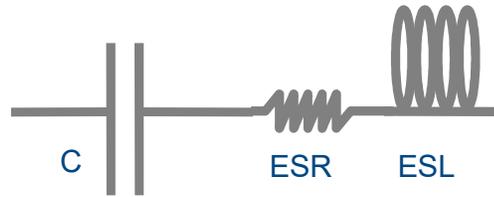
# Capacitor with Equivalent Series Resistance



$$|Z| = \sqrt{X_C^2 + ESR^2}$$



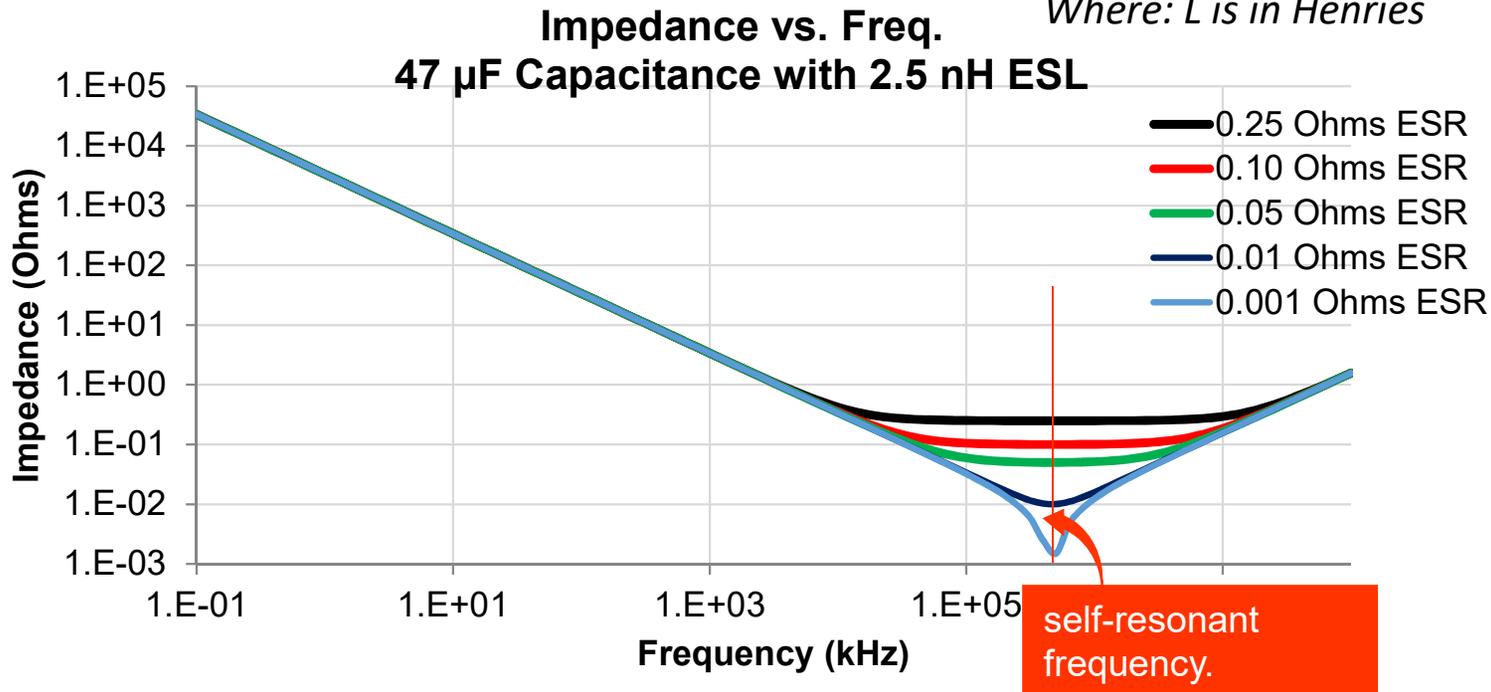
# Capacitor with Equivalent Series Resistance and Inductance



$$|Z| = \sqrt{(|X_C| - |X_L|)^2 + |ESR|^2}$$

$$X_L = 2\pi fL$$

Where: *L* is in Henries

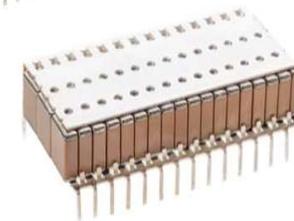
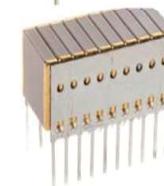
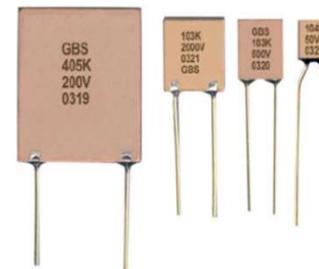
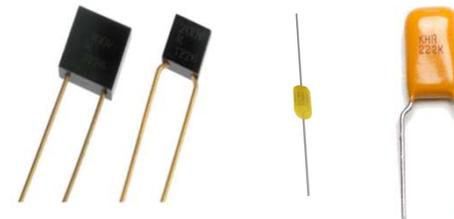
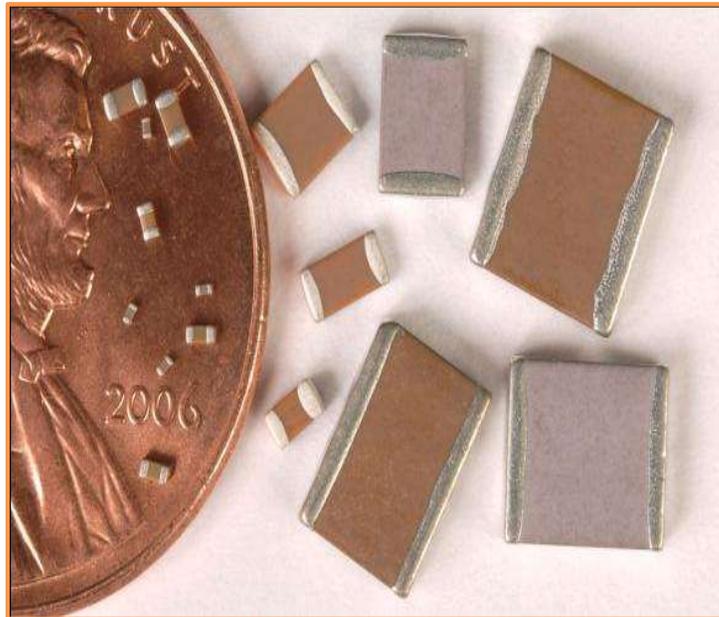


$$f = \frac{1}{2\pi\sqrt{LC}}$$



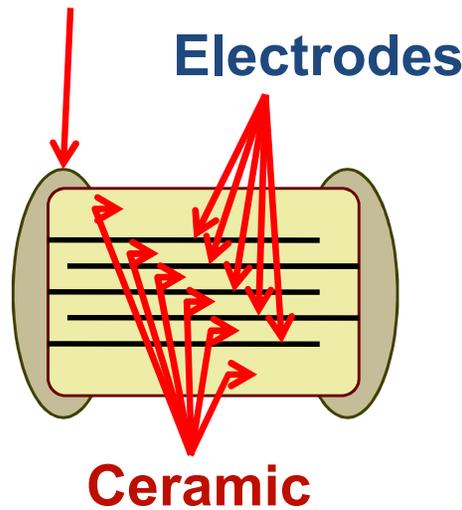
## Ceramic Capacitors

## Ceramic Capacitor Examples

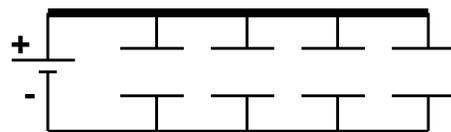


# Ceramic Capacitor Structure

## Termination



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



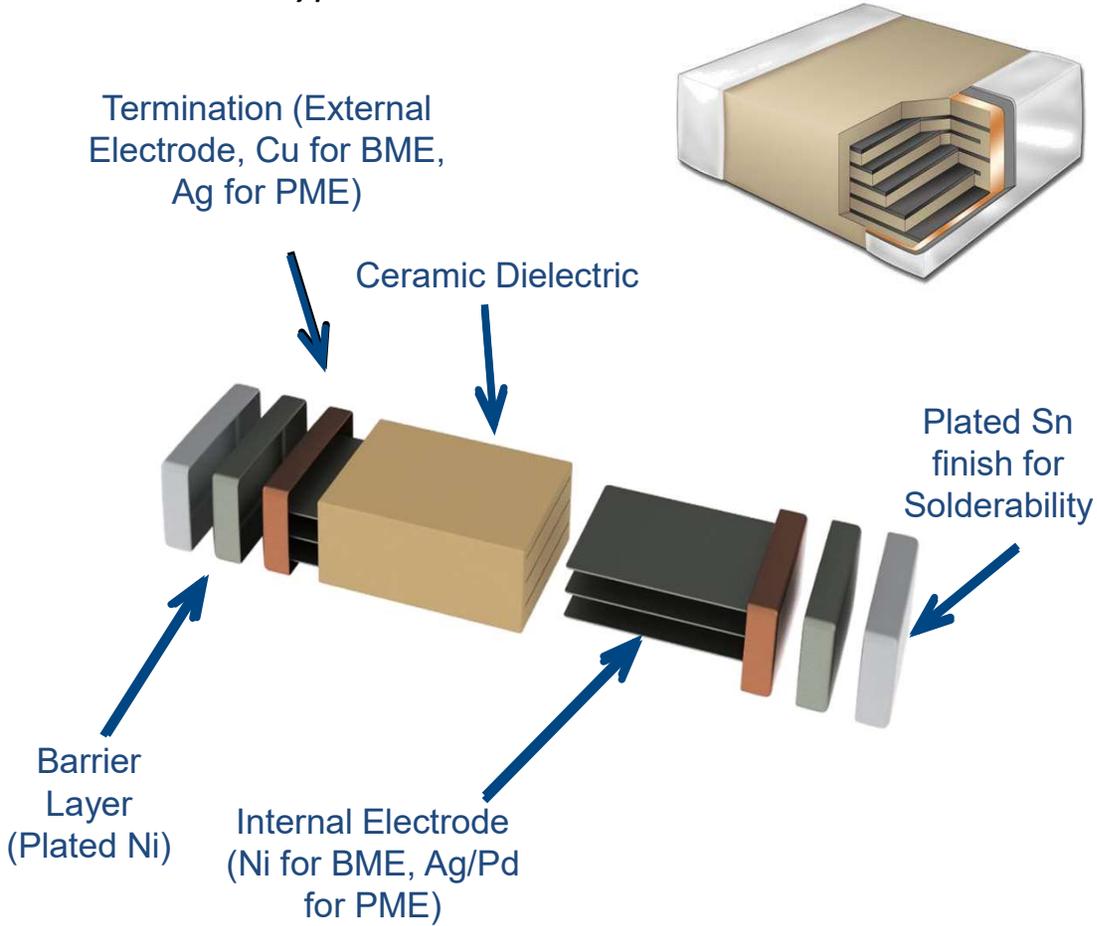
Capacitances in parallel are additive

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

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

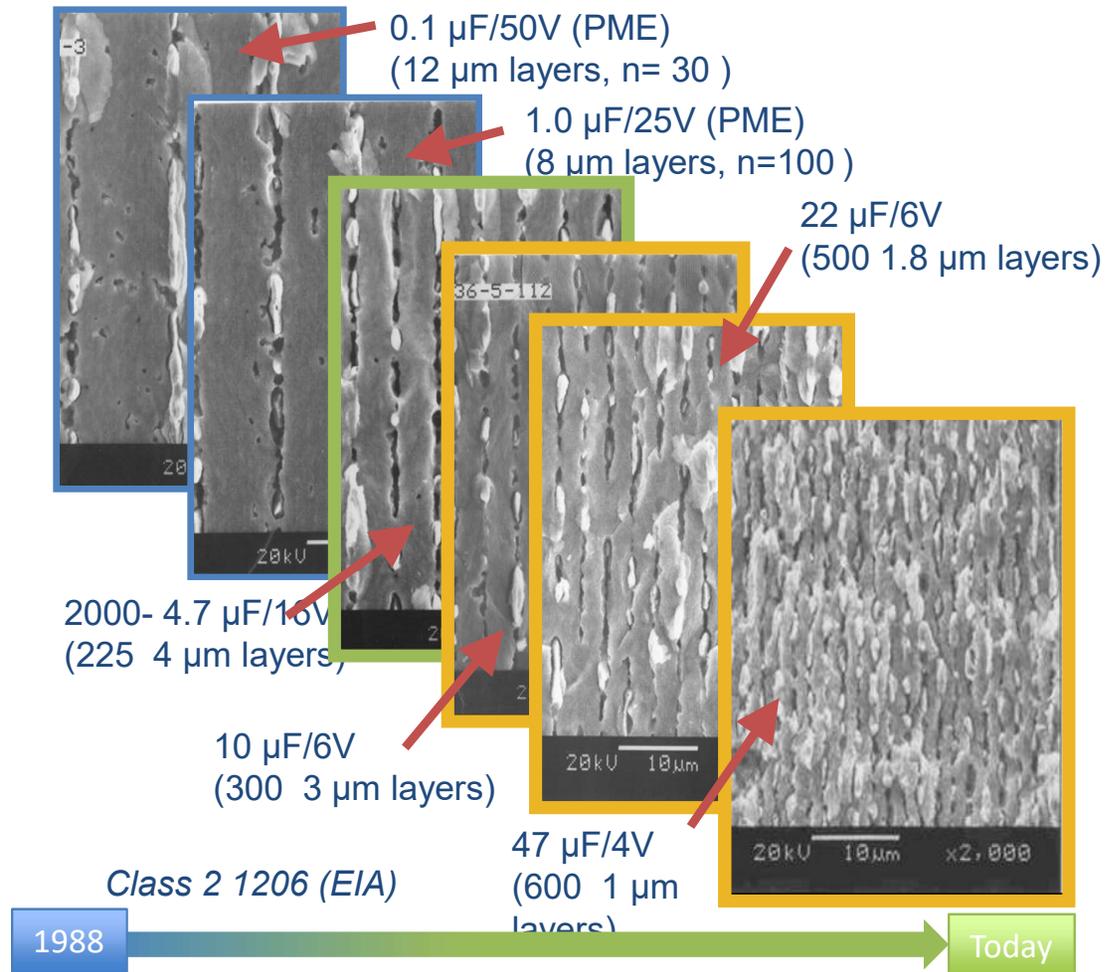
# Multilayer Ceramic Capacitor (MLCC)

*Typical Construction*



# Trend in BME MLCC Technology:

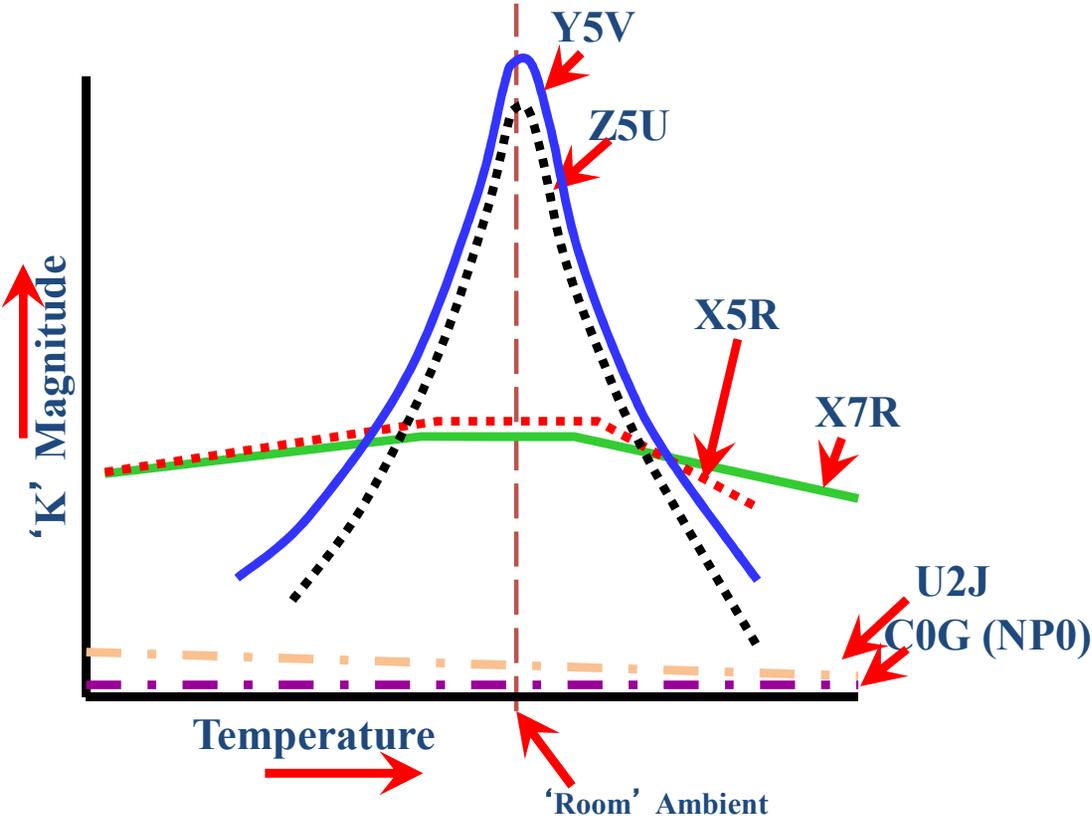
*Dielectric Thickness and Layers Count Progression*





## Temperature Coefficients

# 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
				* I	+15 to -40
				T	+22 to -33
				U	+22 to -56
				V	+22 to -82

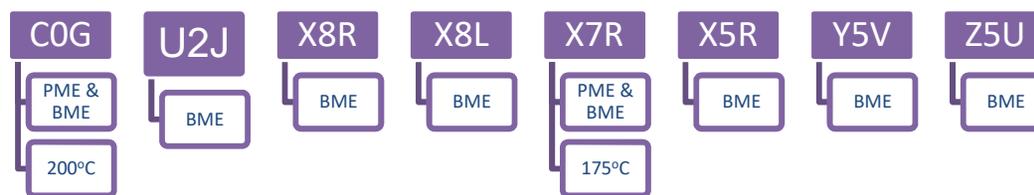
CLASS II

CLASS III

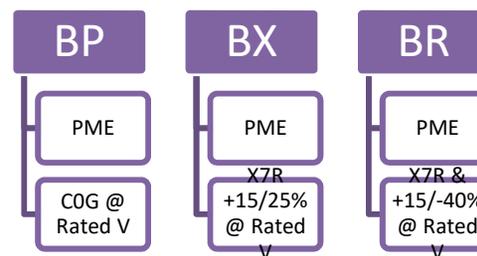
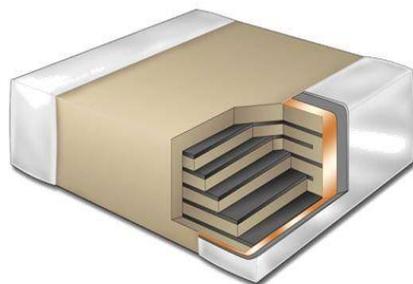
\* Industry Classification  
 (Non EIA-198)

# Dielectric Technology

## Commercial & Automotive Grade Dielectric Materials



## Military & Hi-Rel Dielectric Materials



# MLCC Capacitors

Pros	Cons
Small case size	Piezoelectric effect (class 2)
Wide voltage range	Cap loss with DCV (class 2)
Wide capacitance range	Flex cracks (large cases)
Wide temperature range	
Long life	
Low failure rate	
Ultra stable (class 1)	

# MLCC Cap Applications

- ***DC Link for Power Inverter***
- ***DC Filtering***
- ***Snubber***
- ***DC Pulse Discharge***
- ***AC Power Factor Correction***
- ***AC Motor Run***
- ***AC Harmonic Filter***
- ***Impedance matching***
- ***Decoupling***

# Thank You For Joining Us

- Stay Tuned For Information On
  - Capacitor Basics 201
- Learn more about ESL, ESR and getting a better understanding of design parameters.