High Voltage Film Capacitors

CDÉ CORNELL DUBILIER

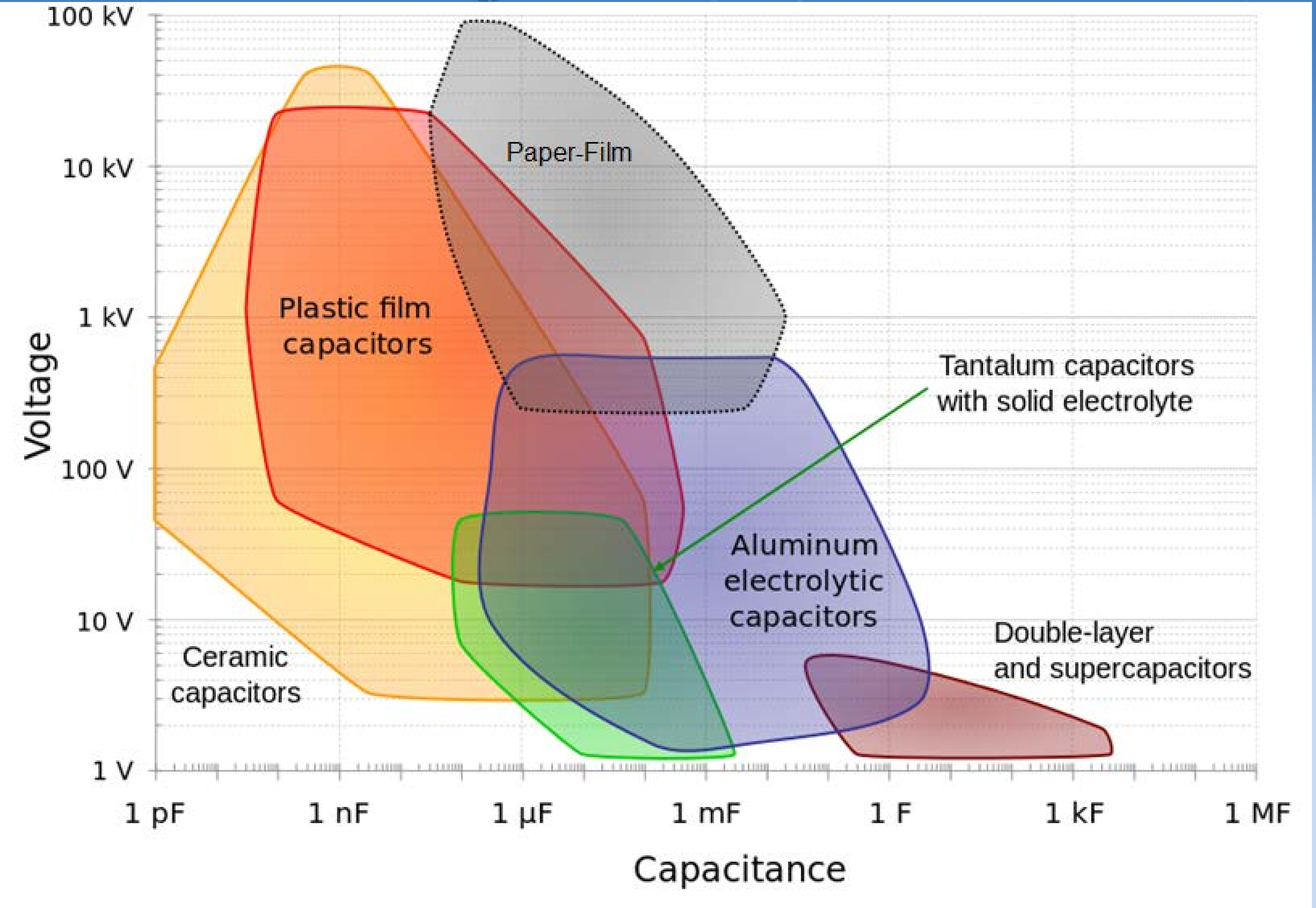
ENERGIZING IDEAS

High Voltage Film Capacitors

Everything you wanted to know about high voltage film capacitors, but were afraid to ask

- How do high voltage film capacitors (HVFCs) compare with other capacitor technologies?
- What films are typically used in HVFCs for power electronics applications?
- What are the most common applications for high voltage film capacitors?
- How do HVFCs compare with aluminum electrolytics
- What are the primary application considerations for HVFCs
- What are some of HVFC design options for meeting customer requirements

High Voltage Film Capacitors



High Voltage Film Capacitors

Common Capacitor Film Dielectrics

Material	Dielectric Constant (K)	Dissipation Factor , 1 KHz, 25°C	Maximum Dielectric Withstand (V/µm)	Max Operating Temperature (°C)
PET (Polyester)	3.2	<0.5%	<300	105-125
PEN	3.0	<1.0%	<270	105-125
Polypropylene	2.2	<0.1%	<350	85-105
PPS	3.0	<0.6%	<250	125-150
Polycarbonate	2.9	<0.3%	<275	125-150

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Polypropylene is the most widely used film dielectric for Power Electronics Applications

Advantages of Polypropylene

- High voltage breakdown strength
- Wide voltage range (50 to >10,000 Vdc)
- Very low loss, low DF (Dissipation Factor)
- High ripple current capability
- Good for AC or DC applications with ripple
- Dry or impregnated designs

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Disadvantages of Polypropylene

- Lower dielectric constant than other capacitor film dielectrics.
- Lowest high-temperature capability.

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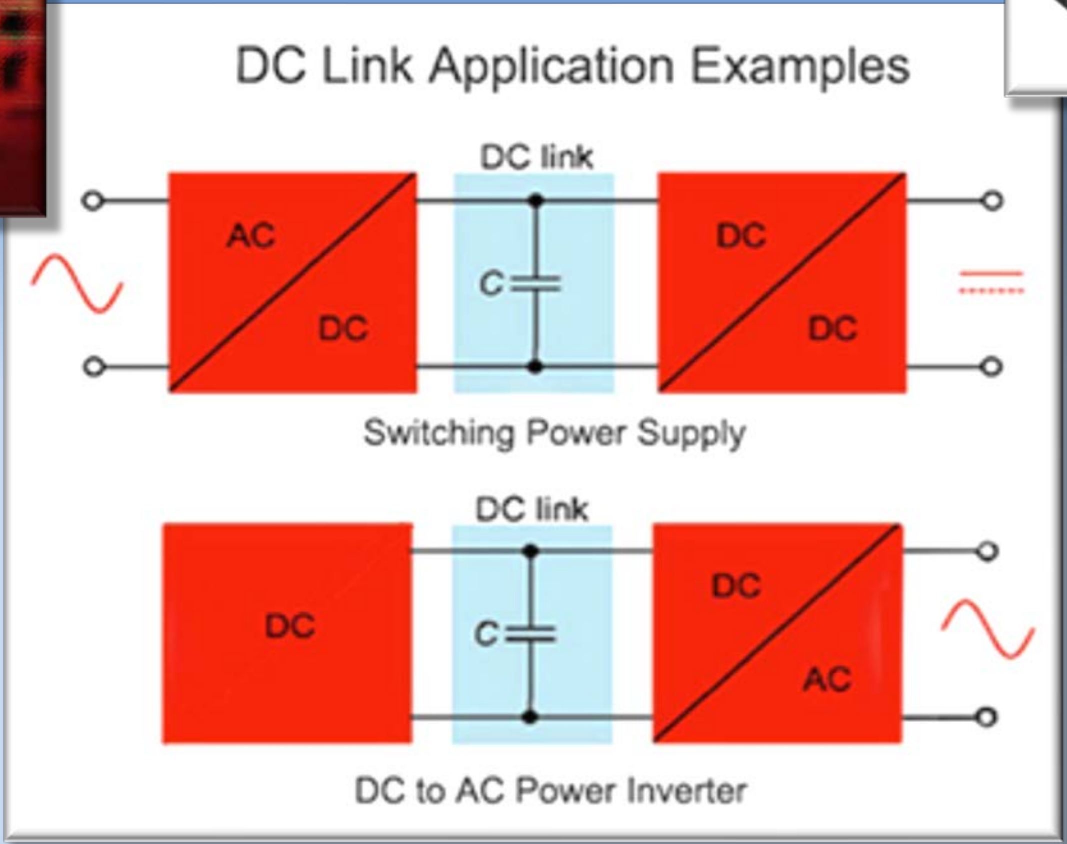
Typical Applications for polypropylene capacitors in Power Electronics

- High frequency Coupling / Decoupling (DC)
- High pulse operation (DC)
- Snubber for IGBTs (DC)
- DC Link (DC with ripple)
- Input / Output filtering (AC or DC)

High Voltage DC Film Capacitors

Capacitor Design example using Inverter DC Link



High Voltage DC Film Capacitors : DC Link

Capacitor Design example using Inverter DC Link

- Large inverters for grid-tie and commercial / industrial off-grid applications :
  - 10's of KW to MW
- IGBT switching frequencies:
  - several KHz to 50 KHz.
- Typical DC Link CV:
  - Voltage Range: 600-1500 Vdc
  - DC Link Capacitance: 10 µF to several mF

High Voltage DC Film Capacitors : DC Link

The two principal capacitor technologies for Power DC Link:

Characteristic	Aluminum Electrolytic 	Polypropylene Film 
Capacitance Range (µF)	10 - 10^6	10-3000
Rated Voltage Range (Vdc)	6.3 – 600	600-1500
*Energy Density (Joules/Liter)	100-800	200-250

*Comparison @ 450 Vdc

High Voltage DC Film Capacitors : DC Link

Cost Comparison: Aluminum Electrolytic versus PP Film:

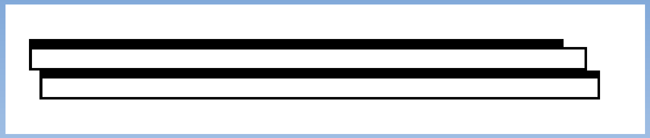
	$ Per Joule	$ Per Amp
Film	$0.20 – 0.50	$1
Lytic	$0.05 – 0.10	$3

High Voltage DC Film Capacitors: DC Link

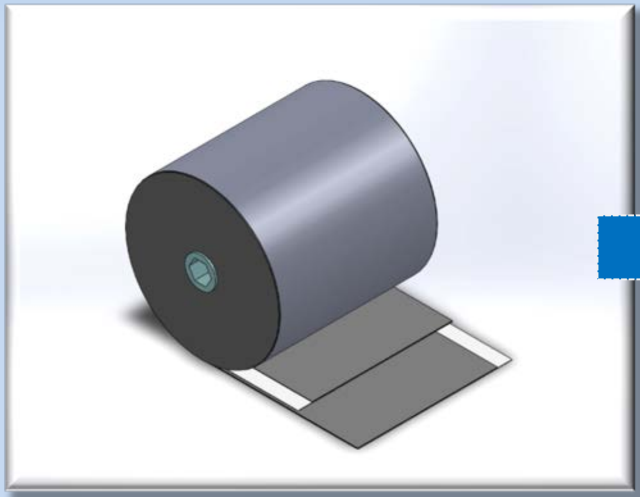
Basic Construction of a metallized Polypropylene Film DC Link Cap

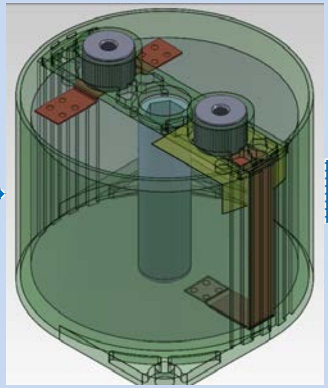
Metalized Electrodes

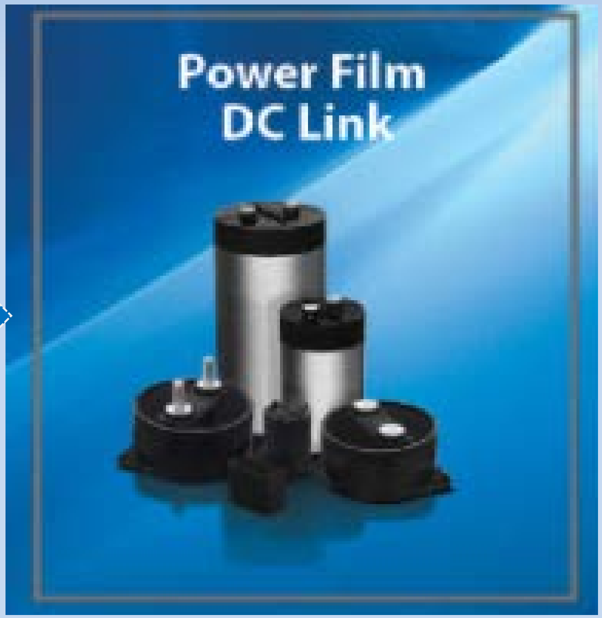
"Metalized Film Capacitor"



Self Healing Capability







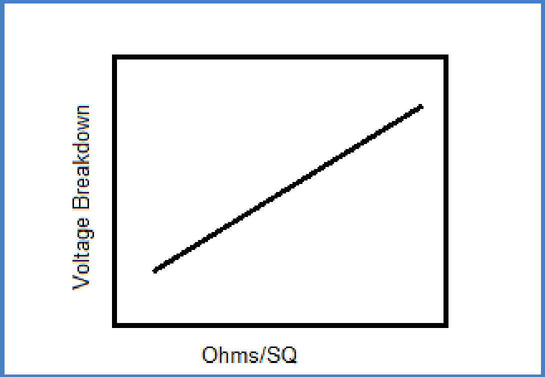
DC Link Film Capacitors: Primary Design Considerations

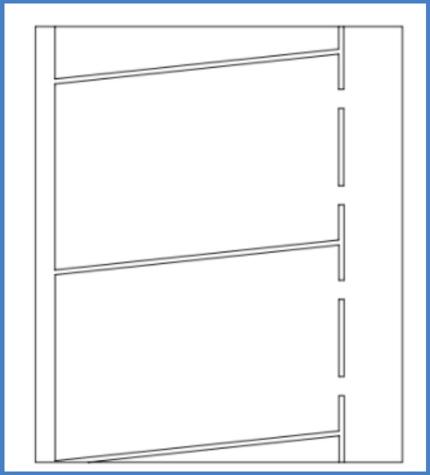
- Bus Voltage
- Total Cap (μF)
- Max Ripple Current
- Ambient Temp
- Life
- Reliability
- Inductance
- Size
- Mounting

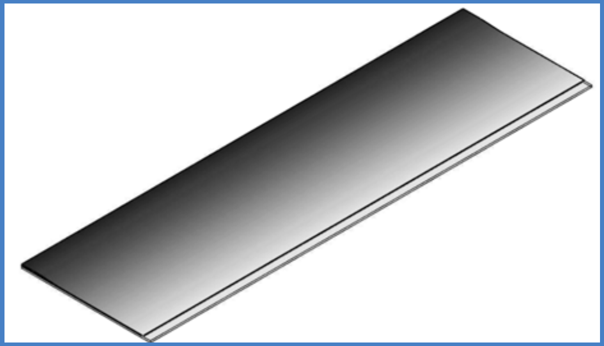
Capacitor Design Options: Voltage Rating

Need higher voltage?

- Increase dielectric thickness (V/µm)
- Metallization
  - Lighter metallization results in higher voltage rating for a given dielectric thickness
  - Metallized patterns such as segmented or graded metallization can improve voltage rating



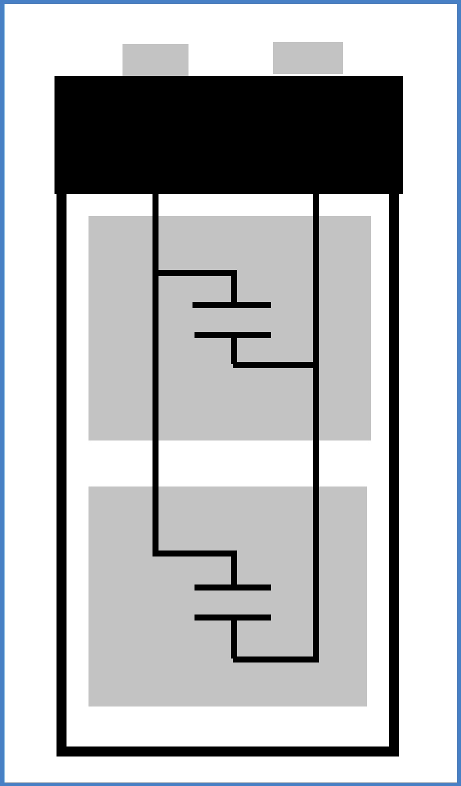




Capacitor Design Options: Capacitance

Need more capacitance?

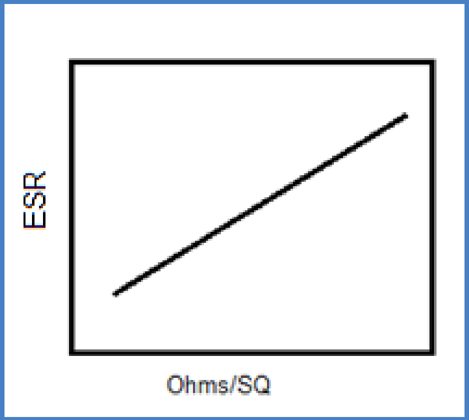
- Increase plate area, winding size
- Recommend capacitors in parallel
- Parallel-connect windings internally



Capacitor Design Options: Ripple Current

Need Higher Ripple Current?

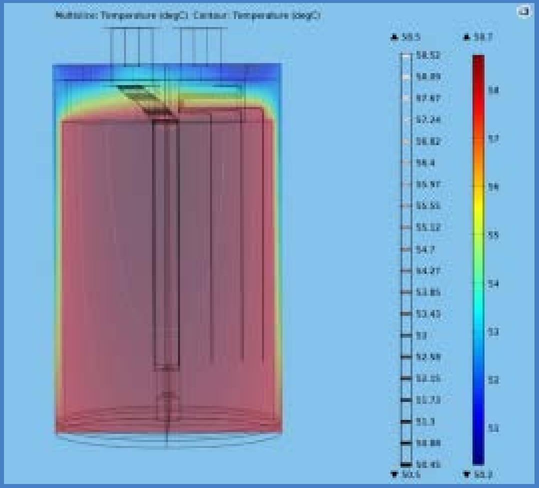
- Minimize ESR
    - Lower ohms per square metallization
    - Increase diameter of winding
    - Reduce capacitor height
- Improve heat dissipation
    - Increase capacitor surface area
    - Recommend air flow or cooling if needed

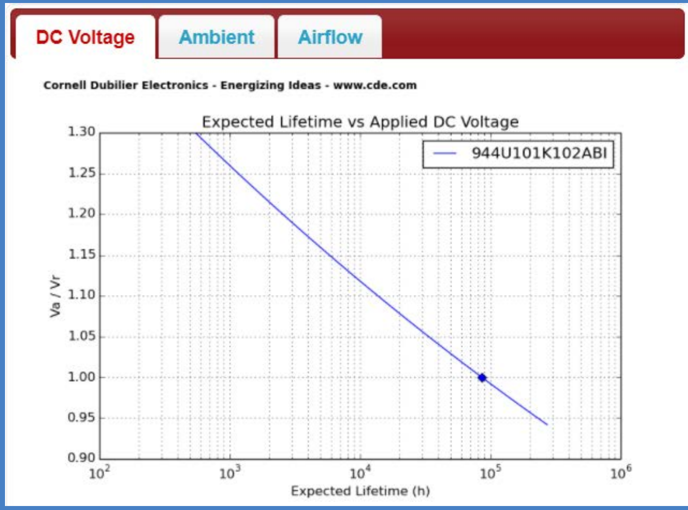


Capacitor Design Options: Life Expectancy

Need Longer Life?

- Thermal modeling
  - Thermal couple insertion
  - COMSOL thermal modeling
- Life Calculator
  - Applied voltage
  - Ambient temperature
  - Calculate hotspot
  - Airflow





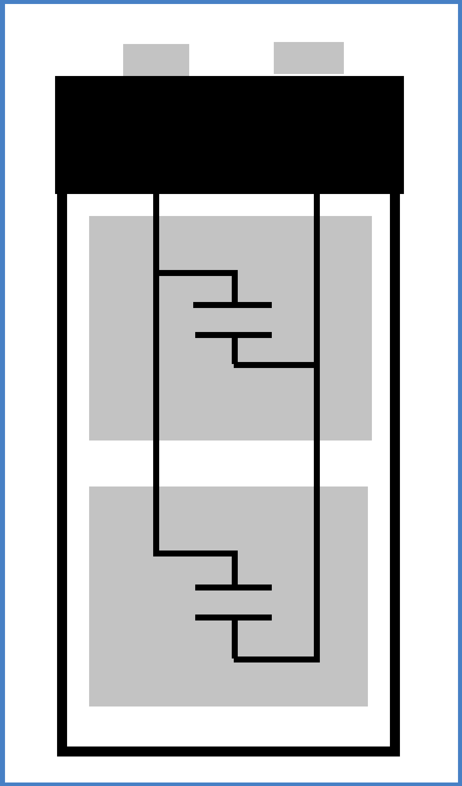
Capacitor Design Options: Reliability

- Need high reliability?
  - Base film selection
  - Metallization
    - Reliable self healing
  - Capacitor Processing (Key processes to control)

Capacitor Design Options: Inductance

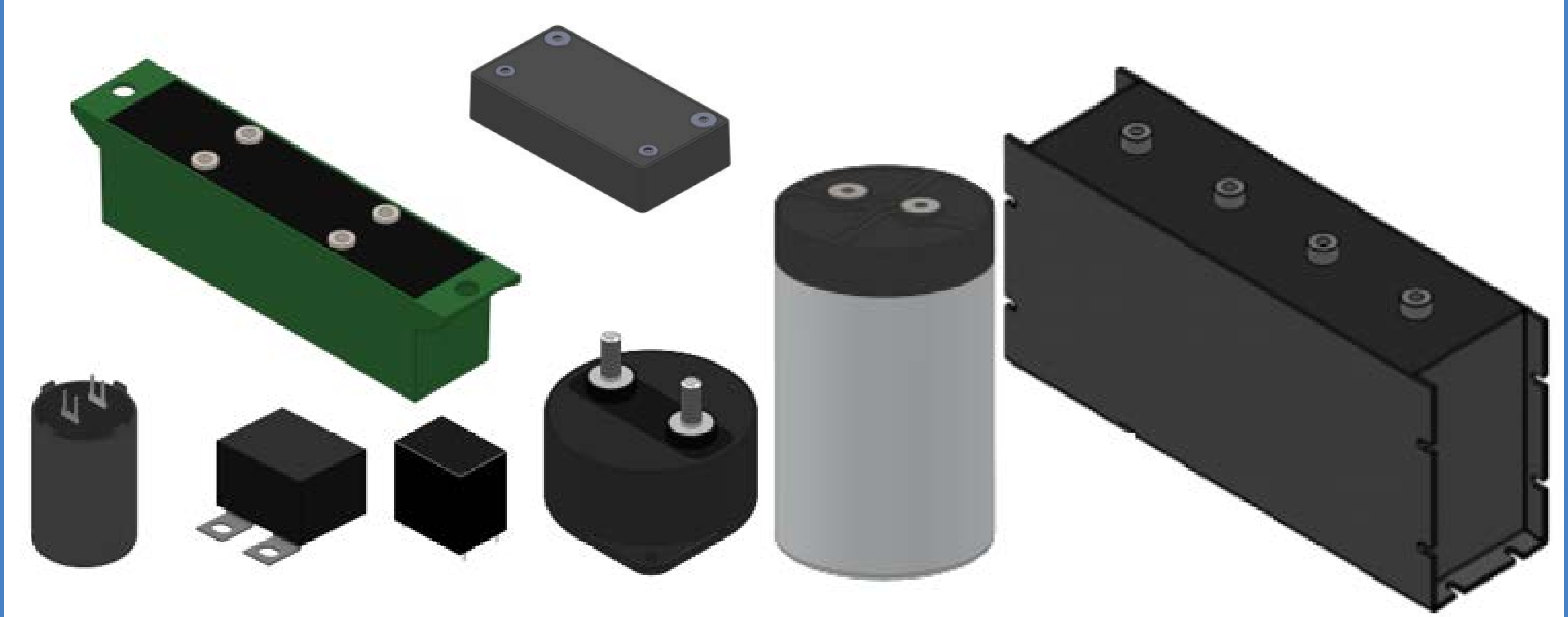
Need Lower Inductance?

- Shorter capacitor
- Geometry of leads and lead placement
- Two windings in parallel versus one



Capacitor Design Options: Size and Packaging

- Size Constraints
  - Energy Density
  - Form Factor
    - Cylindrical or Prismatic
- Mounting Preference
  - Bus Mount, Board Mount



Thank You!

High Voltage Film Capacitors

Bio for Scott Franco

- Bachelor of Science Degree in Physics from UMass, 1989.
- Began working at Cornell Dubilier in 1989 as AC and DC Film Capacitor Applications and Design Engineer
- Received MBA in 1997 from Bryant College.
- Transitioned from engineering to product management and sales management roles.
- Currently serves the company as Director of Market Development