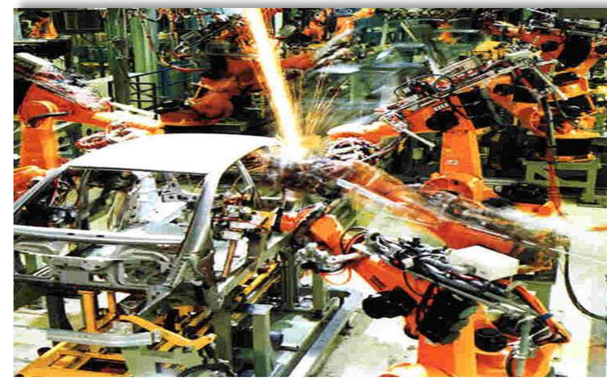
DC-Link Technology Comparison: Aluminum Electrolytic vs. Film Capacitors



Norbert Eumes

Verogenselectronica, Den Bosch, 14th June, 2018

14 juni 2018
1931 Congrescentrum Den Bosch

POWER ELECTRONICS 2018

• Aluminum Electrolytic

- Screw Terminal
- Snap-in
- Radial
- Polymer
  (Radial & SMD)

• Power film Capacitor

- DC-Link
- AC, X2
- Snubber
- Module
- Customized

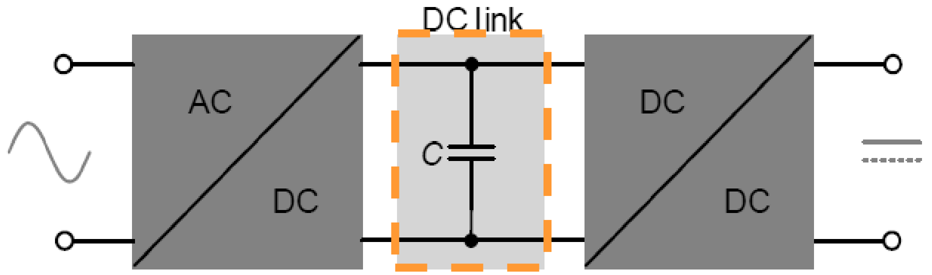
• Super Capacitor

- EDLC (Coin, Radial, Snap-in)
- LIC (Soft package, Radial)
- Modules

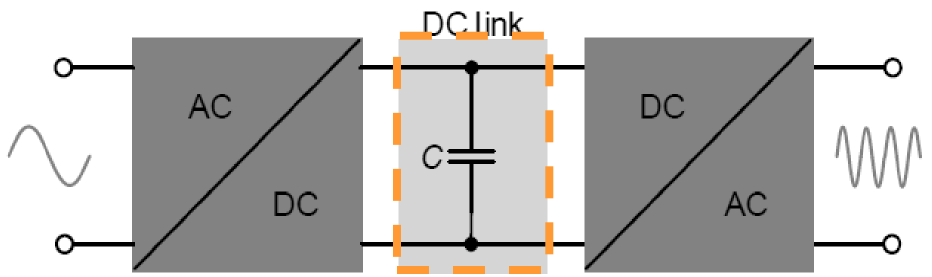
• Material & Sub-Parts

- **Etched foil**
- **Formed foil**
- Cover for screw
- Carbon coated foil
- **Metallized Film**
- Lithium Coated Copper Foils

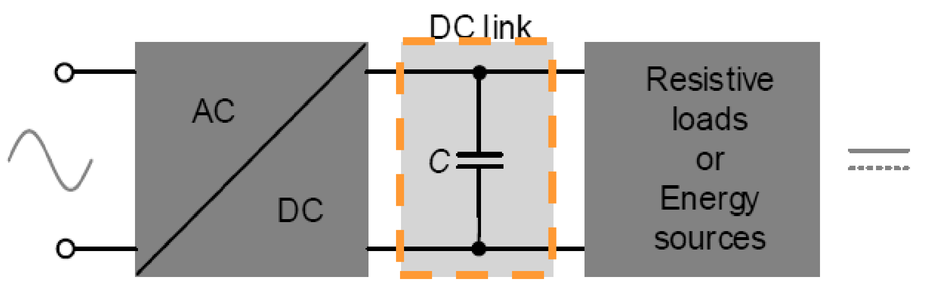
Typical Configurations of Power Electronic Converters with DC-Link Capacitors [1]



(a) AC-DC-DC or DC-DC-AC power converters with a DC-link.



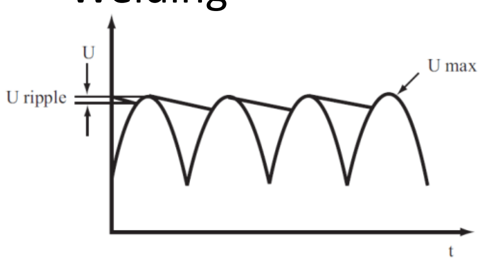
(b) AC-DC-AC power converters with a DC-link.



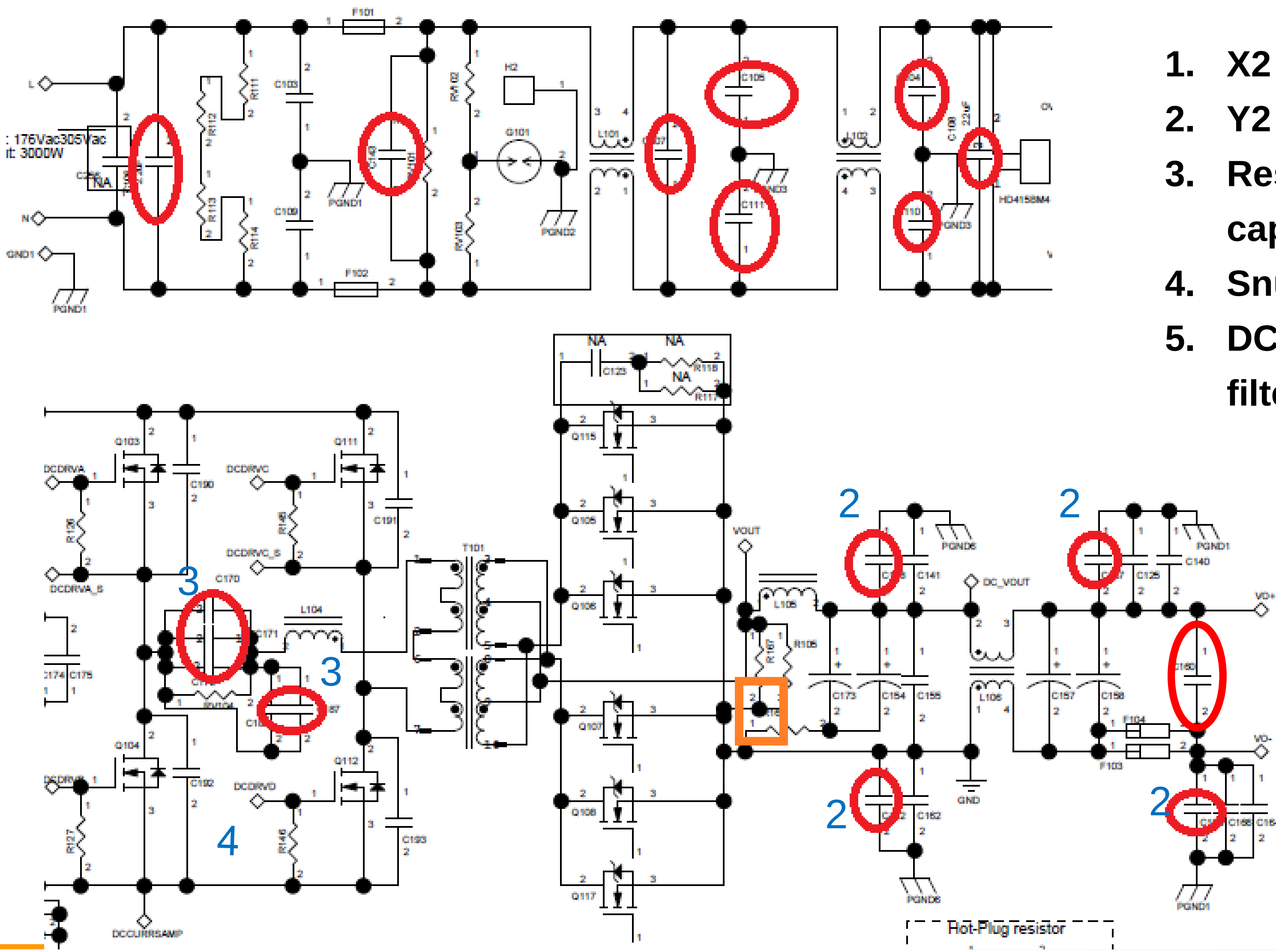
(c) AC-DC or DC-AC power converters with a DC-link.

Application Examples

- Wind Turbines
- Photovoltaic Systems
- Motor Drives
- Electric Vehicles
- Lighting
- Welding

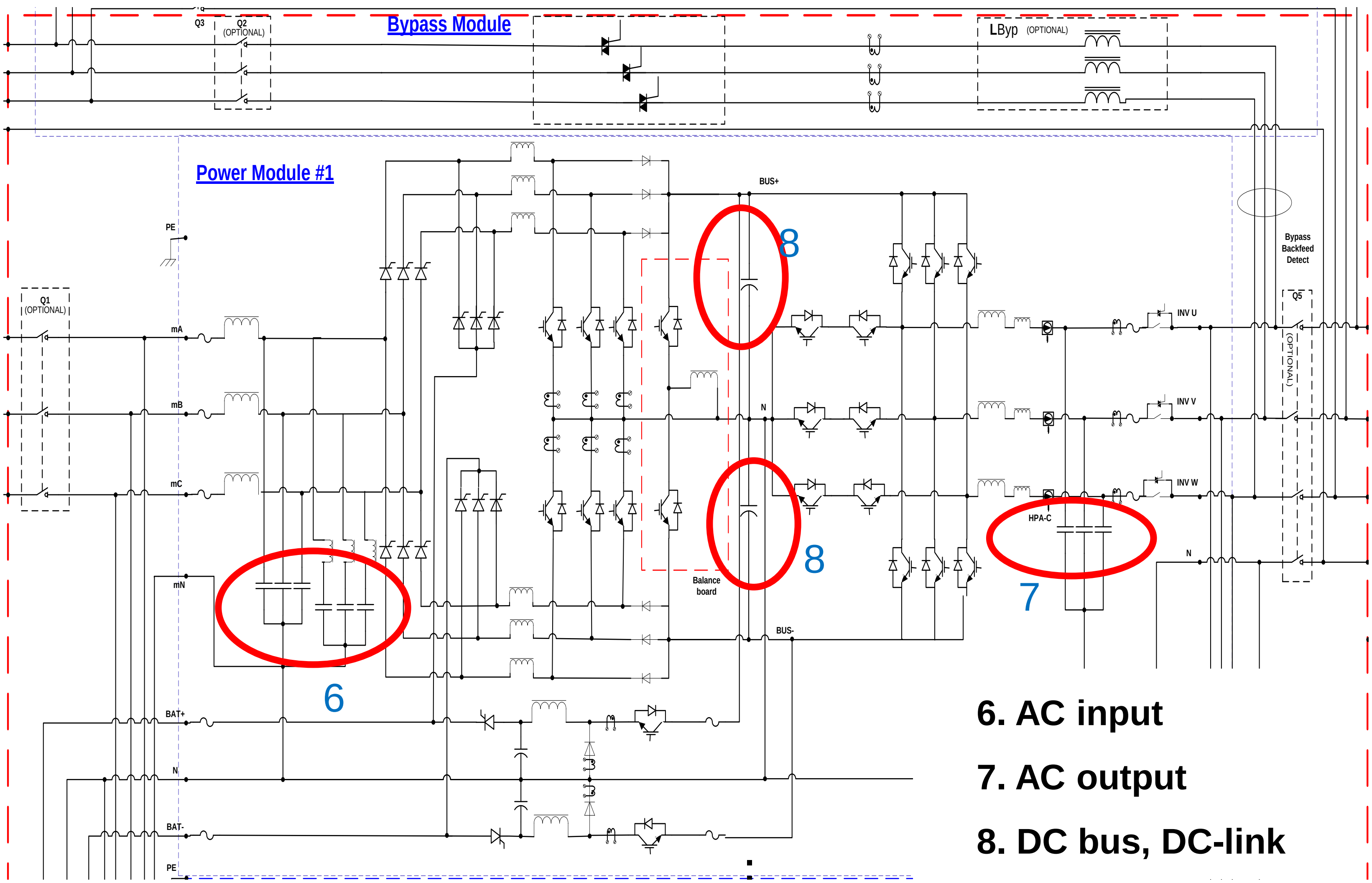


Capacitors found in switched mode power supplies



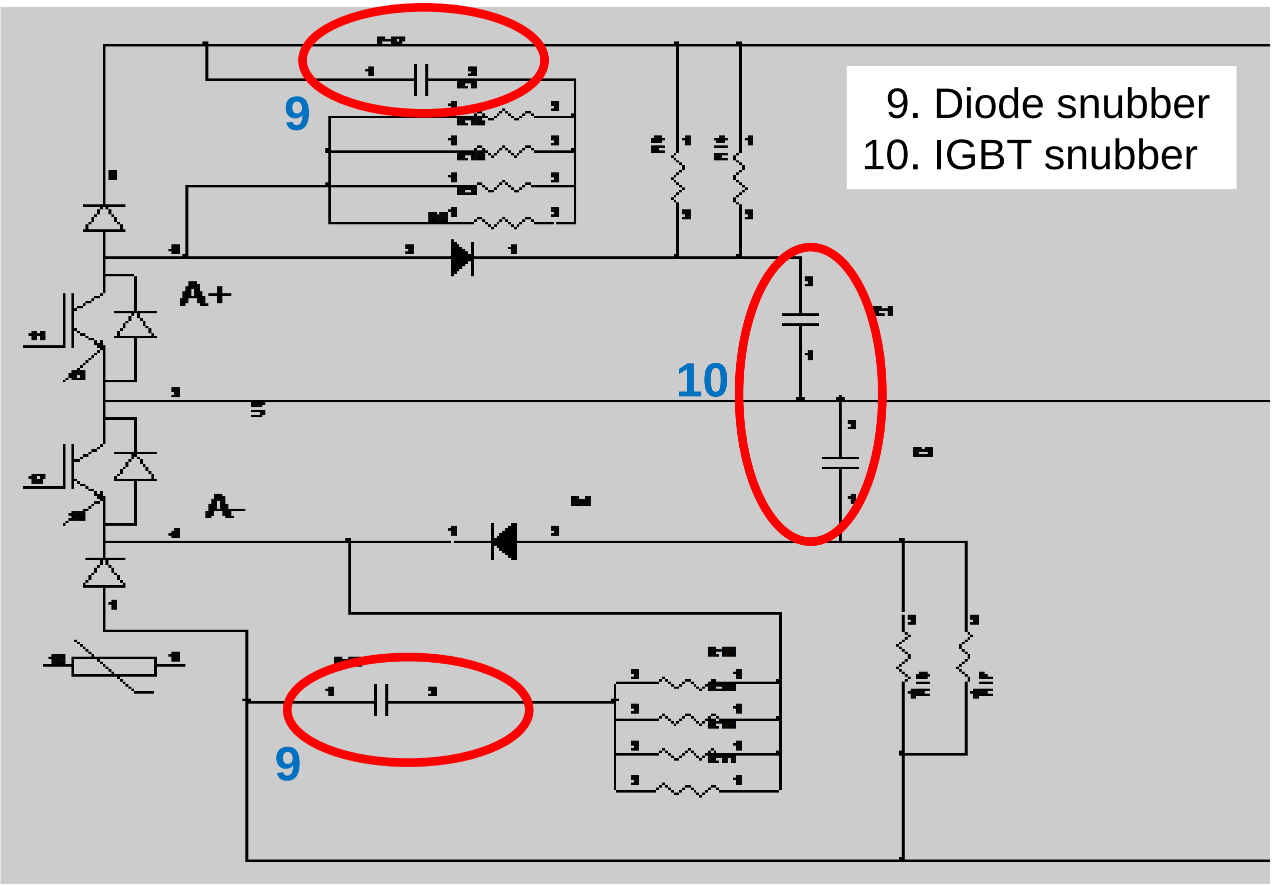
1. X2
2. Y2
3. Resonance capacitor
4. Snubber
5. DC output filtering

High Power Inverter

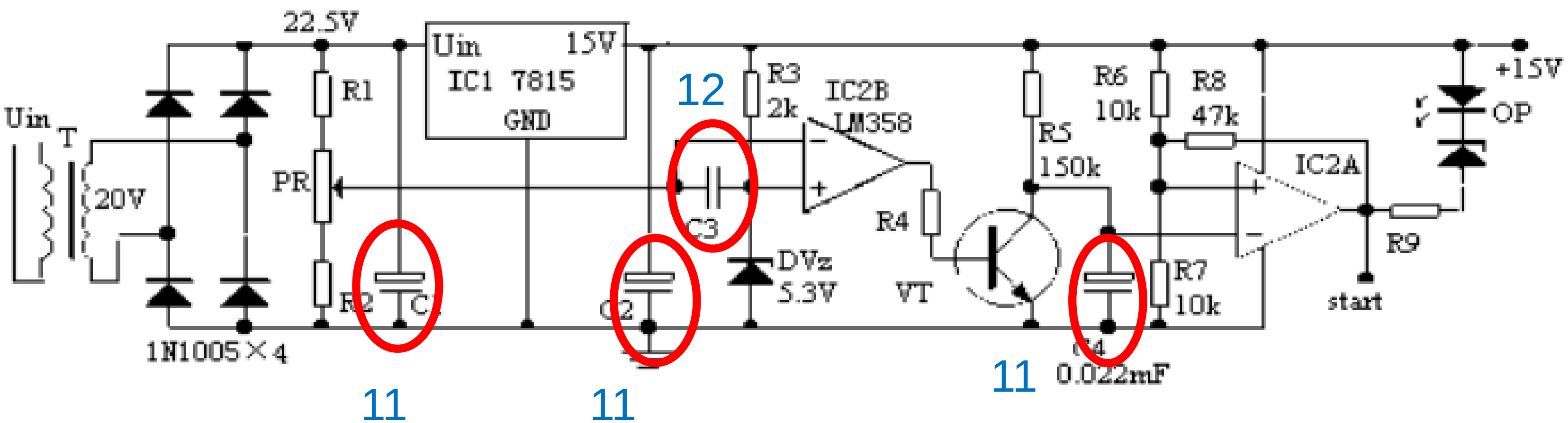


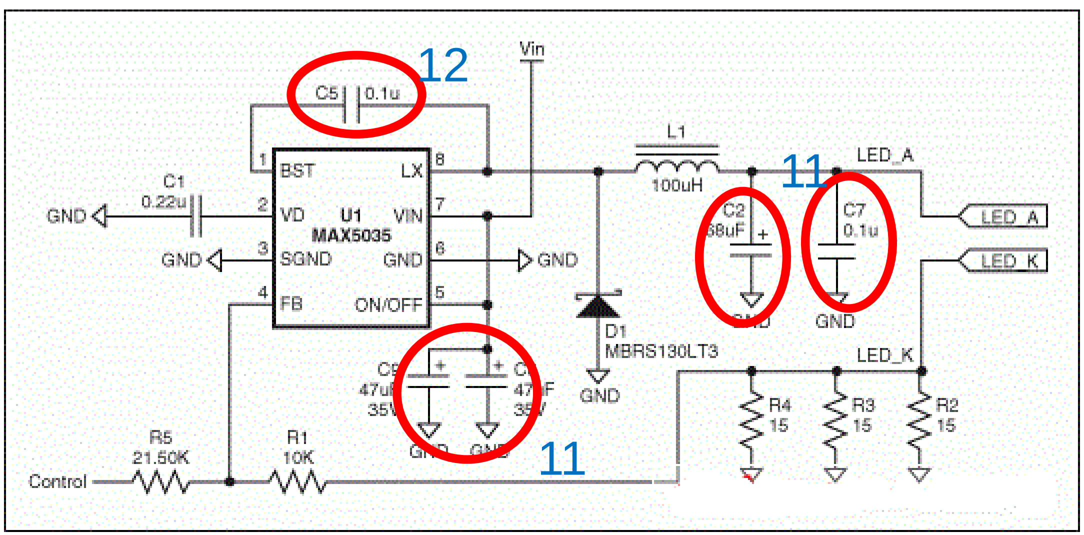
6. AC input
7. AC output
8. DC bus, DC-link

Snubber Circuits



Auxiliary Power Supply





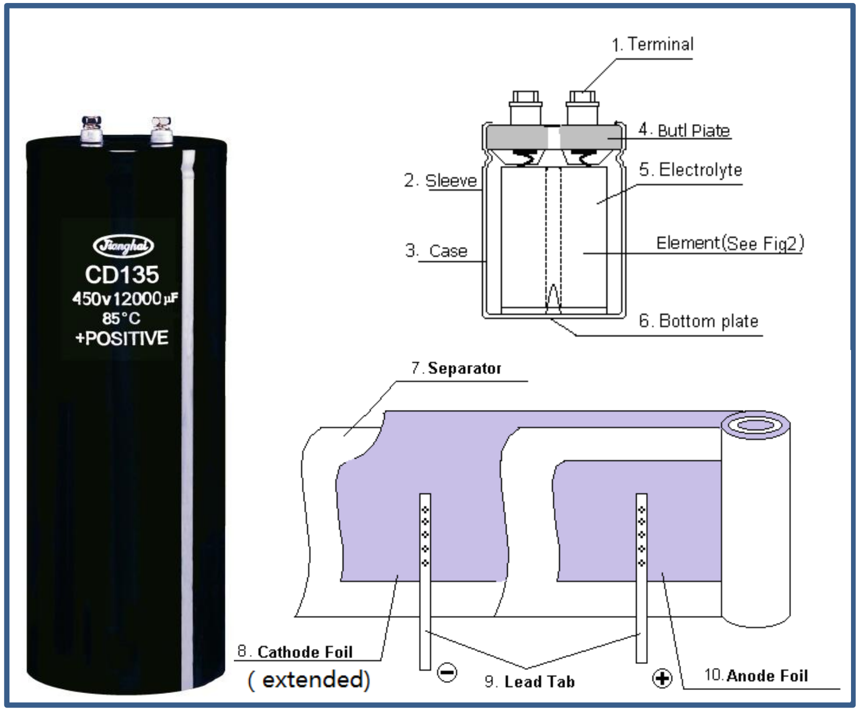
11. Filtering

12. Coupling

Typical Performance of various Capacitor Types

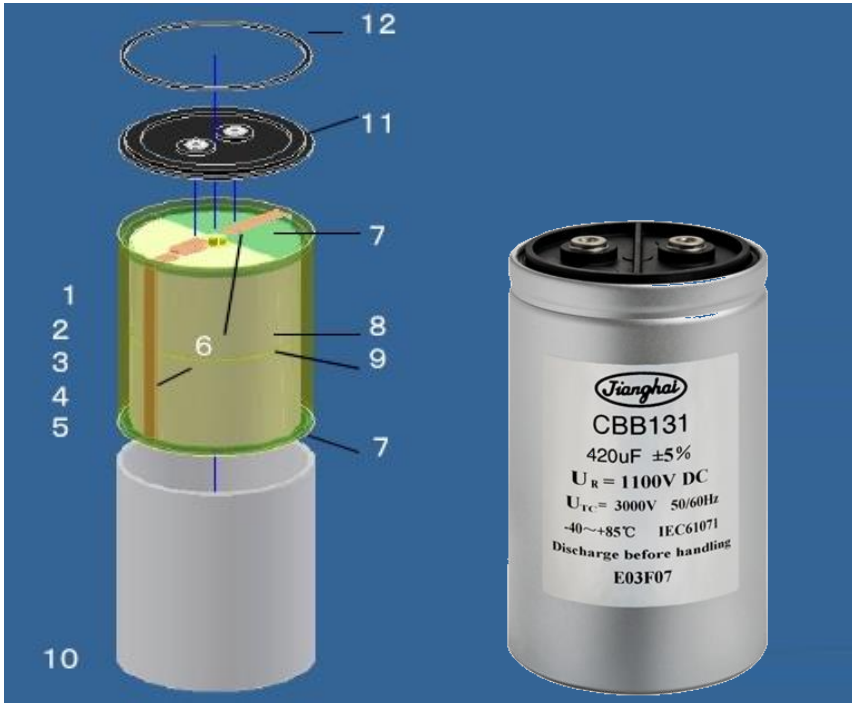
	Ceramic capacitors	Film Capacitors	Ta-Capacitors	Aluminum Electrolytic
Capacitance	1 pF – 10 µF	1 nF – 1000 µF	0.1 µF – 470 µF	0.1 µF – 1000 mF
Operating voltage range	10 ～ 3000 V	50 ～ 100000 V	6.3 ～ 50 V	2.5 ～ 650 V
Voltage drop	0.75	0.7	0.5	0.8
tan δ	0.001	0.01	0.10	0.25 – 0.05
Leakage current	small	small	large	large
frequency characteristics	good	better	Poor	depends
Operating temperature	-25,+85, -55,+125	-40,+85 -55,+105	-55,+125	-25,+85 -55,+105 or＋125
Rated life	No assessment	Long	Long	Short 2000—10000h
Capacitance Tolerance	±10％， ±15％ ＋30—80％	±5％， ±10％	±20％	±20％
Form Factor	Smaller	Small	Big	Large
Package Shape	Multilayer or Monolayer Ceramic	Boxed, cylindrical, radial tape on reel	SMD leaded: Single-ended, Axial	Cylindrical single-ended, Axial, Screw Terminal, SMD

Aluminum Electrolytic Capacitor



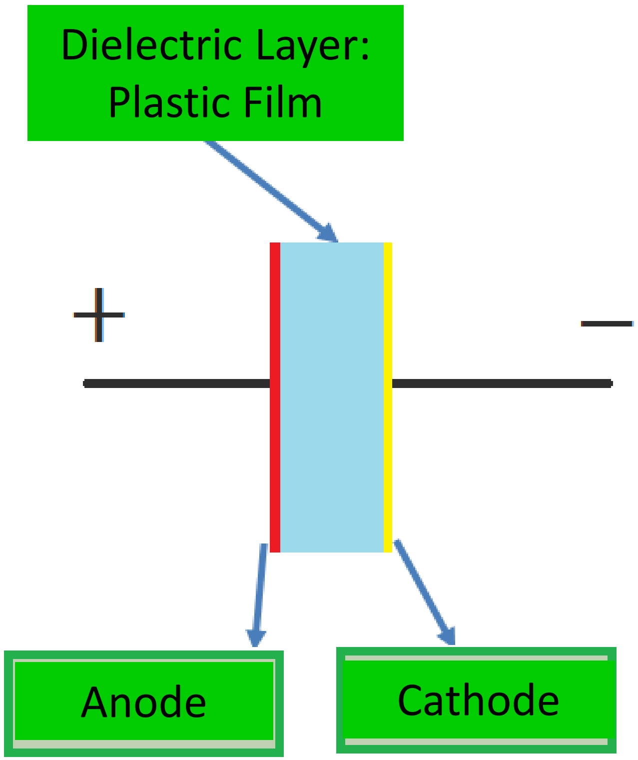
No.	Parts	Material
1	Terminal	Aluminum
2	Sleeve	Polyvinyl Chloride
3	Case	Aluminum
4	Top Deck	Duroplast
5	Electrolyte	**Organic Solvent**
6	Bottom Plate	Polyethylene Terephthalate
7	Separator	Electrolytic Capacitor Paper
8	Cathode Foil	Aluminum
9	Lead Tabs	Aluminum
10	Anode Foil	**Etched and Anodized Aluminum**

Polypropylene Film Capacitor

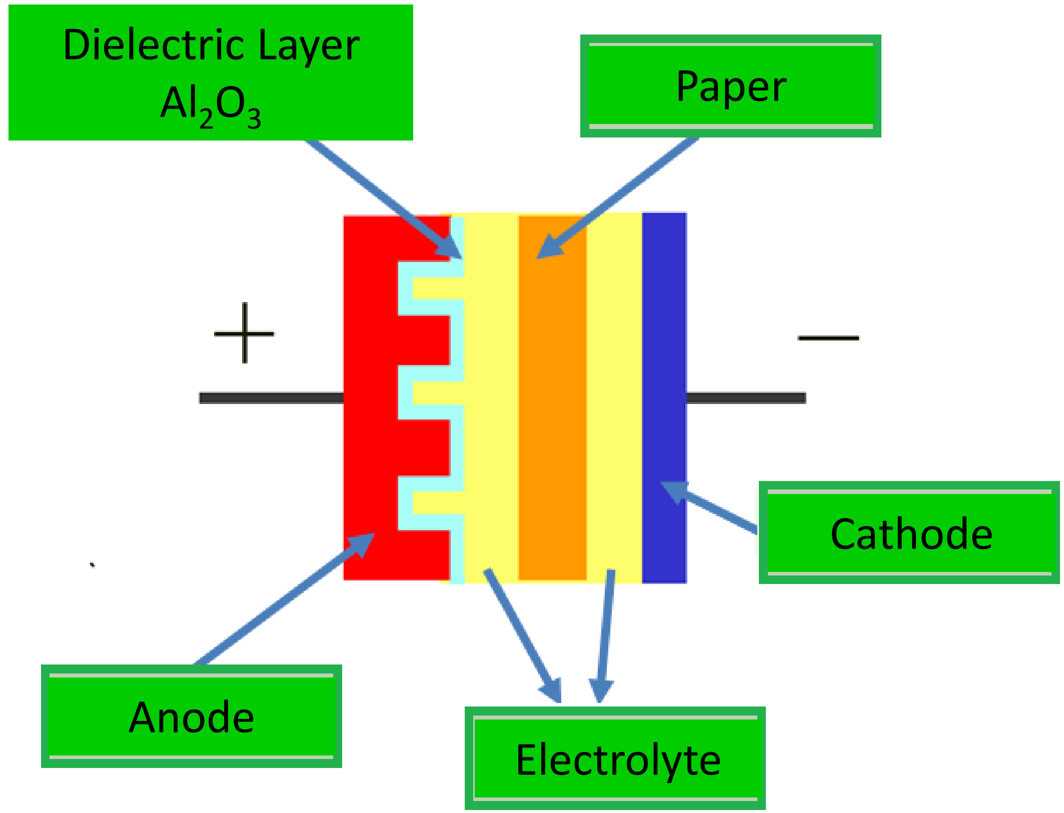


No.	Parts and Materials
1~4	Winding: **metallized BOPP Film**, Core Bar, Packing Film
5	Metal spray layer
6	Copper Strip
7	Isolation Cover
8	PU resin
9	Isolation Paper
10	Aluminum Can
11	Terminal Deck
12	Sealing Ring

DC film capacitors vs. electrolytic capacitors

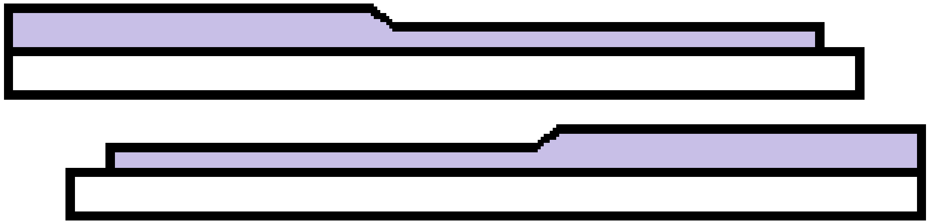


Film Capacitor

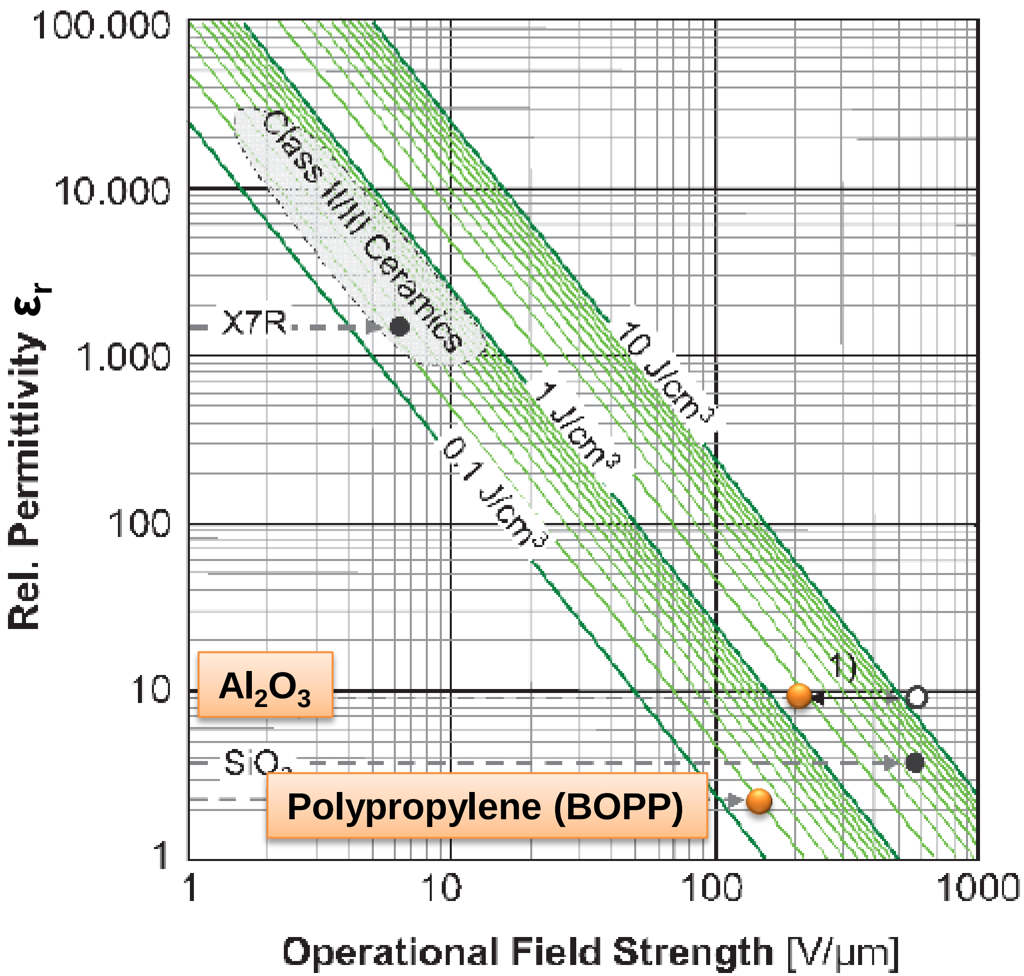


Electrolytic Capacitor

Metallized film structure (for DC-link products)



Energy Density: Aluminum Electrolytic Capacitor excels Polypropylene Film Capacitor



Energy Density [2]

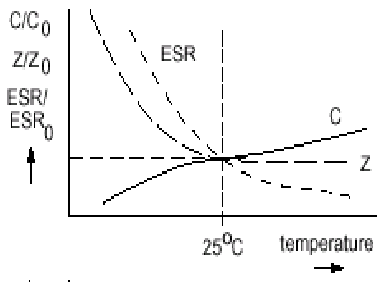
- Al_2O_3: 2 J/cm³
- BOPP: 0,2 J/cm³

Temperature and Frequency Characteristics

Aluminum Electrolytic Capacitor

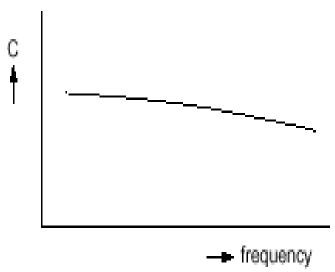
Temperature Characteristics

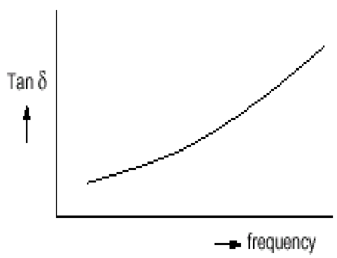
Parameters show strong dependency on T



Frequency Characteristics

Parameters show strong dependency on f

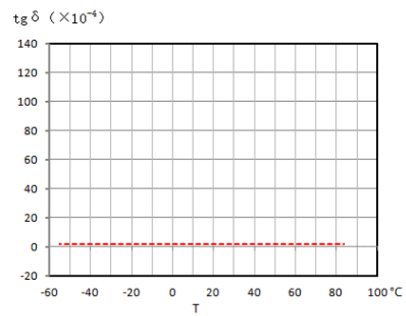




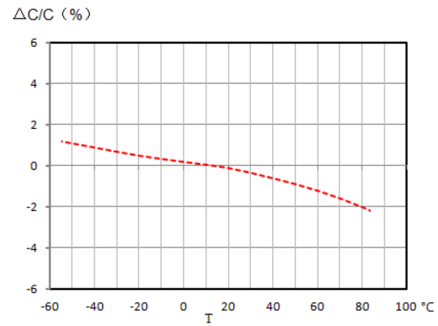
Polypropylene Film Capacitor

Temperature Characteristics

Parameters show weak dependency on T



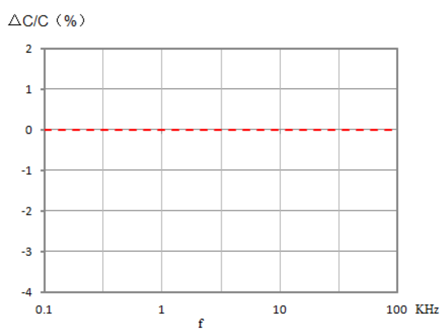
Dissipation factor VS. temperature（1KHz）



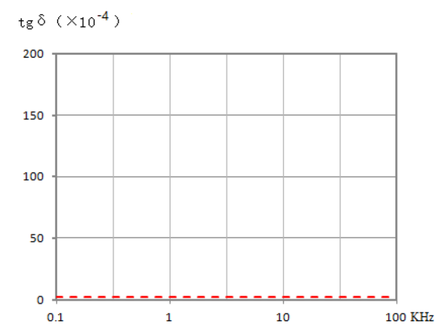
Capacitance VS. temperature（1KHz）

Frequency Characteristics

Parameters show flat dependency on f



Capacitance VS. frequency（20℃）



Dissipation factor VS. frequency（20℃）

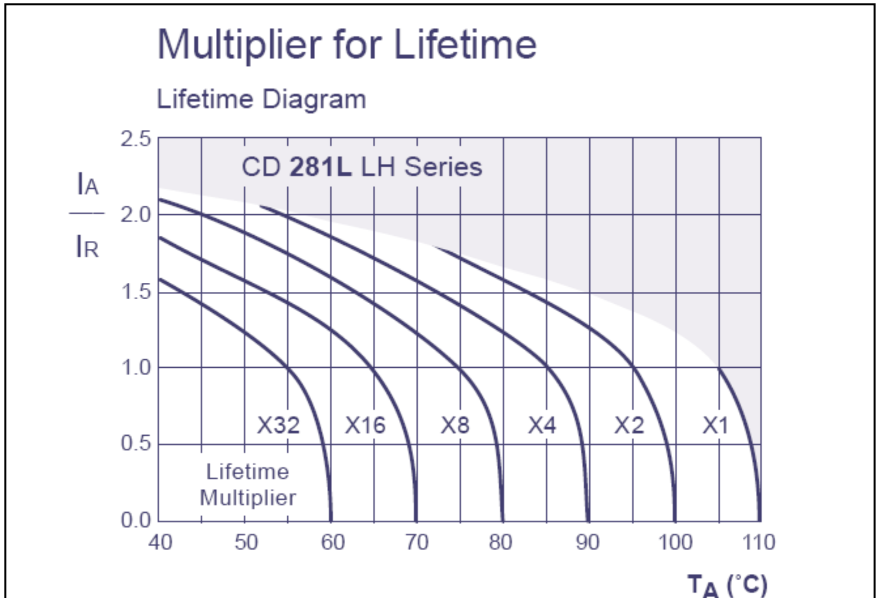
Comparison of Failure Modes and Self-Healing Capabilities [1]

	Alu e-caps	PP film caps
Dominant failure modes	wear out open circuit	wear out open circuit
Dominant failure mechanisms	electrolyte loss electrochemical reactions	moisture corrosion dielectric loss
Most critical stressors	$T_{ambient}$, V_{op}, I_{ripple}	$T_{ambient}$, V_{op}, humidity
Self-healing capability	moderate	good

Aluminum Electrolytic Capacitor

Typical End of Life Criteria

- Capacitance drop 20 ~ 30%
- tan δ doubled ~ tripled
- Leakage current beyond original limit

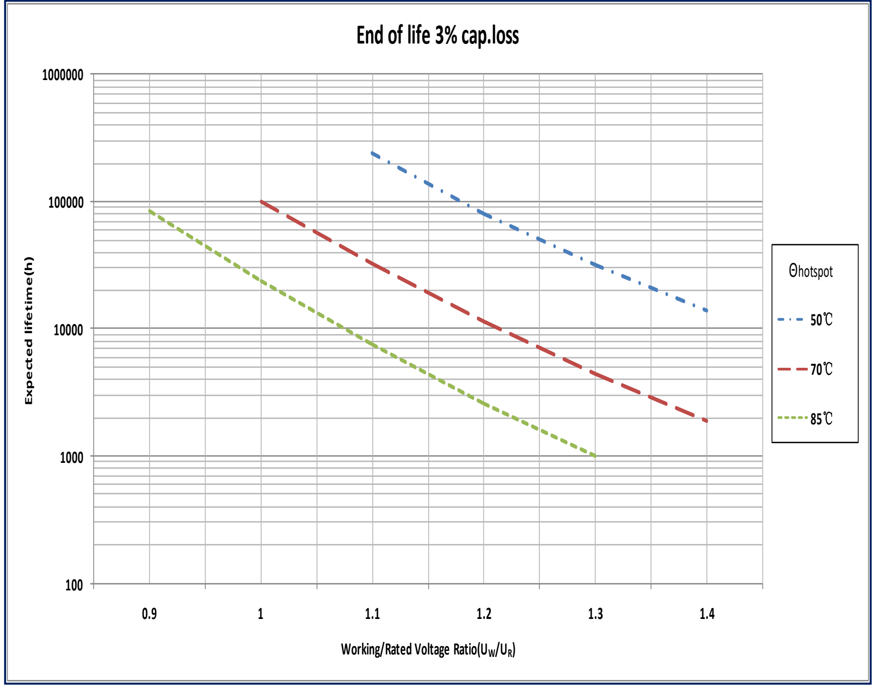


I_A = actual ripple current at 100kHz, I_R = rated ripple current at 100kHz, 105°C
Multiplier of Useful Life as a function of ambient temperature and ripple current load

Polypropylene Film Capacitor

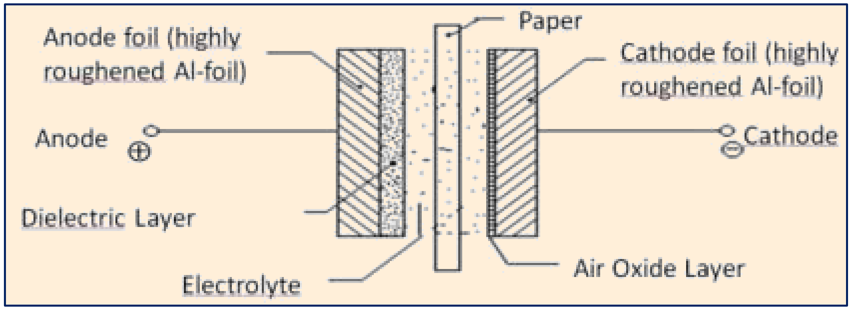
Typical End of Life Criteria

- Capacitance drop 3%
- tan δ doubled ~ tripled



Qualitative Performance Comparison [1]

Category	Al-Caps	PP Film-Caps
Capacitance	Green	Yellow
Voltage	Red	Green
Ripple Current	Yellow	Green
ESR and tan δ	Red	Green
Frequency	Red	Green
Capacitance stability	Yellow	Green
Voltage Derating	Yellow	Green
Temperature Range	Yellow	Yellow
Reliability and Lifetime	Yellow	Green
Energy Density	Green	Red
Cost per Joule	Green	Yellow
Cost per Ampère	Yellow	Green



Foil capacitance (µF/cm²)
Ex. 530V$_f$ (for 400V capacitor)

0.68 — t = 110µm
0.72 — 115µm
0.75 — 120µm
0.88µF/cm² — 140µm

530V$_f$: 0.88µF/cm²
590V$_f$: 0.75µF/cm²
640V$_f$: 0.64µF/cm²

Inorganic acid
- Long lifetime
- Stable

Mixed acid
- High capacitance

Etched Foils
- High strength
- High capacitance

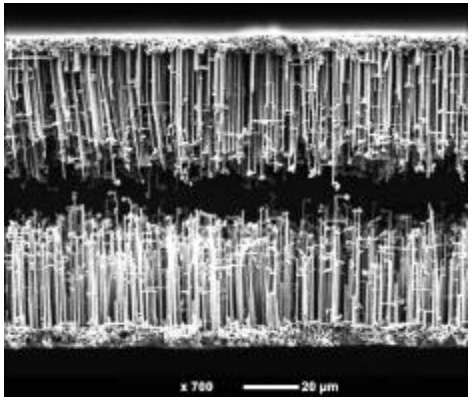
"HG" type
- High ripple current
- Charge and discharge
- Best performance

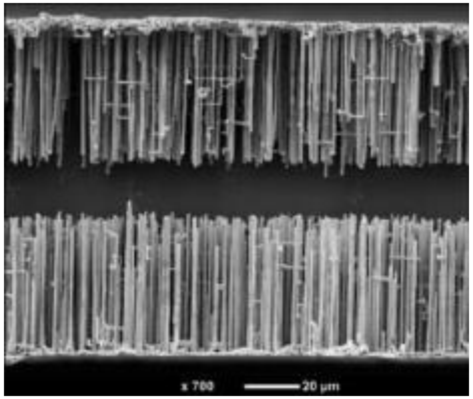
Super high voltage
- **Forming**: 1000V$_f$ Forming voltage for 750V capacitor
- 3 lines 800 ~ 900V$_f$
- **Etching:** Low voltage, high cap. foil for automotive

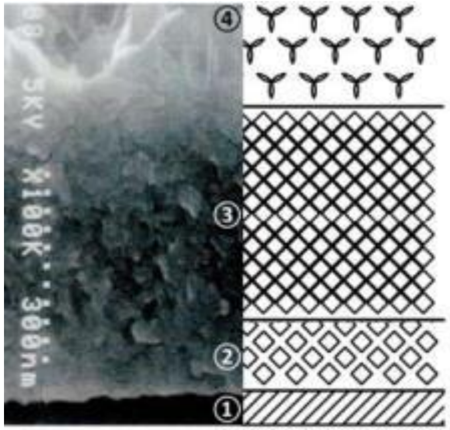
"HEAP" Type Foils
- Ultra high Capacitance

2008 | 2010 | 2012 | 2014 | 2016 | 2019 | 2021

120µm anode foil **140µm anode foil** **Cross-section of the dielectric layer**







Increased aluminum foil thickness and improved etching

- +15 ~ +20 % more capacitance and improved tensile/bending strength

+ Optimized dielectric layer for low losses at high switching frequencies

- Increased ripple current capability

= More compact dc-link capacitor banks

Jianghai to start JV for new base film material production

- EV/HEV
- Solar
- Wind
- Inverter
- Traction

Capacitor Products

- DC-Link (cylindrical, boxed, leaded)
- Snubber (boxed, leaded)

- Customized types
- Automotive (105˚C)

- AC capacitors dry & oil impregnated
- X

- High voltage 3~5kV
- Larger capacitance
- Automated production line
- Y1, Y2

- Ultra high voltage (10 kV)
- Large capacitance (80.000 µF)

Pre-Material

Film capacitors

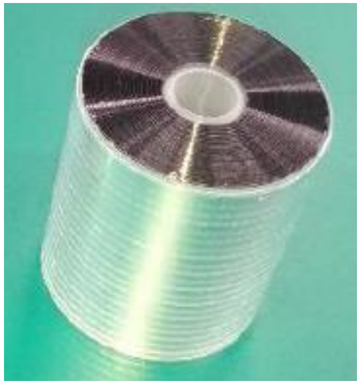
Film Metallization
Minimum thickness 2,8µm; PP: 2,2µm; PET: 1,2 µm

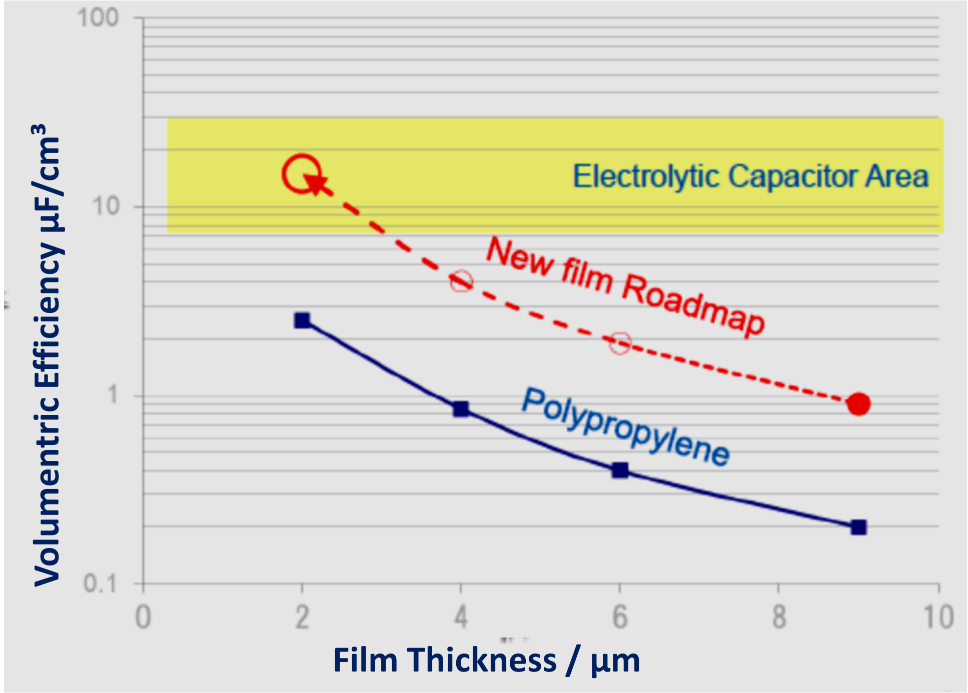
Base film PP & PET

New Base Material
Higher ε_r, Higher T_{max}

2011 | 2014 | 2016 | 2018 | 2020 | 2022

New base film material to offer high volumetric efficiency





PP
ε_r = 2,2
9 µm thick
D x L = 29 x 30
V = 19,8 cm³

New Material
ε_r = 12
9 µm thick
D x L = 15 x 30
V = 5,3 cm³

For film thicknesses < 3µm, the volumetric efficiency compares to that of aluminum electrolytic capacitors.

New base film material – development schedule

Jianghai Innovations enable new capacitor solutions

1. Enhanced anode foils for aluminum electrolytic capacitors

- ✓Increased aluminum foil thickness (140 µm) and optimized etching
- ✓Specific capacitance gain 15 ~ 20 %
- ✓Dielectric layer for low losses at high switching frequencies
- ✓Target application: compact dc-link capacitor banks
- ✓Engineering samples 2H 2019

2. Novel dielectric plastic film material for dc-link film capacitors

- ✓High permittivity $\varepsilon_r > 5$
- ✓High operating temperature $T_{operation, max.}$ = >125 ˚C (150 ˚C)
- ✓Proprietary, patent pending plastic material
- ✓Joint Venture operations for production and marketing under preparation
- ✓Target application: drives, electric vehicles and hybrid vehicles
- ✓Engineering samples 1H 2020

Talk to us!


Jianghai
A5000
SGP
2.7v 2000 F
SGP
2.7v 650 F
CBB131
CBB136
CD137
400v18000μF
85°C
+ POSITIVE