Electromobility xEV

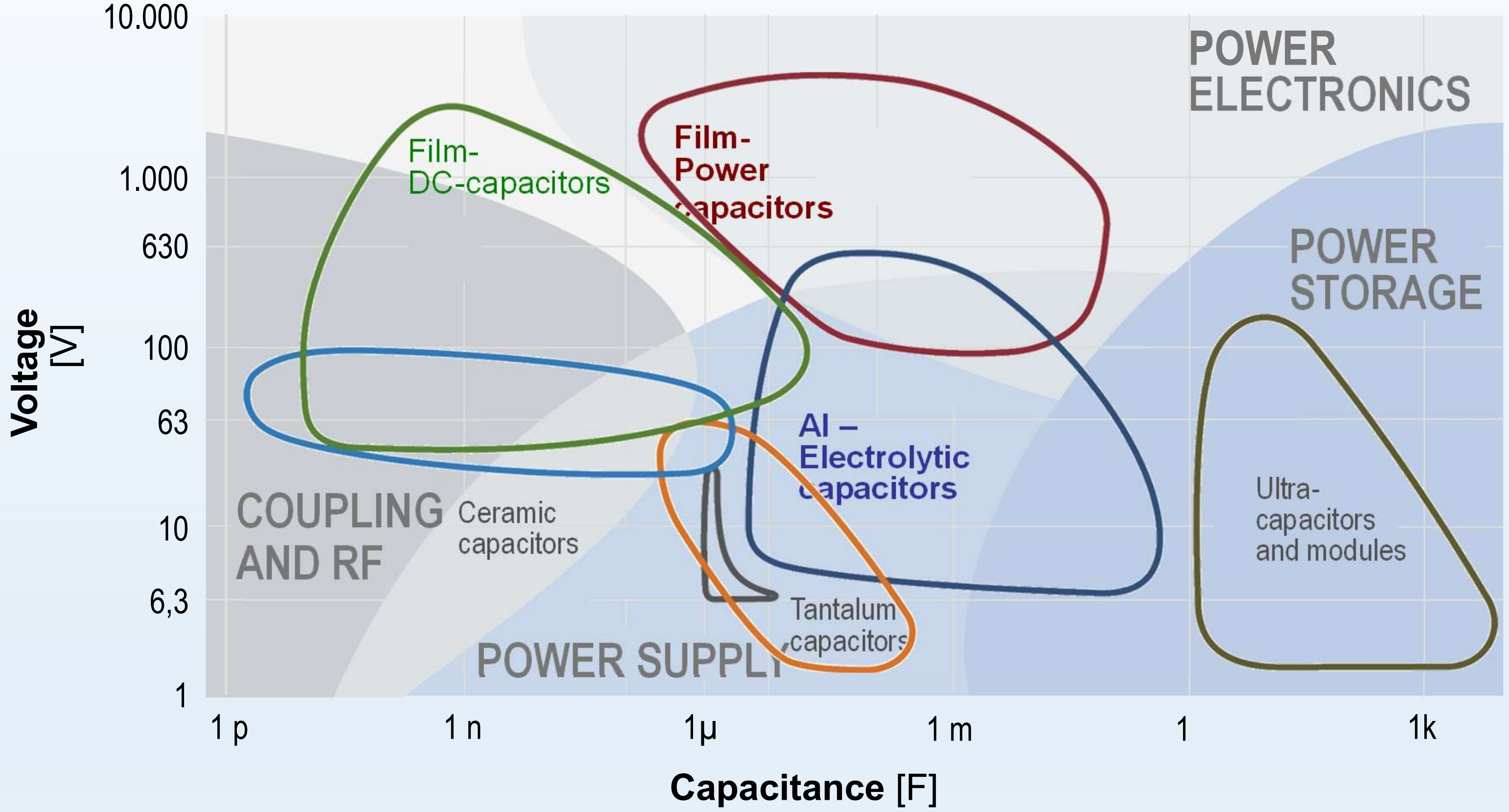
Capacitors Overview / DC-Link Capacitor Technology

by Dipl. Ing. Wolfgang Rambow | February 2025 | www-mankel-engineering.de

Content

1. Capacitor Technology

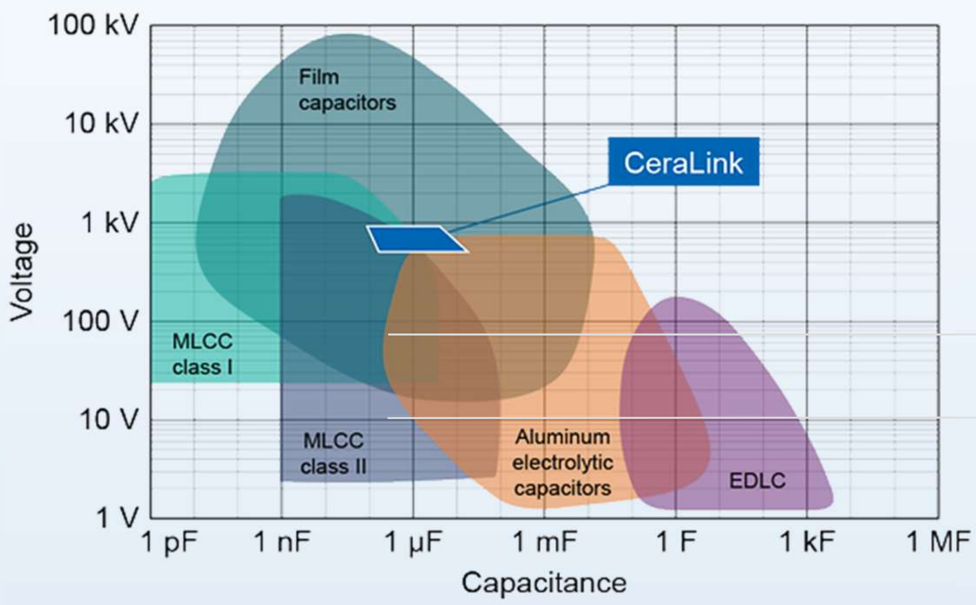
Capacitor versus application → 2010



Source: TDK

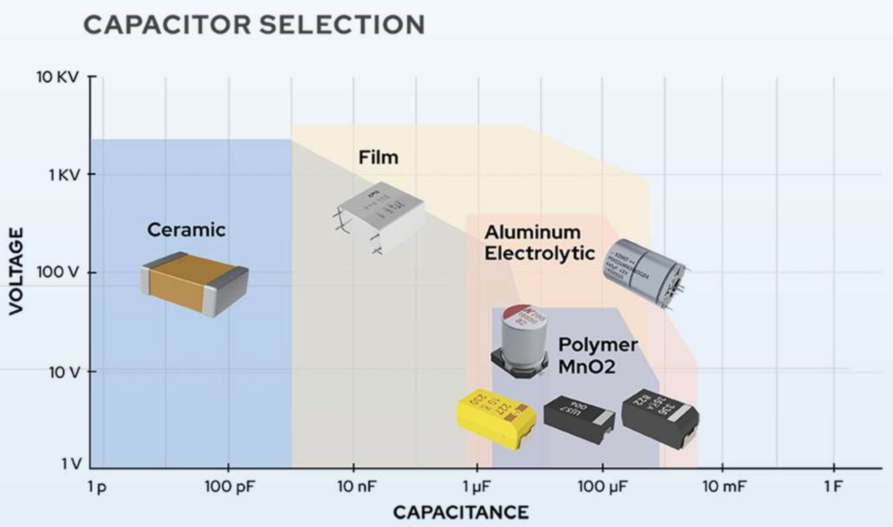
1. Capacitor Technology

Capacitor versus Technology → 2021



Newcomer CeraLink added

Source: TDK

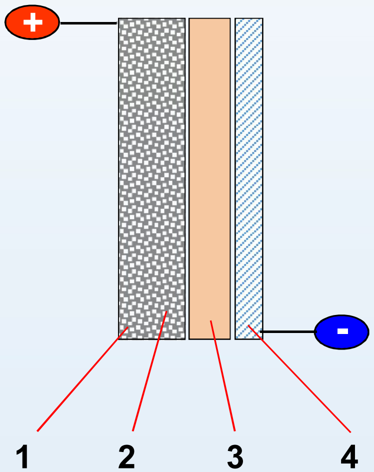


Source:KEMET

1. Capacitor Technology

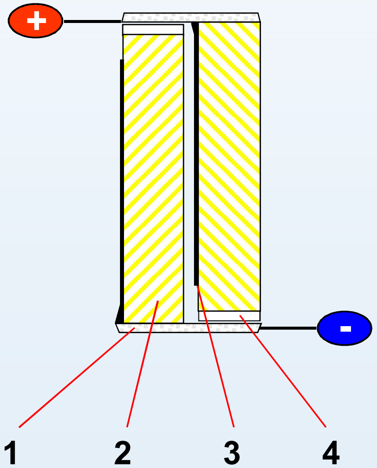
Focus Capacitor Technology*

Alu



1) Al-anode foil
2) Al_2O_3 dielectric area
3) Electrolyte and paper
4) Al-cathode foil

Film

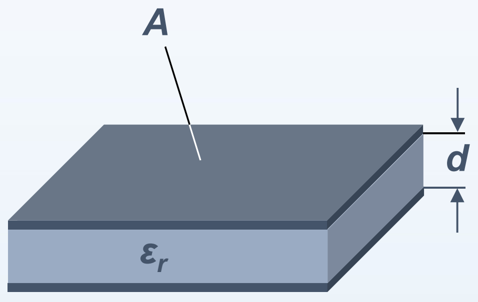


1) Metal Spray Layer
2) Polymer dielectric film
3) Metallized electrode
4) Wave cut

* The focus for power capacitors in this compilation is on Aluminum electrolyte and Film (Foil), with the latter dominating the automotive power train sector.

1. Capacitor Technology

General Formula



$$C_{vol} \propto \varepsilon_r \cdot 1/d^2 \left[F/m^3\right]$$

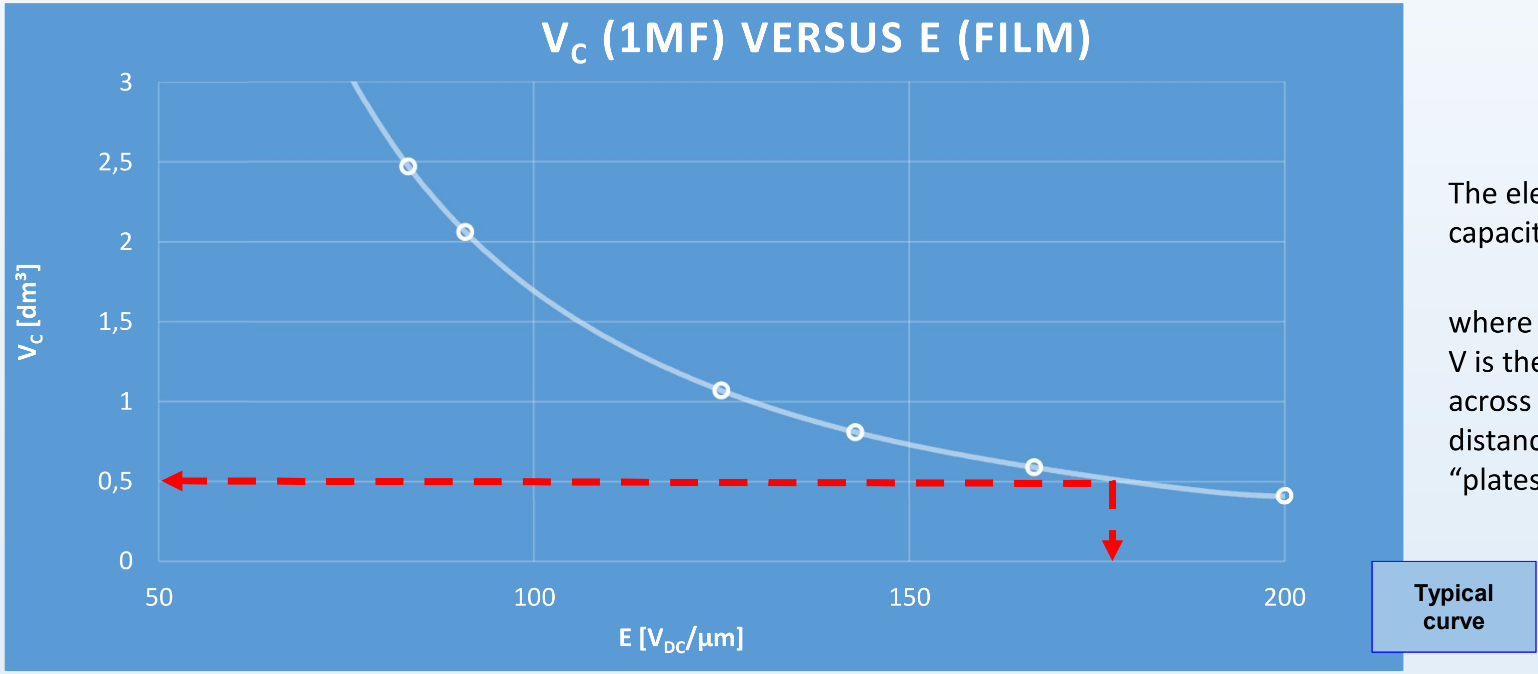
$$W_{vol} \propto \varepsilon_r \cdot E_{\max}^2 \left[J/m^3\right]$$

$$C = \varepsilon_0 \cdot \varepsilon_r \cdot \frac{A}{d}$$

C = Capacity	[As/V]
ε_0 = El. field constant ($8{,}854 \times 10^{-12}$)	[As/Vm]
ε_r = Dielectric constant	[-]
A = Active area of capacitor	[m²]
d = Thickness of dielectric	[m]
E = Electric field strength	[V/m]

1. Capacitor Technology

Volume - V_C [dm³] versus Field Strength ($E = V_{DC}/d$)



The electric field strength inside a capacitor is given by the formula

$$E = V_{DC}/d$$

where E is the electric field strength, V is the potential difference (voltage) across the capacitor, and d is the distance between the capacitor "plates".

1. Capacitor Technology

Capacitor Energy / Volume - Theoretical

Technology	Dielectric	T_{max} [°C]	ε_r	$E_{break\ down}$ [V/µm]	E_{max} [V/µm]	V_{min} [cm^3]	C_{Vmax} [µF/cm^3]	$W_{V\ max}$ [J/cm^3]
Film	**[PHD]** Polypropylene, ht grade	**125**	**2,2**	650	**180**	510	**2,0**	**0,25**
	[PET] Polyester	**130**	**3,2**	570	**140**	590	**1,7**	**0,21**
	[PEN] Polyethylene Naphtalate	**150**	**3,1**	550	**130**	770	**1,3**	**0,16**
	[PPS] Polyphenylene Sulfid	**170**	**3**	500	**110**	1020	**1,0**	**0,12**
Alu	**[Al_2O_3]**	**105**	**9**	800	**500**	16	**63**	**7,8**
Ceramic MLCC	**[Class I, low DK]** TiO_2	**125**	**100**	150	**10**	314	**3,2**	**0,40**
	[Class II, high DK] $BaTiO_3$	**125**	**5000**	70	**6**	320	**3,1**	**0,39**

These values are not actual, to protect new film designs. Nevertheless they show the tendency. Values calculated for 1mF, 500VDC – just for comparison!

1. Capacitor Technology

Capacitor Energy / volume - Practical, tanδ [kHz]

Product	Dielectric	T_{max} [°C]	V_{min} [cm³]	$G_{eometry}$	T_{emp}	V_{oltage}	$dC_{vs\ time}$	VFF	$V_{typ\ tech}$ [cm³]	$W_{V\ typ\ tech}$ [J/cm³]	$tan_{(1kHz)}$ [-]
Film	[PHD]	125	510	0,97	0,98	1,00	0,97	0,92	553	0,23	1,5 * E^{-4}
	[PET]	130	590	0,97	1,05	1,00	0,95	0,97	610	0,20	50 * E^{-4}
	[PEN]	150	770	0,97	1,02	1,00	0,93	0,92	837	0,15	40 * E^{-4}
	[PPS]	170	1020	0,97	1,08	1,00	0,92	0,96	1058	0,12	6,0 * E^{-4}
Alu	[Al_2O_3]	105	16	0,08	0,80	1,00	0,95	0,06	268	0,47	30 * E^{-4}
Ceramic MLCC	[Class I, low DK]	125	314	0,97	0,90	0,98	0,90	0,77	408	0,31	10 * E^{-4}
	[Class II, high DK]	125	320	0,97	0,85	0,75	0,50	0,31	1035	0,12	150 * E^{-4}

As before, values based on available capacitor data, calculated for 1mF, 500VDC

1. Capacitor Technology

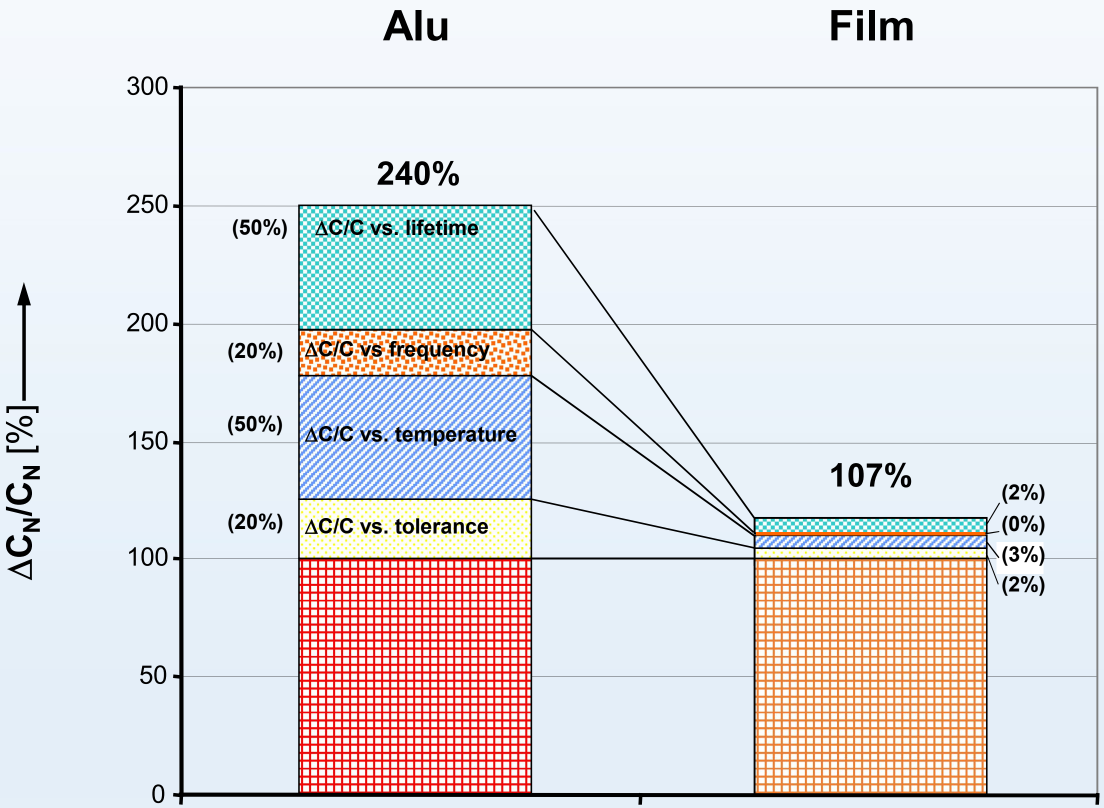
Target for technology optimization

Which parameters needs to be optimized to achieve more performance?

Parameter	General target	Unit
E	high	V/µm
ε_r	high	°C
T_{hs}	high	-
$\tan\delta_0$	low	-
Volume fill factor	high	-

1. Capacitor Technology

Design-in optimization Alu versus Film



1. $\Delta C_N/C_N$ versus capacitor technology

   ➔ $C_{Film} \approx 0{,}4 * C_{Al\text{-}electrolyte}$

2. C_N versus capacitor current*

   ➔ $C_{Film} \approx 0{,}1 * C_{Al\text{-}electrolyte}$

* how much Capacitance is needed to cover the needed current

1. Capacitor Technology

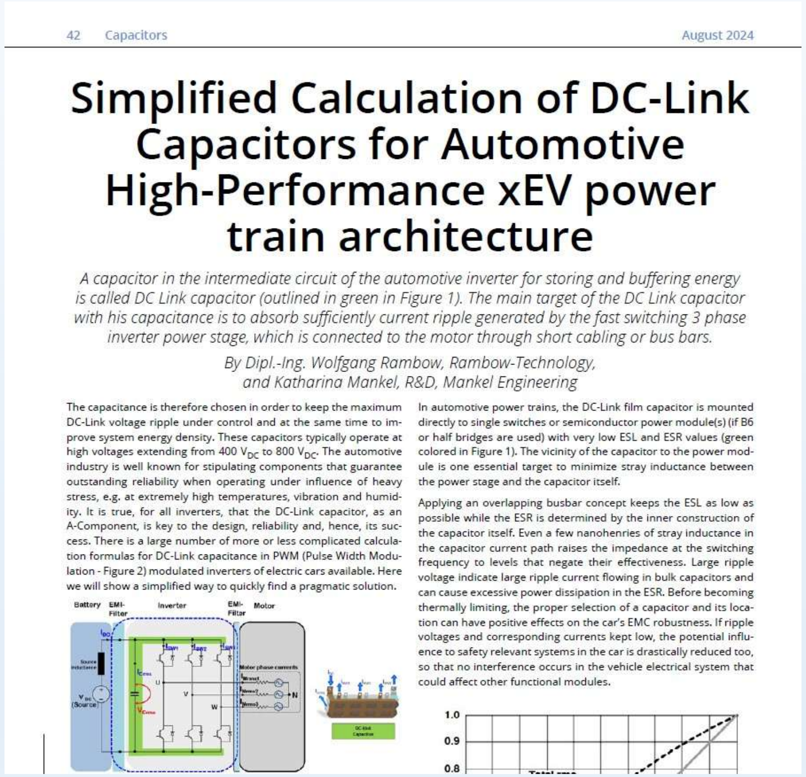
Design-in demand follows target specification

- ➔ Capacity
- ➔ Currents
- ➔ Voltages
- ➔ Inductance
- ➔ Insulation
- ➔ Cooling
- ➔ Tests required
- ➔ Environmental load
- ➔ Reliability
- ➔ Mechanical
- ➔ **Target price and quantity**

Content

2. DC-Link Capacitor

Automotive Power – Calculation of DC-Link Capacitors in Power Trains isn't easy – see report*



42 Capacitors August 2024

Simplified Calculation of DC-Link Capacitors for Automotive High-Performance xEV power train architecture

A capacitor in the intermediate circuit of the automotive inverter for storing and buffering energy is called DC Link capacitor (outlined in green in Figure 1). The main target of the DC Link capacitor with his capacitance is to absorb sufficiently current ripple generated by the fast switching 3 phase inverter power stage, which is connected to the motor through short cabling or bus bars.

By Dipl.-Ing. Wolfgang Rambow, Rambow-Technology, and Katharina Mankel, R&D, Mankel Engineering

The capacitance is therefore chosen in order to keep the maximum DC-Link voltage ripple under control and at the same time to improve system energy density. These capacitors typically operate at high voltages extending from 400 V_{DC} to 800 V_{DC}. The automotive industry is well known for stipulating components that guarantee outstanding reliability when operating under influence of heavy stress, e.g. at extremely high temperatures, vibration and humidity. It is true, for all inverters, that the DC-Link capacitor, as an A-Component, is key to the design, reliability and, hence, its success. There is a large number of more or less complicated calculation formulas for DC-Link capacitance in PWM (Pulse Width Modulation - Figure 2) modulated inverters of electric cars available. Here we will show a simplified way to quickly find a pragmatic solution.

In automotive power trains, the DC-Link film capacitor is mounted directly to single switches or semiconductor power module(s) (if B6 or half bridges are used) with very low ESL and ESR values (green colored in Figure 1). The vicinity of the capacitor to the power module is one essential target to minimize stray inductance between the power stage and the capacitor itself.

Applying an overlapping busbar concept keeps the ESL as low as possible while the ESR is determined by the inner construction of the capacitor itself. Even a few nanohenries of stray inductance in the capacitor current path raises the impedance at the switching frequency to levels that negate their effectiveness. Large ripple voltage indicate large ripple current flowing in bulk capacitors and can cause excessive power dissipation in the ESR. Before becoming thermally limiting, the proper selection of a capacitor and its location can have positive effects on the car's EMC robustness. If ripple voltages and corresponding currents kept low, the potential influence to safety relevant systems in the car is drastically reduced too, so that no interference occurs in the vehicle electrical system that could affect other functional modules.

* see report published in issue 8/2024 Bodo's Power Systems® /bodospower.com or at https://www.mankel-engineering.de/Presse/

Mankel-Engineering.de

2. DC-Link Capacitor

For Industrial Power

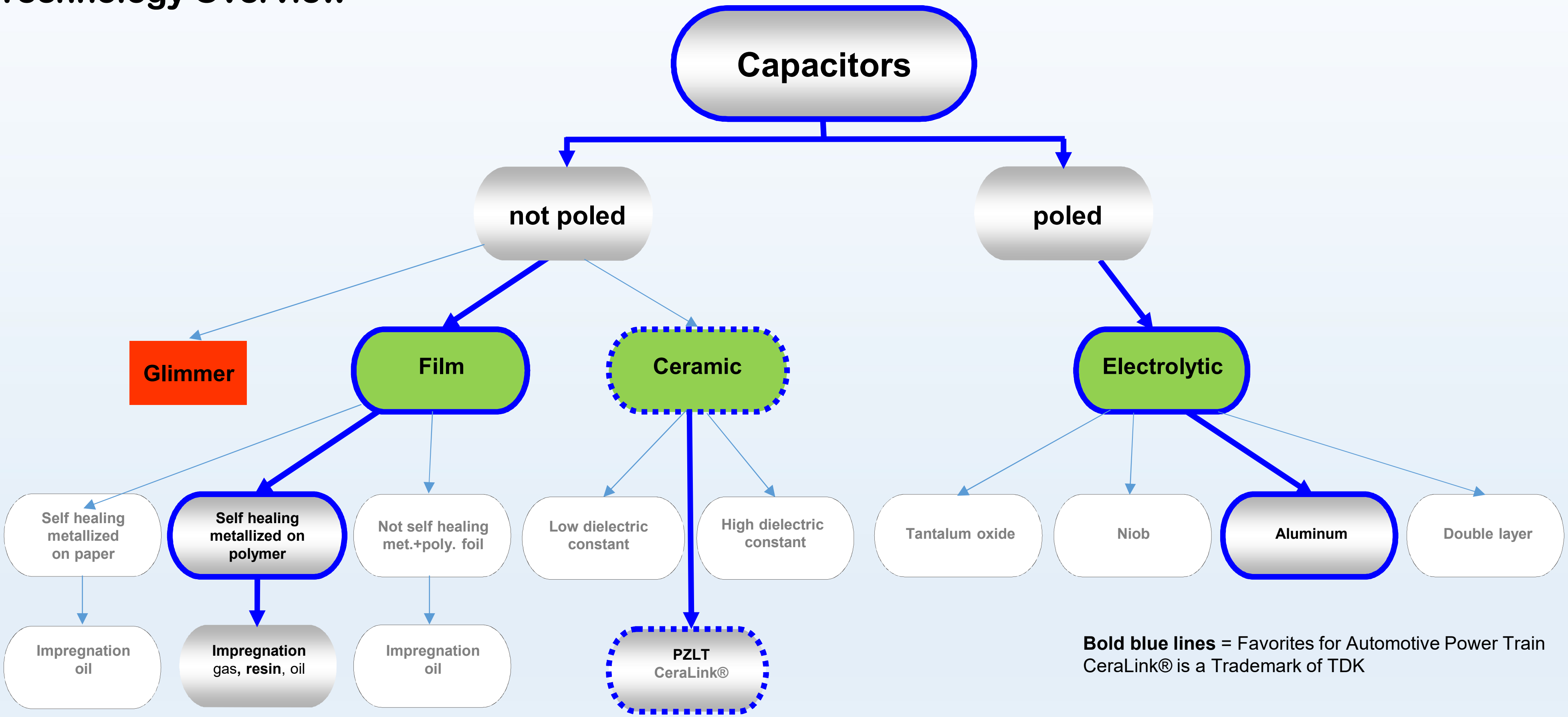
due to a extremely wide variety of applications it is not so easy to find the "only" right one.

Lots of calculation tools are available in the Internet.

Kemet, TDKs Clara,..

2. DC-Link-Capacitor

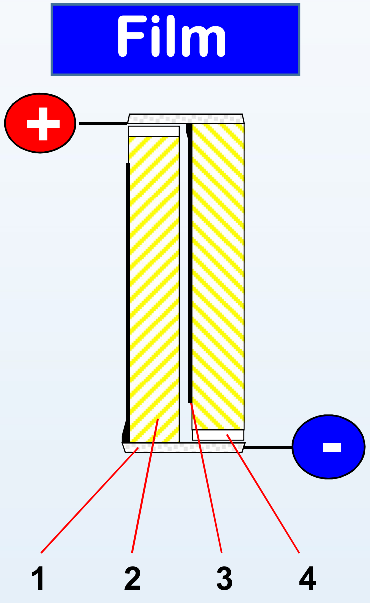
Technology Overview



Bold blue lines = Favorites for Automotive Power Train
CeraLink® is a Trademark of TDK

Content

3. Power Capacitor / FILM



1 Metal Spray Layer
2 Polymer dielectric film
3 Metallized electrode
4 Wave cut

A foil capacitor, better known as a film capacitor, is produced by winding or layering extremely thin plastic films that serve as a dielectric.

The plastic films are made of materials such as polyester, polypropylene or other plastics and all have different properties.

Among other things like electric, temperature and above all price naturally play a role.

As the film must have virtually no **holes, which could lead to the notorious breakdowns**, there are only a few manufacturers worldwide for these films (less than a handful).

The thickness of the films varies from only ultra lpw 1.5um to a few micrometers.

These films are then either metallized or covered with metal foils. You can even look through some of the metallized films in their final state if low thickness is used. The wide film rolls are then slit to the desired dimensions.

After that they are then wound or stacked to the required capacity on separate machines.

3. Power Capacitor / FILM

Example for portfolio of Film Capacitors

There are a large number of film capacitors manufacturer. But very important - especially for automotive industry and high power - is their reliability. Price may be a criterion, but there are many companies that simply promise specified values without ever having measured them. Therefore

→ **Take a critical look at the exact selection and whether the capacitors on offer are free from restrictive global patents. Don't jeopardize your series/wholesale production just because a buyer wants you to do!**

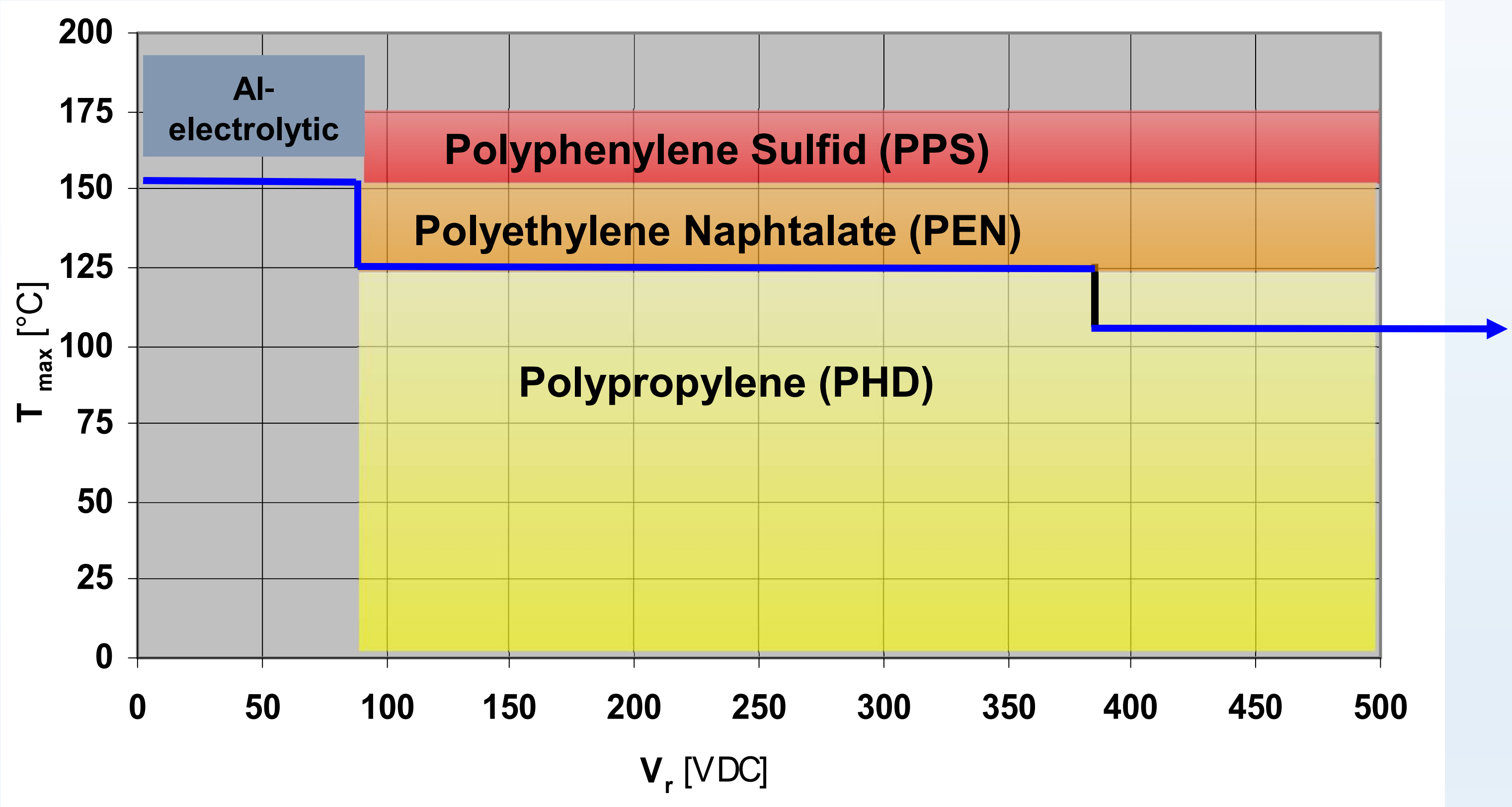
Some brands for e.g. automotive are as an example:

- Electronicon (Germany)
- Fischer and Tausche (Germany)
- Panasonic (Japan)
- TDK (ex EPCOS)
- Vishay (Germany)
- Advanced Power Conversion Solutions Inc. (USA)
- Electronic Concepts (USA)
- Ningguo Yuhua Electrical Products Co.,Ltd (Ruva Capacitors – China)

But there are many other companies in China, Korea and the USA that are quite large and reliable.

3. Power Capacitor / FILM

Performance comparison: T_{max} versus V_{rated}



A variety of new films are available. But nevertheless main decision for automotive is price! The new films might get a chance of change with upcoming SiC power modules used in Automotive Power Trains.
Films for higher temperature often need more thickness to withstand the electric field strength, so that the volume versus standard films with same capacitance can quadruple! and polypropylene is cheap compared with the special films (e.g. PPS,PEN, PHD strechted...).

Source: TDK

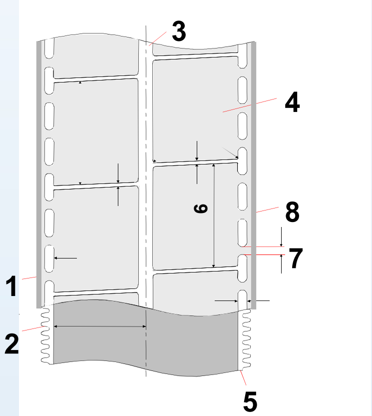
Mankel-Engineering.de

3. Power Capacitor / FILM

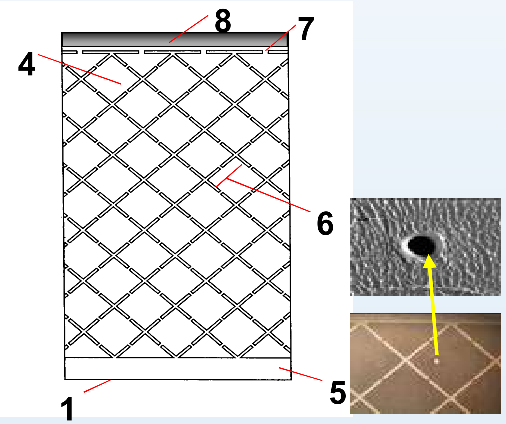
Changes in Metallization Methods during the Decades

Metallization: The films are either metallized (thin layers of aluminum are vapor-deposited onto the films) or covered with metal foils. You can even look through the metallized films in their final state if low thickness is used.

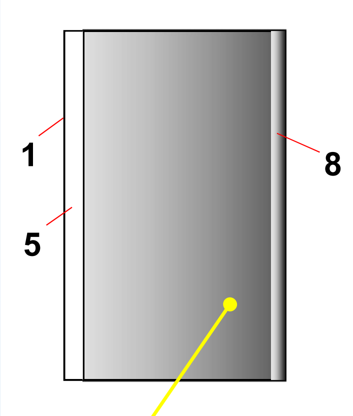
T - Segment



Patterned Electrode



No - Segment



1. Smooth cut
2. Wavy cut
3. Free stripe
4. Partial capacitor
5. Free margin
6. Segment spacing
7. Protection fuse
8. Heavy edge electrode and metallization w / w. o. patterned structure

3. Power Capacitor / FILM

Metallization

System
- Velocity: >15 m/s
- Film width: 920mm
- Roll net weight: >200kg

Technology:
- Film range: 1um – 12um
- Metallization: Al & Al+Zn
- Flat and structured
- Metallization width typical : 8.8 – 163mm

Source: TDK

3. Power Capacitor / FILM

Slitting

System (older device):
- Slitting speed: 40 m/sec
- Film width: 920mm
- Various film profiles

Technology:
- Film range: 3mm – 12mm
- Broad film width range

Source: TDK

Mankel-Engineering.de

3. Power Capacitor / FILM

Winding

Winding or layering:

The metallized or metal foil-covered plastic films are either wound or layered to achieve the desired capacity.

Contacting:

The metal coatings are conductively connected to each other by spray metallization to form the electrical connections. For simple applications, the connections are soldered; for power capacitors, the connections are usually welded in order to withstand the temperature cycling tests and the high current requirements.

The finished capacitor is then placed in a housing and encapsulated to protect it from environmental influences and for cooling issues.

→Film or foil capacitors are characterized by their high dielectric strength, low losses and good pulse load capacity.

→ Testing is carried out at every stage of the process!

The test results are stored in a database and form the basis for improving the reliability and design rules in most companies.

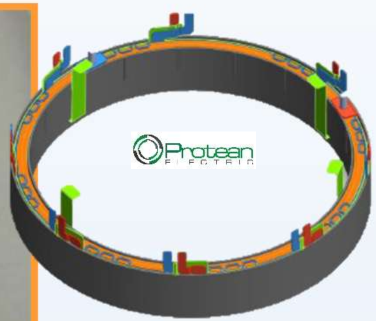
3. Power Capacitor / FILM

Winding Possibilities

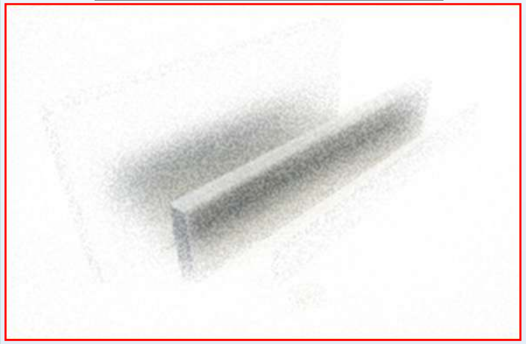
Standard Round

Concentric Round

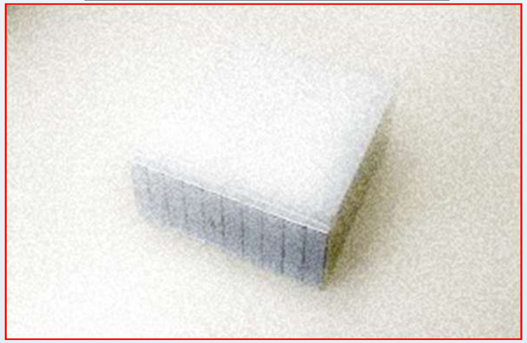
Customized Round



Standard Flat



Stacked Film



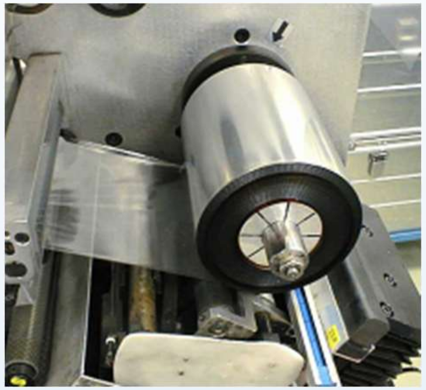
Customized Stacked Film

Source: TDK

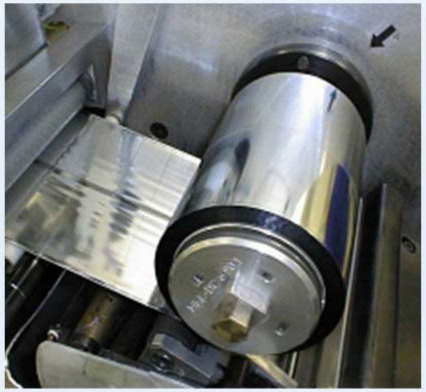
The usage of the different winding topologies depends strongly on their cost. Green marked boxes are used in high volume.

3. Power Capacitor / FILM

Winding



AC Winding

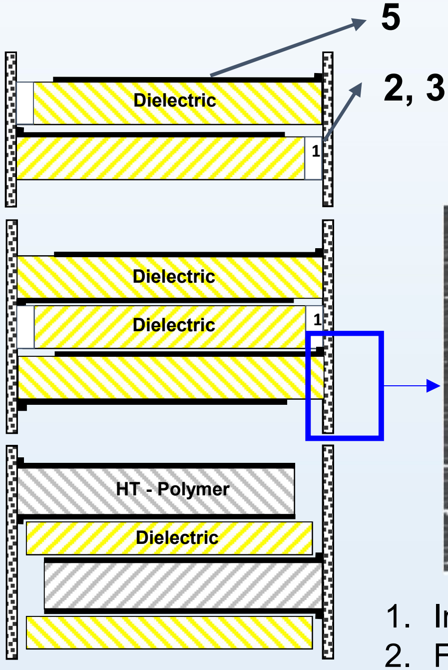


DC Winding

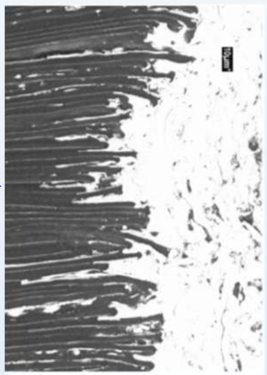
Source: TDK

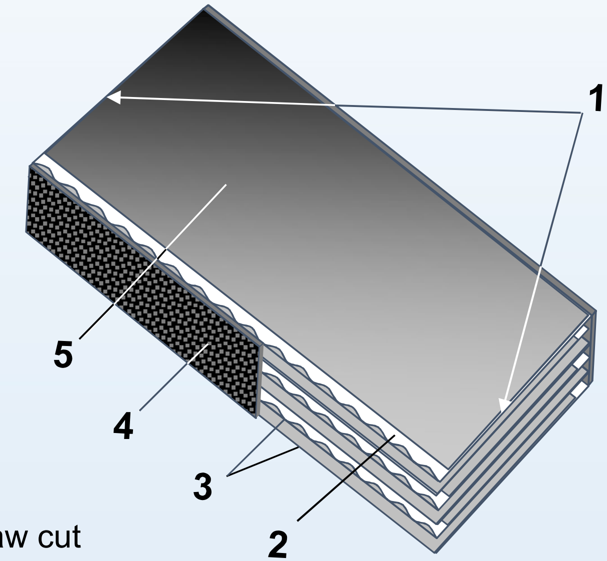
3. Power Capacitor / FILM

Film assembly – as an extract of a winding stack



Cross section





Source: TDK

1. Insulating area via saw cut
2. Free margin
3. Wavy-Smooth cut combination
4. Metal end spray layer
5. Film

Even if flat pressed round capacitors are in todays focus [(see winding possibilities)] the **maximum Volume Fill Factor (VFF) will be achieved with stacked Film – almost near to 1**!

However, the stacked design have disadvantages compared to the round-wound and then mostly flat-pressed windings. Despite a VFF of almost 1, it cannot utilize this advantage due to its significantly lower winding speed (production cost) and the higher amount of used raw material (scrap).

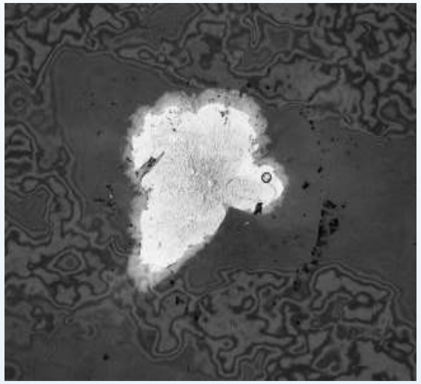
→ Customers use the cheaper round or flat winding variants.

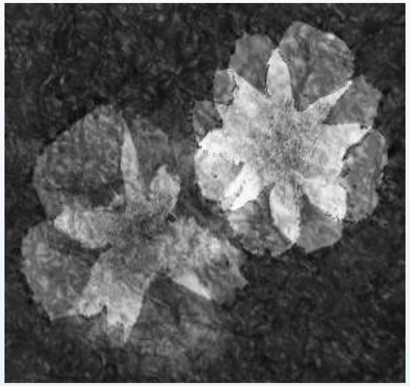
3. Power Capacitor / FILM

Self healing Processes - Film Capacitors versus MLCC

- **Film Capacitors**

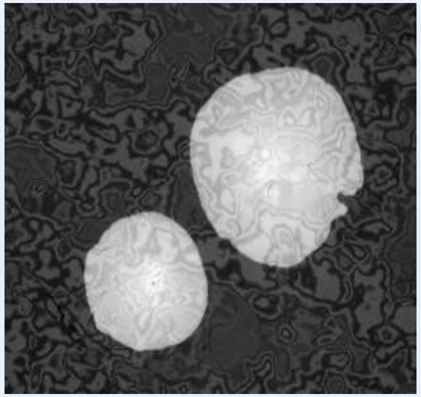
Self-healing punctures

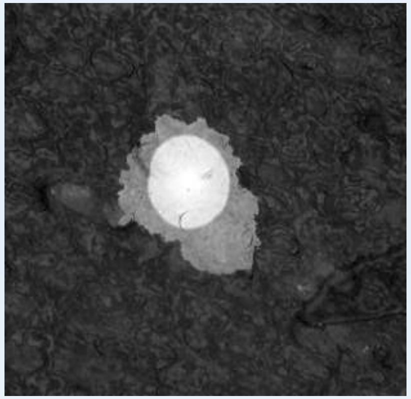




- **Ceramic Capacitors (MLCC)**

Electrochemical self-healing

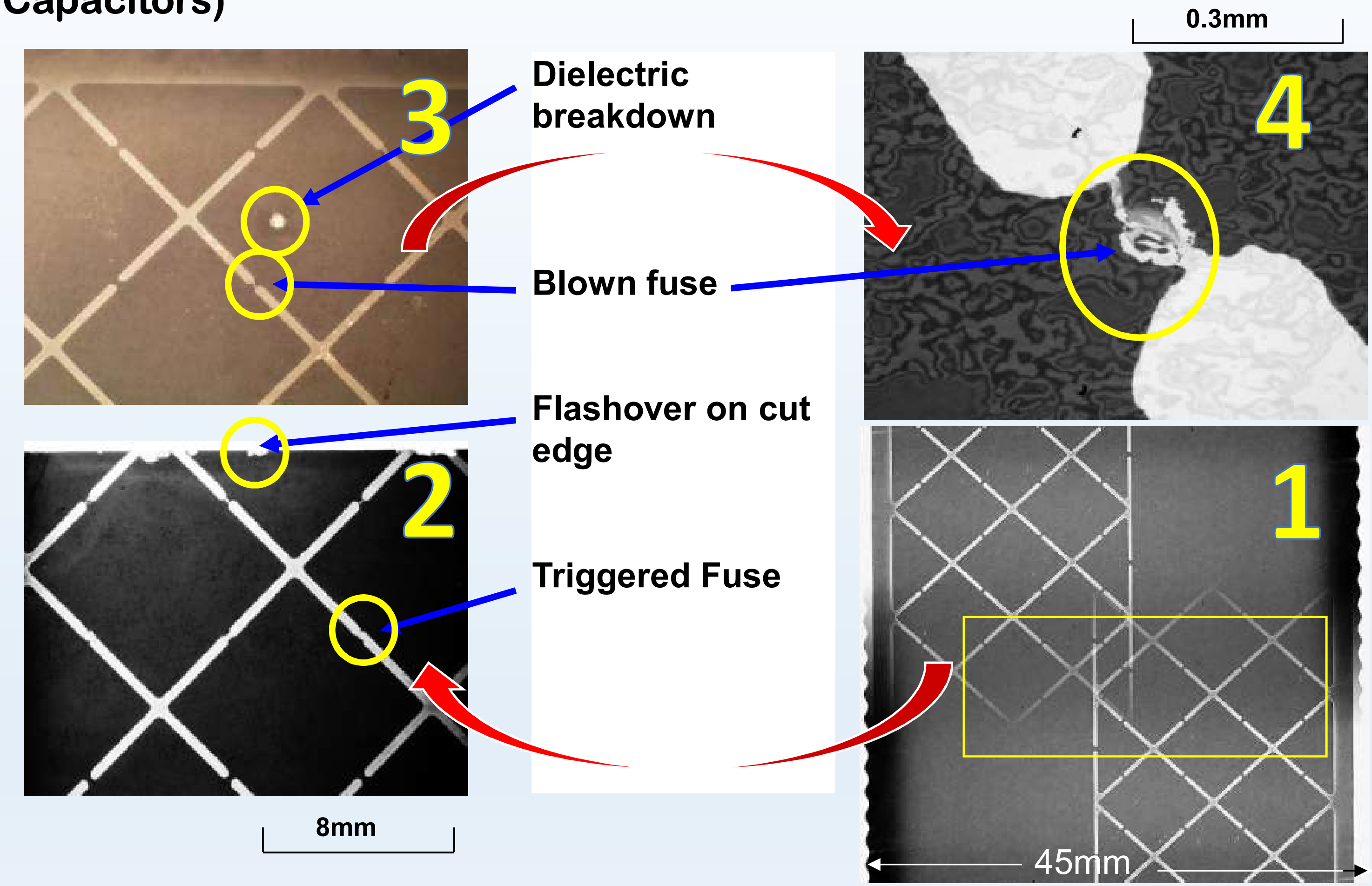




0.3mm

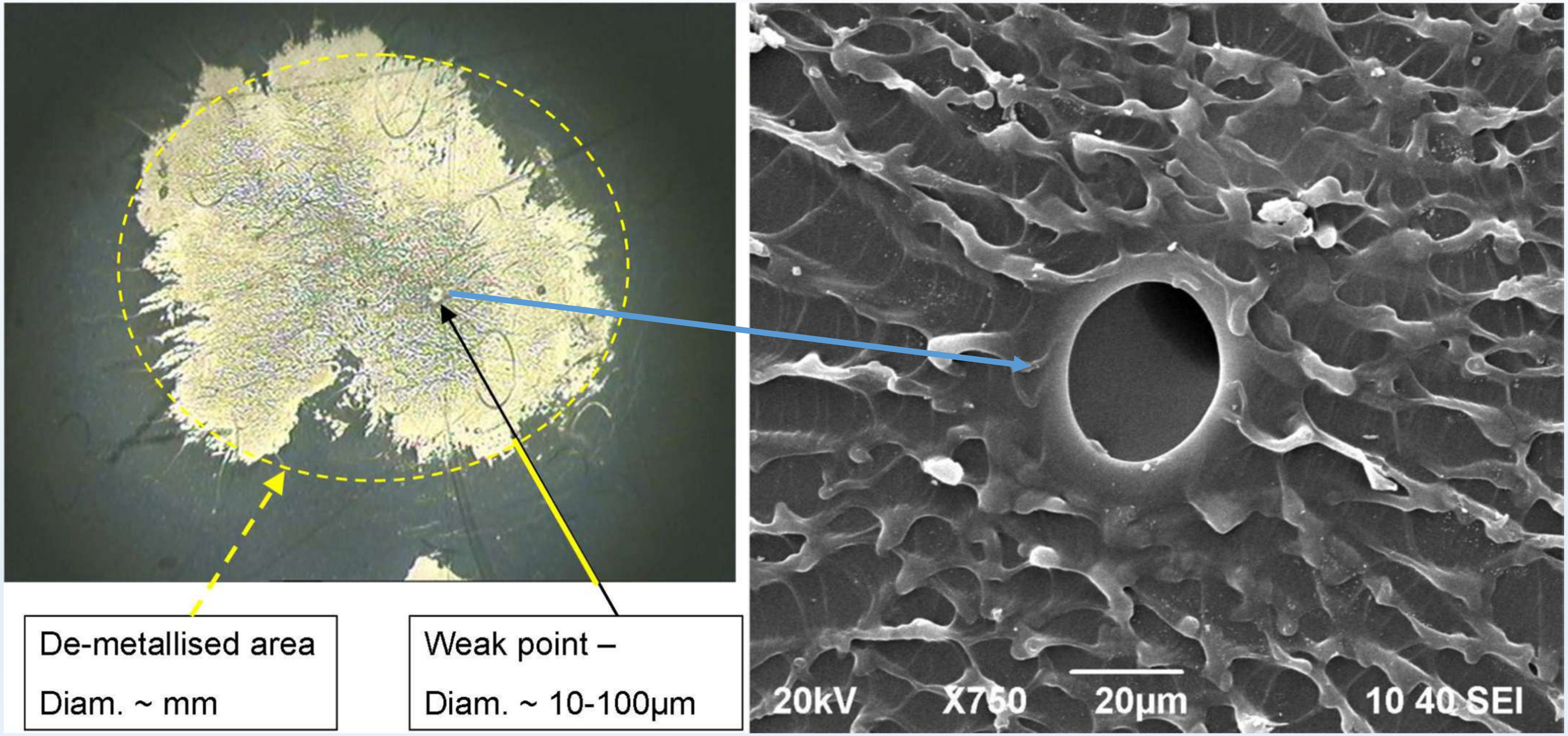
3. Power Capacitor / FILM

Punctures (Film Capacitors)



3. Power Capacitor / FILM

Punctures (Film Capacitors)



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3. Power Capacitor / FILM

Production Pictures

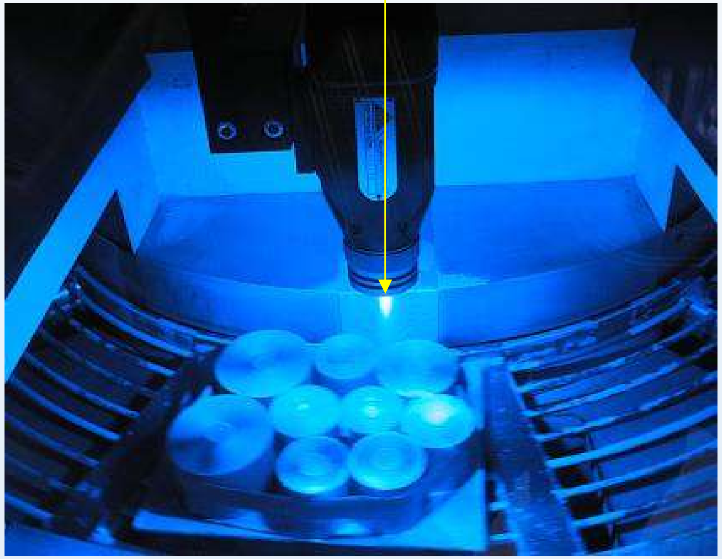
3. Power Capacitor / FILM

Contacting (metal spray)

Winding stack

Welded BusBar

Electric gun (metal spray)



Source: TDK

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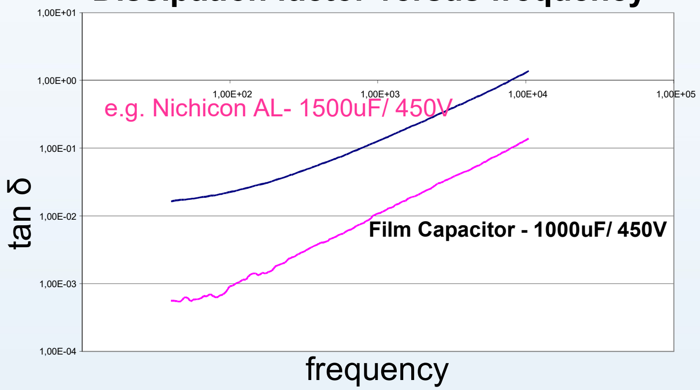
3. Power Capacitor / FILM

ESR, tan δ: Standard / High Density Film versus Alu

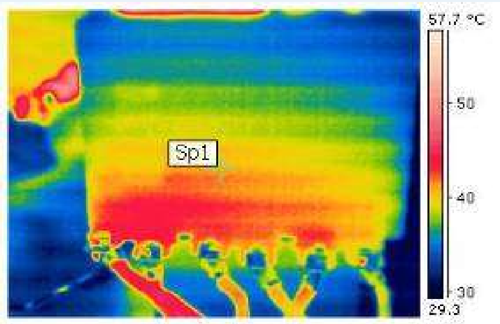
Dissipation factor versus frequency



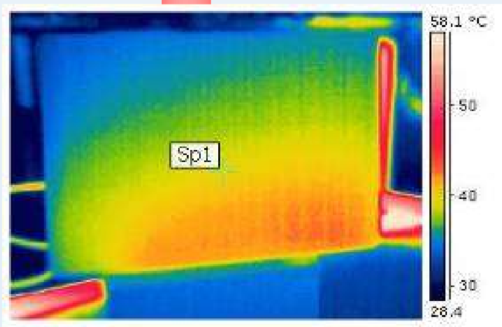
As film capacitors can withstand very high currents they are heated either by ambient temperature, their own ESR or/and externally by the terminals (influenced by the semiconductors temperature) or the "heat sink". However, the temperature of the film inside must not exceed the maximum allowed temperature to avoid any damage.

Thermal stability test results (Film) after 24h runtime // dT = f (I_{rms})

f: 7000Hz	High Density design	Standard design
70A	8K	15K
100A	14K	30K



terminal side



opposite side

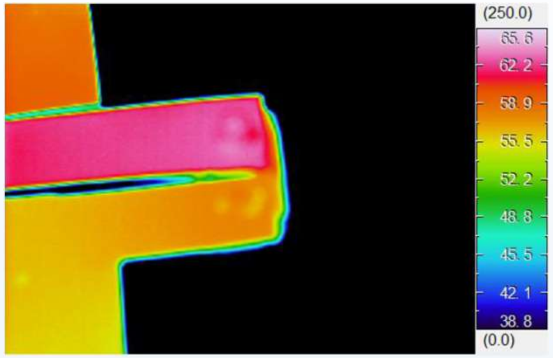
3. Power Capacitor / FILM

Thermal impact from the power module

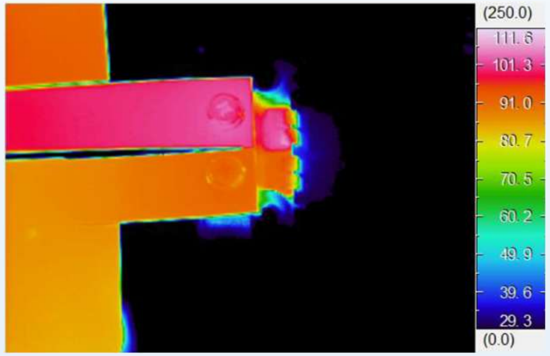
The temperature influence of the semiconductor terminals on the capacitor is enormous. Enclosed you can see three pictures of a Mitsubishi Electric module with different applied currents. The connector of the module reach temperatures of up to 121°C, which also have a direct effect on the capacitor via the capacitor connector tab. In contrast to earlier module designs, where an internal bus bar could be cooled, today the module – to save money for the semiconductor manufacturer - passes this on directly to the capacitor connector tabs. The system as such therefore requires a cooling concept nowadays, otherwise both the semiconductors and the capacitor will die.

High temperature and high field strength can lead to an avalanche effect and thermal breakdown of the film.
→ **Note - also Film Capacitors can fail!**

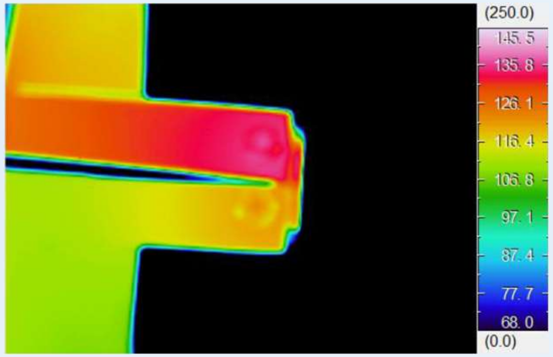
250A
57,7°C



350A
91,7°C



400A
121°C



Source: Mitsubishi Electric

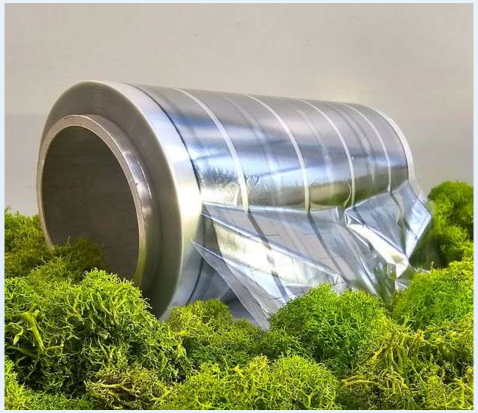
3. Power Capacitor / FILM

Film Capacitor for <u>Industrial High Power</u>

e.g. TDK ModCap®

for Semiconductor modules like

- ABB
- Fuji
- Infineon XHP
- Mitsubishi LV100
- StarPower…
- Wolfspeed
- …



TDK introduced a bio-circular polypropylene (PP) film for all its ModCap series. The ISCC-certified raw material is obtained from second-generation renewable raw materials (bio-circular) which come exclusively from waste and residues: from the production of vegetable oil, from the paper and pulp industry, or used cooking oil, for example. Thus, fundamental ethical issues should be avoided, such as conflicts with food cultivation which could increase food prices. Bio-circular PP raw material can be processed in the very same way as conventional ones. It is chemically identical, and in terms of performance, it has the very same electrical and physical properties.

Announcement by TDK

3. Power Capacitor / FILM

Bullet Points

ADVANTAGES

- **Benign failure mode → no short**
- **High ripple current capacity**
- Low leakage current
- Low ESR
- Wide voltage range
- Low dissipation factor
- Wide temperature range
- Non polarized

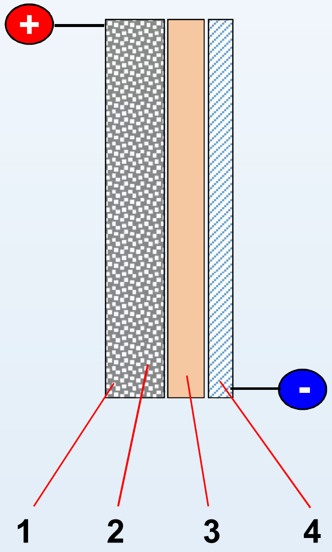
DISADVANTAGES

- **Cost**
- **Medium to low density**

Content

4. Power Capacitors - ALU

Al-Electrolyte

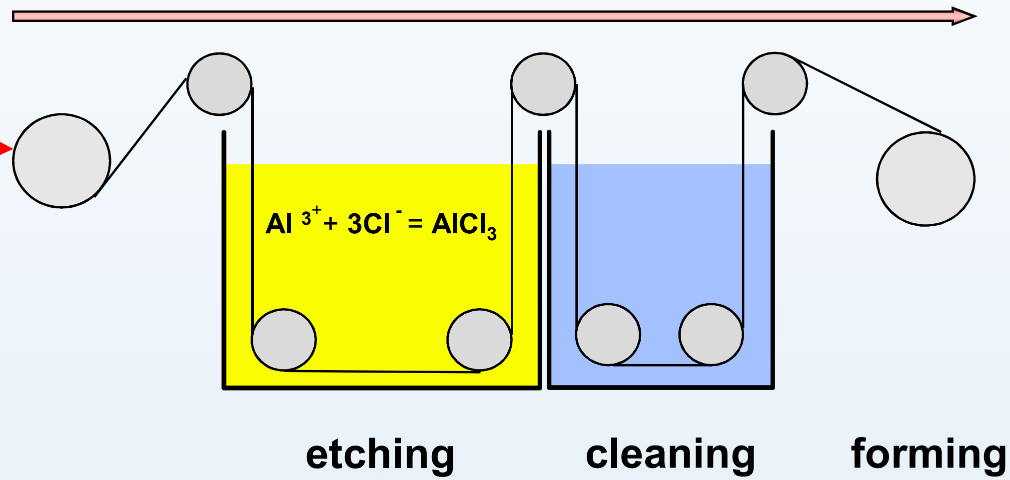


1 Al-anode foil
2 Al_2O_3 dielectric area
3 Electrolyte and paper
4 Al-cathode foil

4. Power Capacitors - ALU

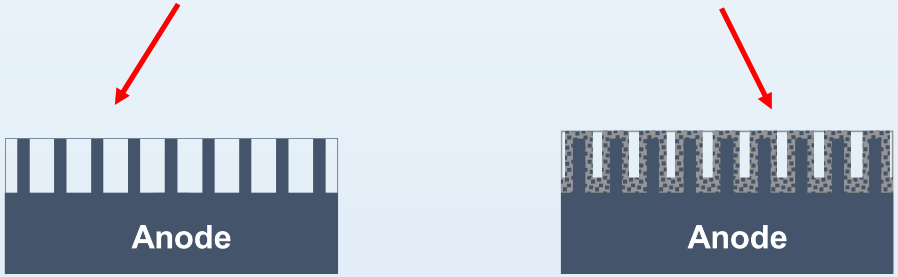
Main process steps

Aluminum foil
a ≈ 60…110µm
Al ≈ 99,99 % Purity



Process steps:

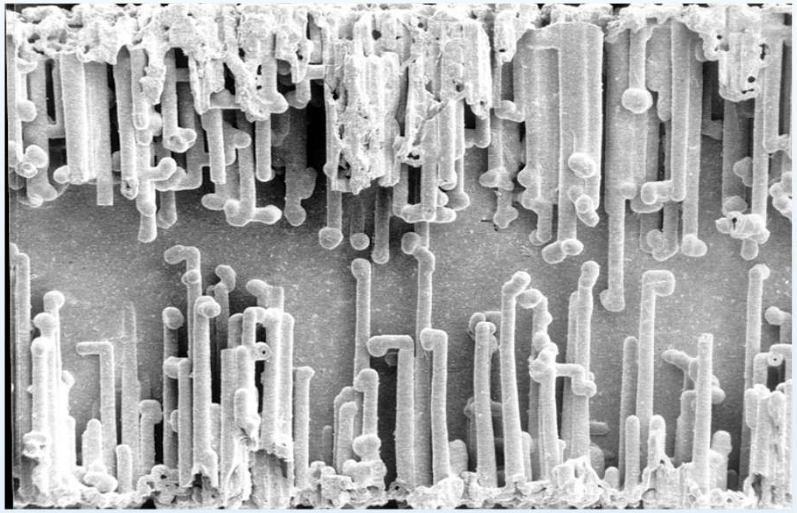
- Tunnel etching + widens
- Etching ➔ current
- Forming ➔ voltage



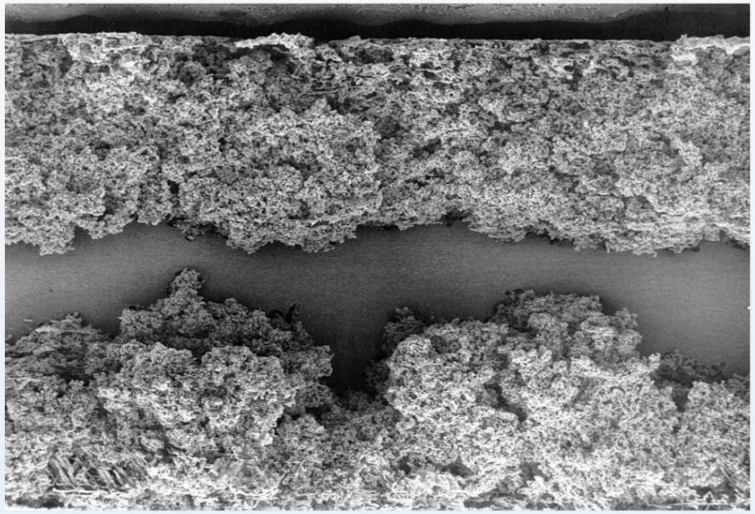
4. Power Capacitors - ALU

High / low voltage etching

25 µm **High voltage**

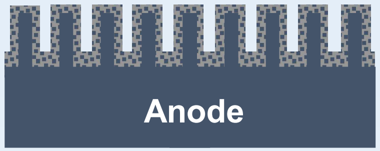


25 µm **Low voltage**



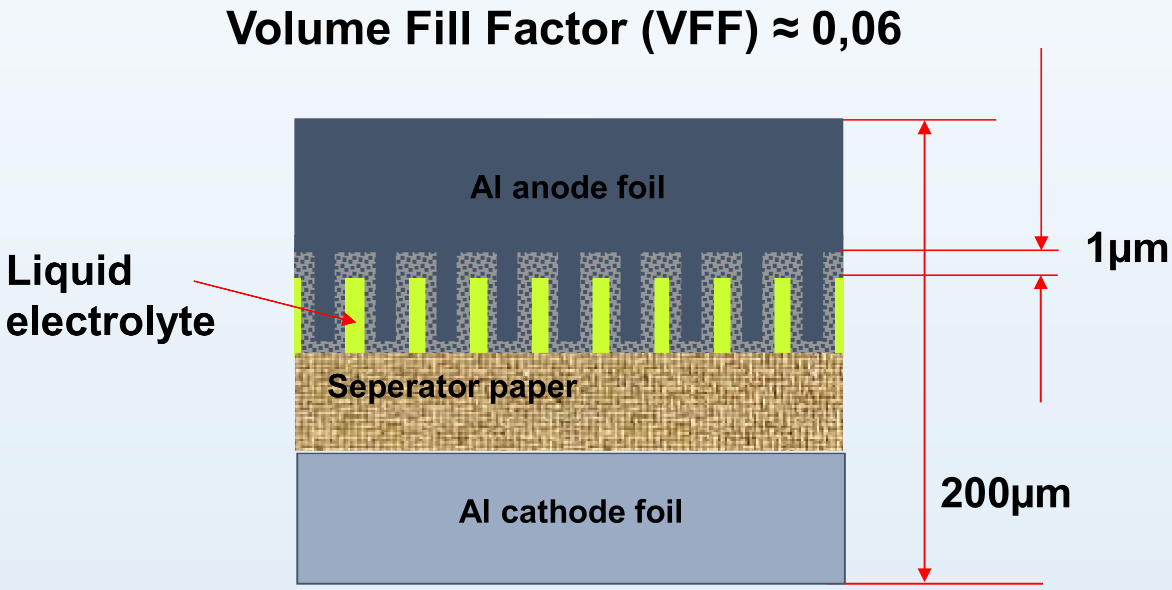
Source: TDK

Dielectric grows during forming



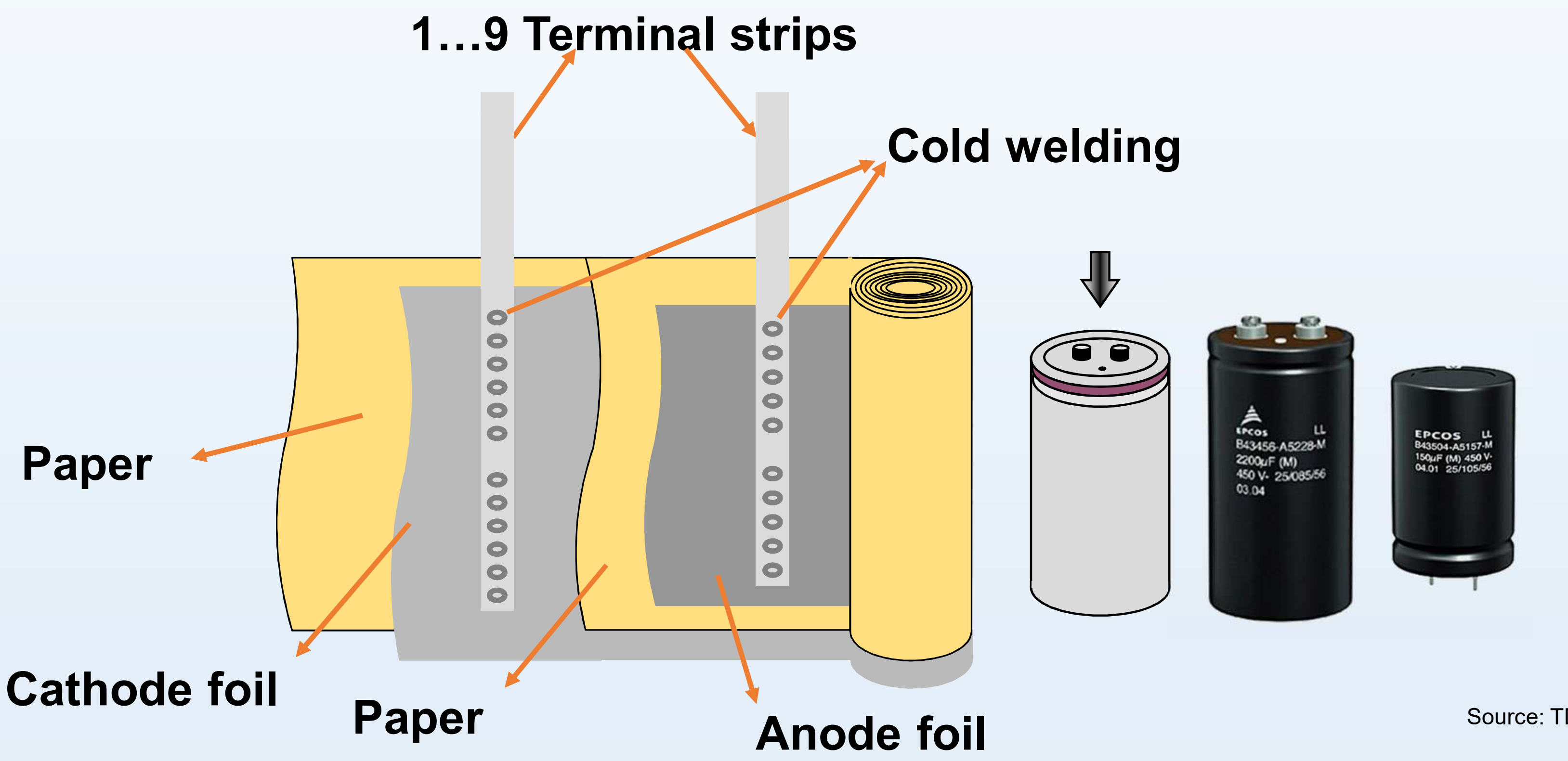
4. Power Capacitors - ALU

Dimensions for explanation the low VFF of a Alu-Capacitor



4. Power Capacitors - ALU

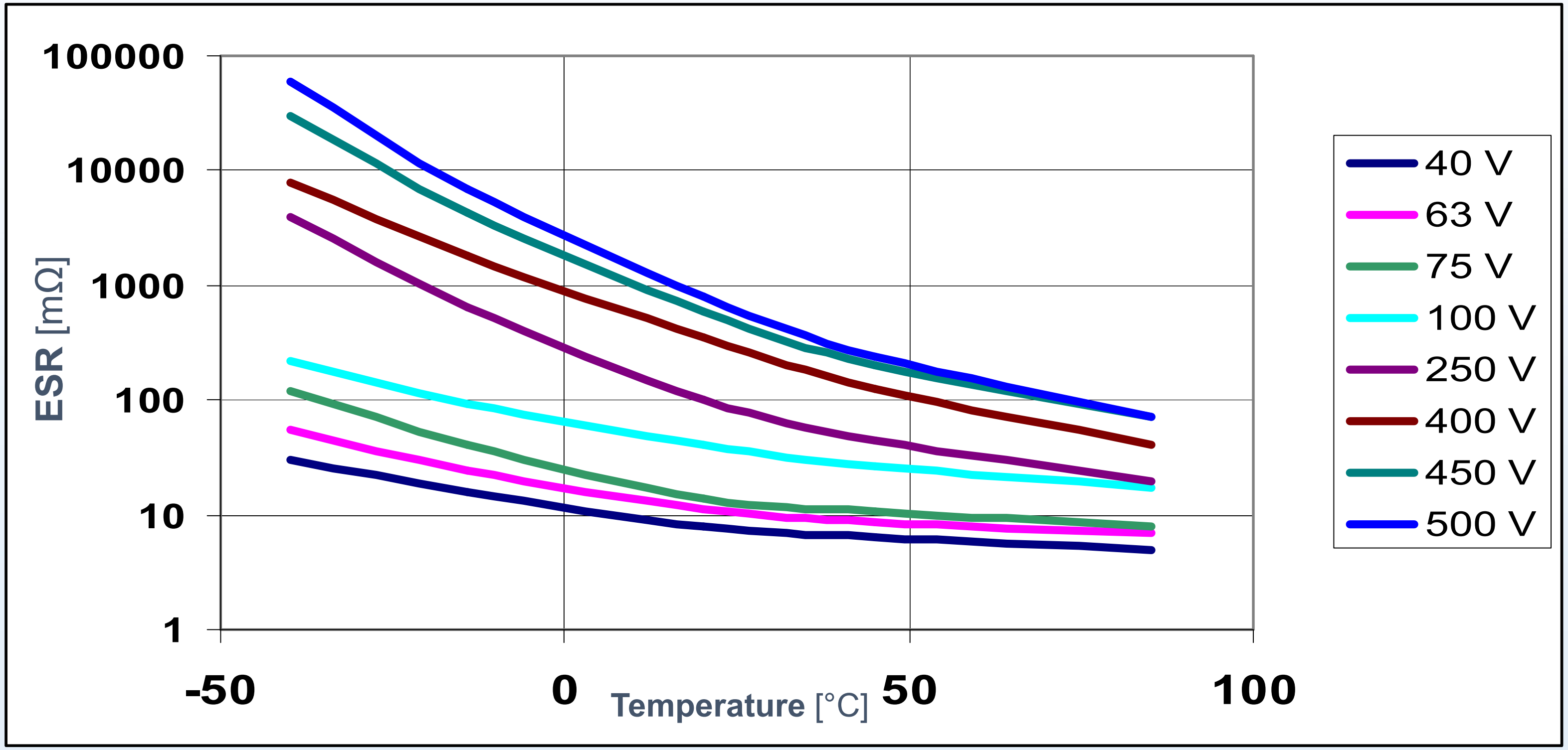
Design details



Source: TDK

4. Power Capacitors - ALU

Alu - Capacitor // ESR $_{(10\text{-kHz})}$ behavior

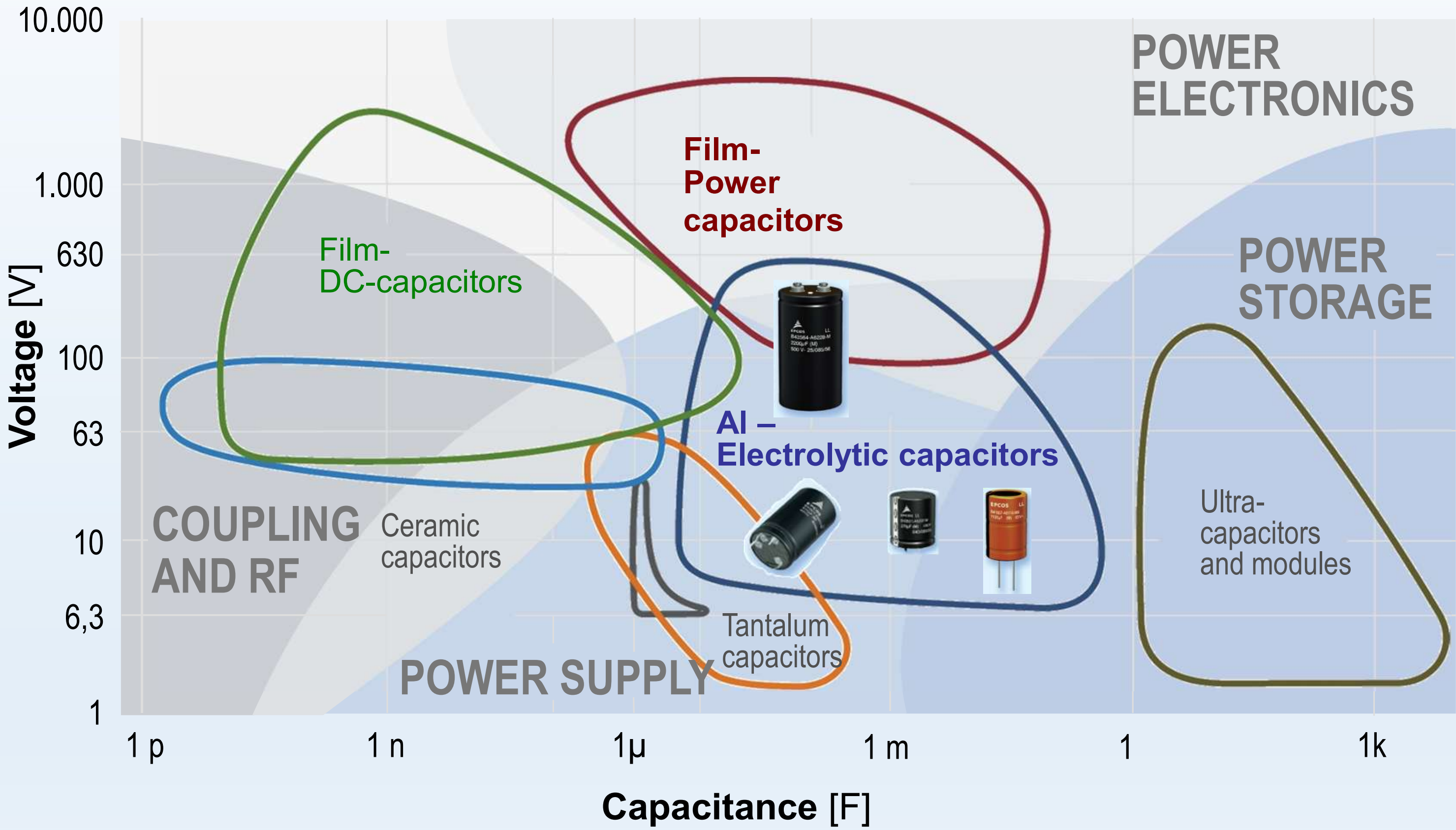


Typical - Capacitors are always subject to technical progress - therefore use the respective data sheet!

Mankel-Engineering.de

4. Power Capacitors - ALU

Alu caps - application guide



Source: EPCOS

4. Power Capacitors - ALU

Bullet Points

ADVANTAGES

- ✓ **Low Cost**
- ✓ **High Capacitance Density**

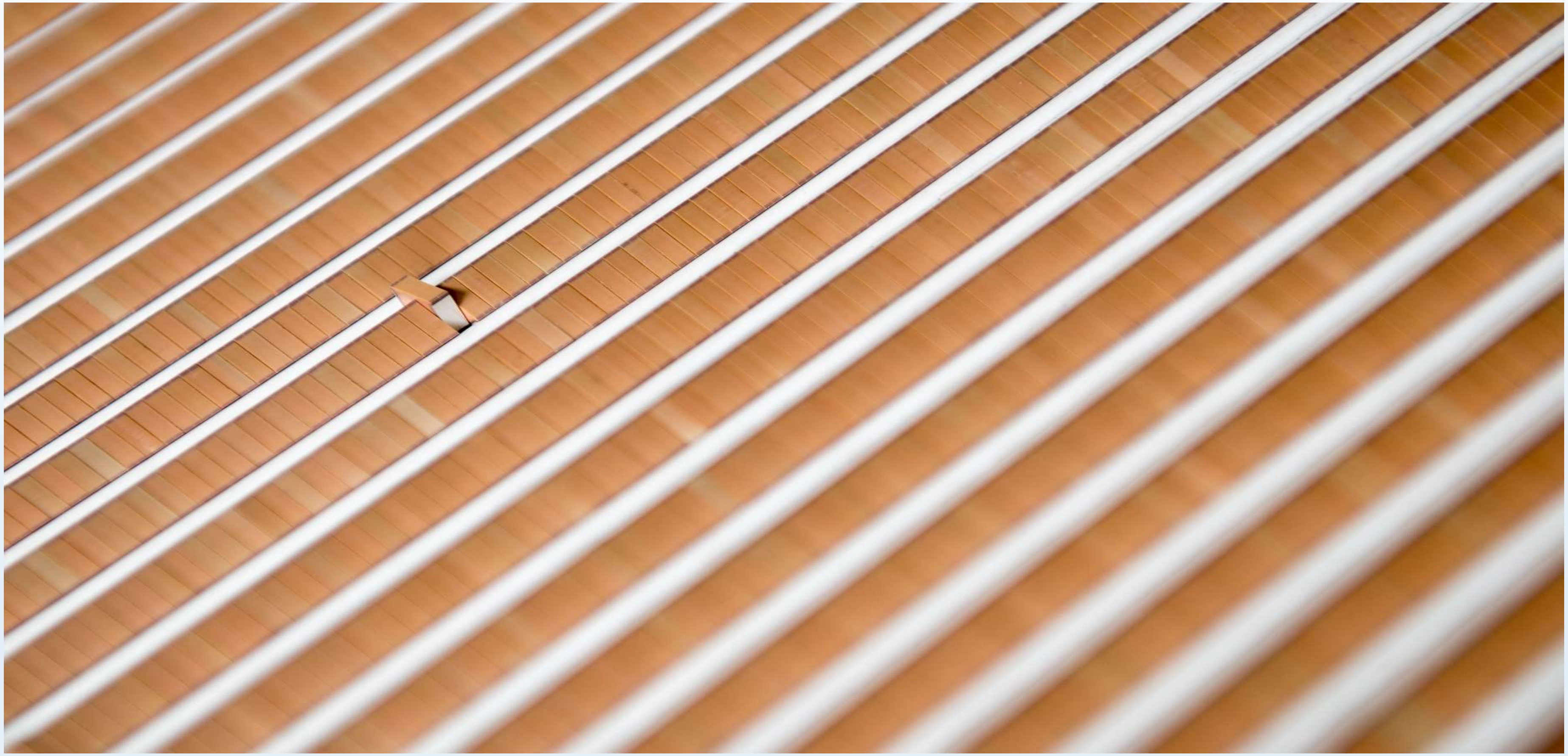
DISADVANTAGES

- **Non-benign failure mode ➔ short**
- Low ripple current capability
- High ESR
- Limited voltage range
- High dissipation factor
- **Limited temperature range**
- Dry out-limited life
- Polarized
- High leakage current

Content

5. Power Capacitor CeraLink® - a TDK speciality

CeraLink



CeraLink® is a Trademark of TDK

5. Power Capacitor / CeraLink® - a TDK speciality

DC-Link Usage

CeraLink® can be used as

- DC-Link capacitor for inverter with higher frequencies – e.g. GaN or SiC or high speed IGBTs
- Output filter capacitor
- Snubber capacitor in combination with a resistor (all Capacitors in parallel to be used as a snubber or in DC-Link combinations without matching or a resistor in series can cause ringing!)

Feature highlights

- Increasing capacitance with DC bias and best in class capacitance density at operating point (Vop + Top)
- High current capability due to low losses at
  - high frequencies (up to several MHz)
  - high temperatures (up to +150 °C)
- No limitation of dV/dt
- Good self-regulating properties
- RoHS-compatible PLZT ceramic (lead lanthanum zirconium titanate)
- Qualification based on AEC-Q200

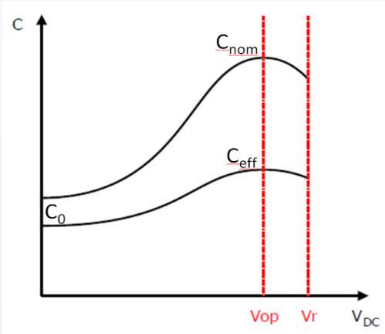
Source: TDK

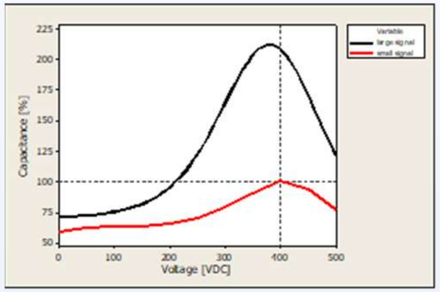
5. Power Capacitor / CeraLink® - a TDK speciality

DC-Link Usage

- high cap-density at V_{op}
- high operating temperature
- low ESL
- high ripple current ratings

- Capacitance strong depending on the V_{op} which may lead to problems in battery-powered devices where the voltage drops during operation
- low ESL **<u>can cause ringing</u>** (paralleling mixed technologgies e.g. snubber), Resistor is needed – but cost effiancy
- Costs





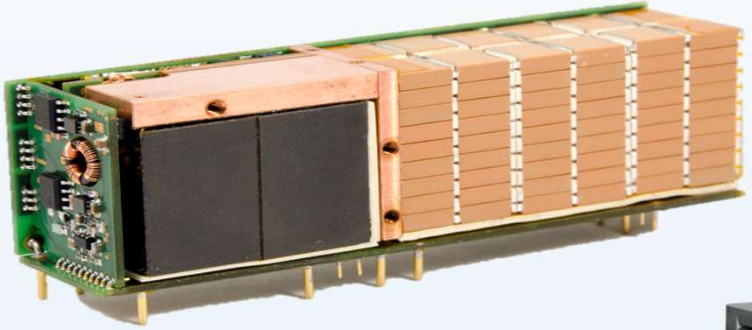
Capacitance increase versus signal

Initial capacitance C_0:	is the value at the origin of the hysteresis without any applied direct voltage.
Effective capacitance C_{eff}:	occurs at V_{op} and is measured with an applied ripple voltage of 0.5 V_{RMS} and 1 kHz. **CeraLink™ is designed to have its highest capacitance value at the operating voltage V_{op}.**
Nominal capacitance C_{nom}:	is the value derived by the tangent of the mean hysteresis as the derivation of the mean hysteresis is dQ/dV ~ C.

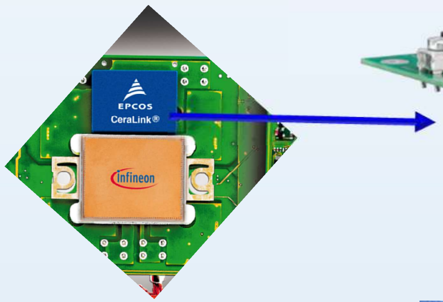
CeraLink® seems to be good in solutions for higher frequencies – especially for high speed IGBTs, GaN or SiC. Since the device is expensive compared to other technolgies you must proof the usage and TOC in your solution! Check Capacitance curve and the actual data sheets! CeraLink® as all other capacitors can cause ringing if used in parallel with other technologies – e.g. used as a snubber.

5. Power Capacitor CeraLink® - a TDK speciality

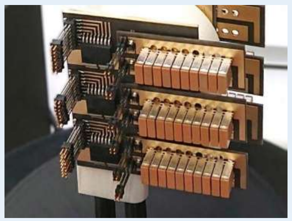
Examples



- 140 µF @ 23.7 cm³ capacitor volume
- 16 W losses at 2 kVA output power (0.8%)



- 2,7kW/100kHz/OBC Demo board with high speed IGBTs Infineon 2011



- Electronica 2024 / 400kW Power Train

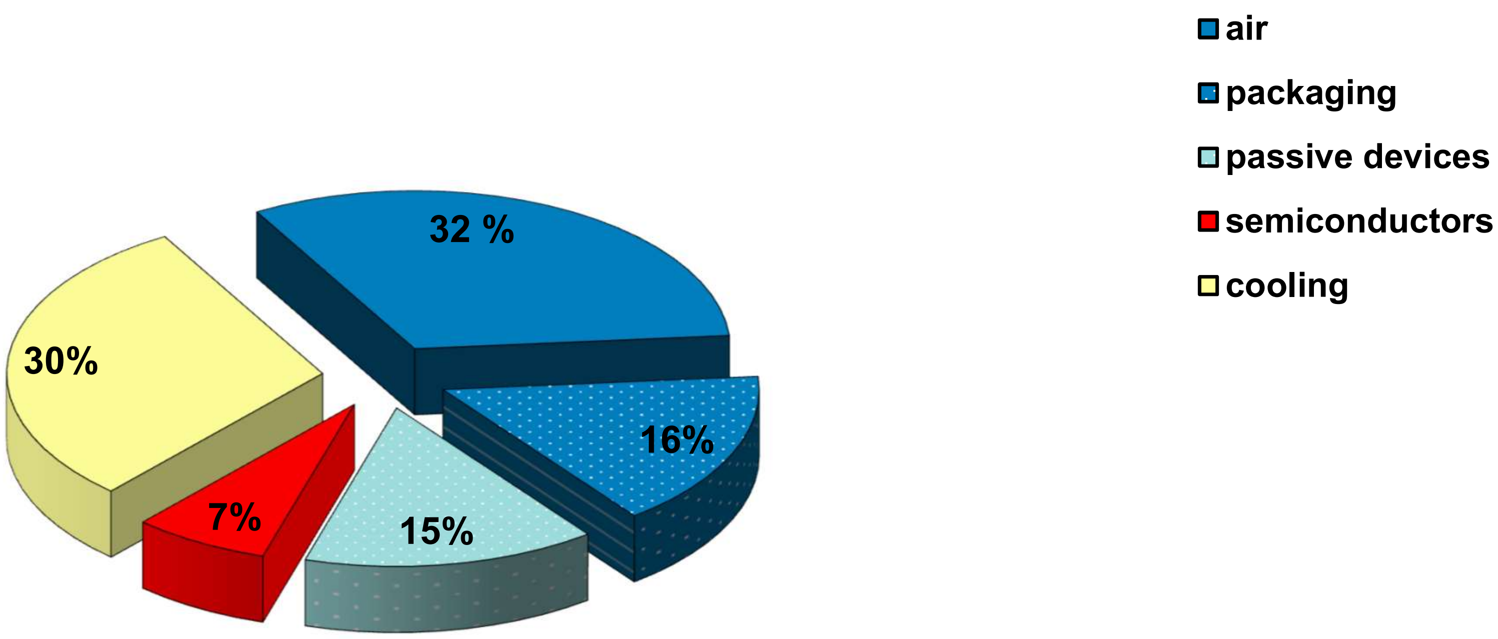
5. Power Capacitor CeraLink® - a TDK speciality

Factory

Content

7. Advanced Design

Typical volume split of a modern DC-AC converter



Typical Converter volume split

7. Advanced Design

Capacitor Size Miniaturizing via Capacitance Reduction

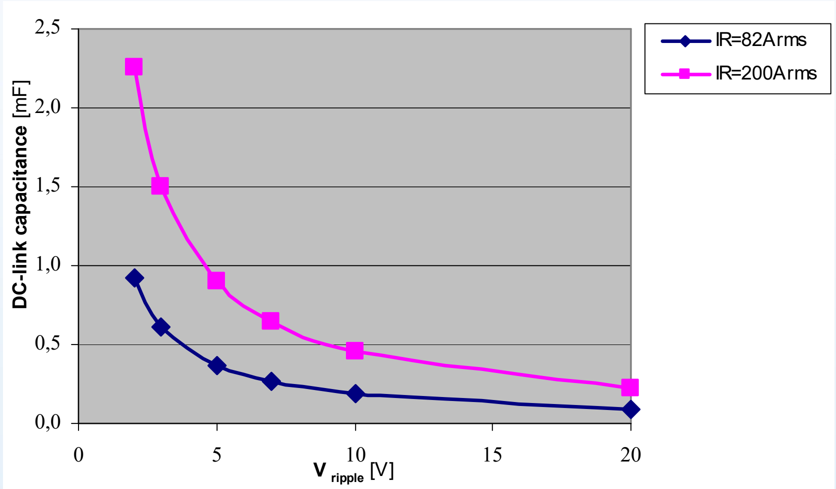
➔ **C_r reduction with increasing f_0**

$$C = \frac{P_{load}}{V_{ripple} \cdot \left(V_{\max} - \frac{V_{ripple}}{2} \right) \cdot f_{rect}}$$

➔ **C_r reduction with designing to I_{rms}**

Examples for this trend:

- **30µF/kW** ➔xEV (2005)
- **6µF/kW** ➔xEV (2020)
- **4µF/kW** ➔xEV SiC 800V (2022)

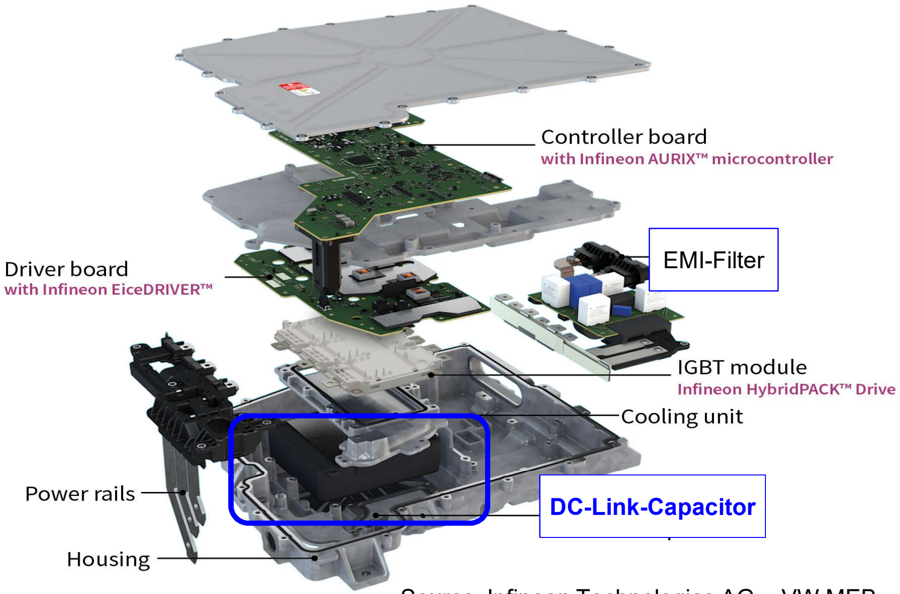


The capacitance C can be calculated via allowed ripple voltage e. g. for the HV-Battery of a HEV drive system (a typical V_{ripple} value is 2…10V). See report published in issue 8/2024 Bodo's Power Systems® /bodospower.com or at https://www.mankel-engineering.de/Presse/

7. Advanced Design

Capacitor Size Miniaturizing via Mechatronic Integration

xEV converter always achieve higher power density compared to other applications



Source: Infineon Technologies AG - VW MEB

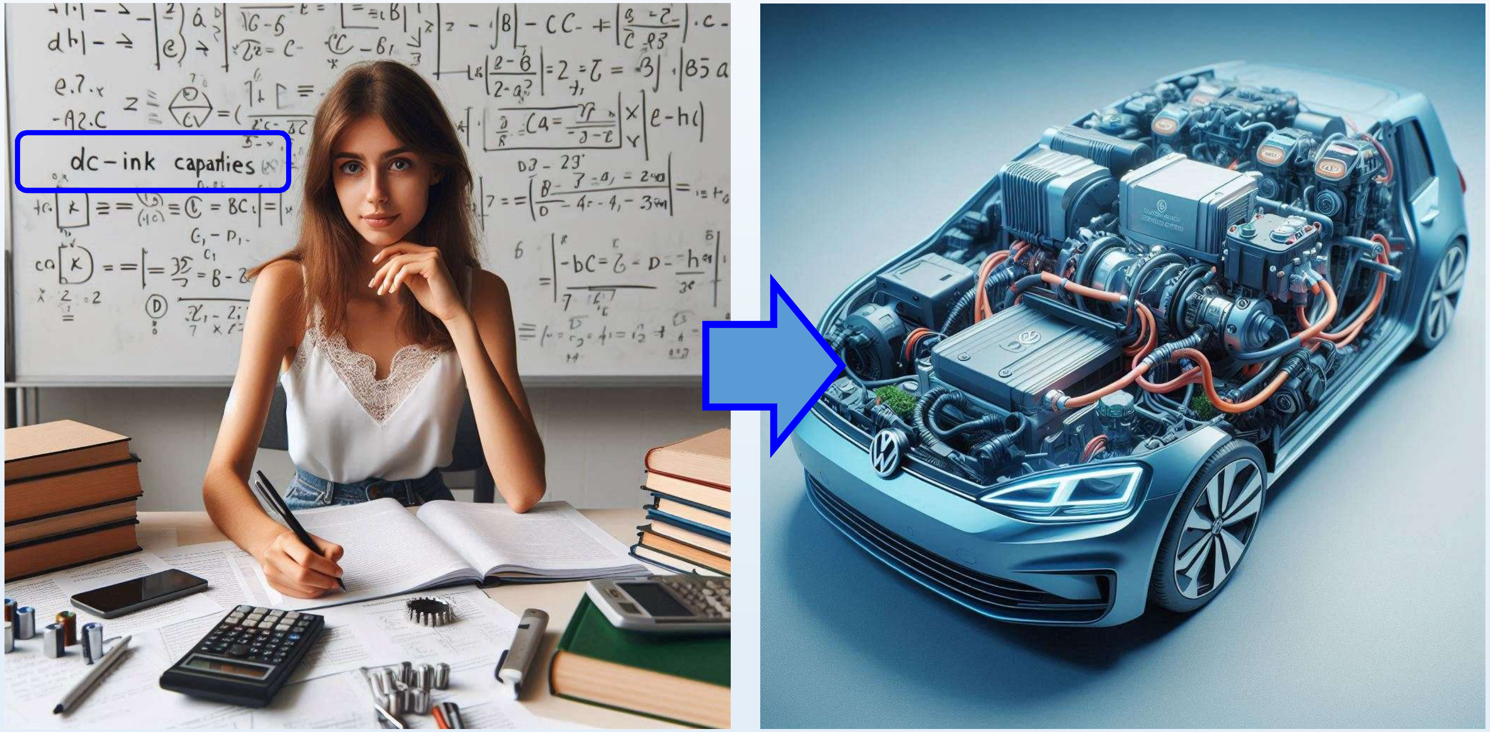
Reducing volume and weight is one of the key requirements of the automotive industry. However, this is not always absolutely necessary for a purely electric car, as the effort required for the reduction often costs a lot of resources combined with later market entry and is therefore no longer in any meaningful proportion. e.g. MEB is a platform designed for 120kW/450V but housing should fit for Hybrid Cars also - with all their room restrictions.

Just note:

Since the film capacitor is a massive ALU-block, it will respond to rising currents with an very slowly temperature increase. Nevertheless the semiconductor will die immediately to limited cooling.

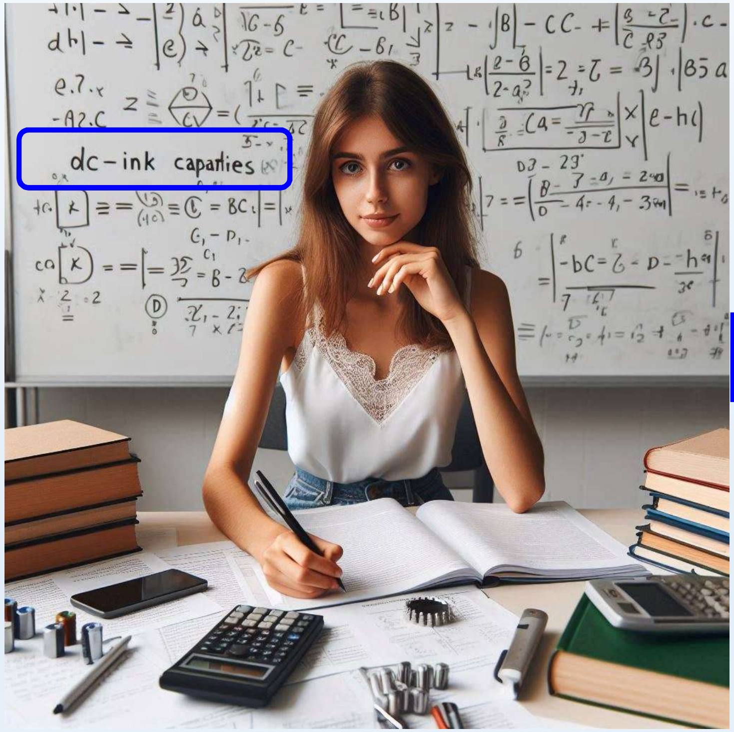
6. Advanced Design

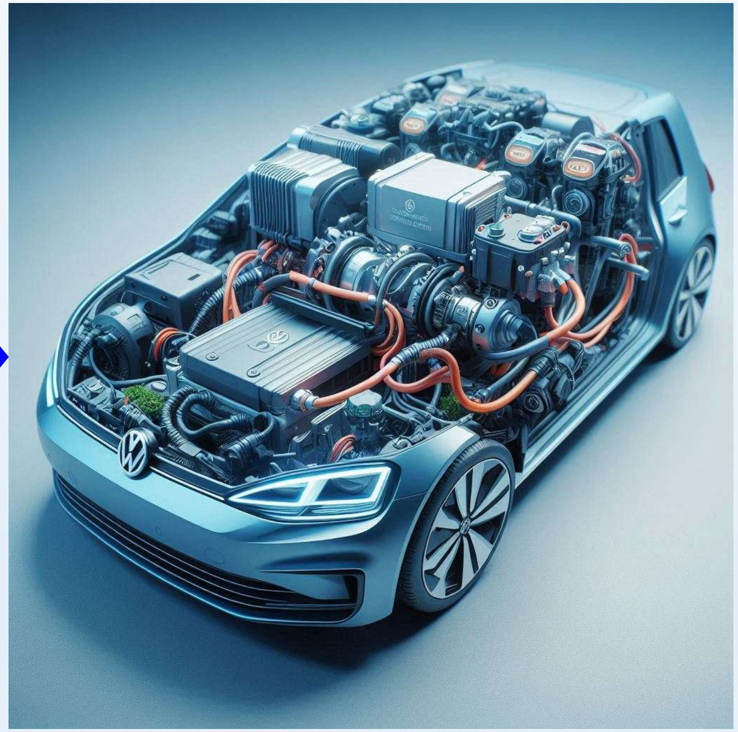
The usage of AI is not always good and of course it shouldn't look like this!



6. Advanced Design / AI(Artificial Intelligence)/KI

When you think about the development of a power train inverter with SiC, GaN, fast IGBT,…
check for the motor isolation, which is typically in the range up to 15kV/us …
but e.g. SiC rising speed is much faster with more than 25kV/us.
→ Think about what is the <u>best, cheapest and quickest</u> solution for your project!





Generated by Ai/Ki(Künstliche Intelligenz)-software with input uses our report!

6. Advanced Design – from Mankel-engineering.de

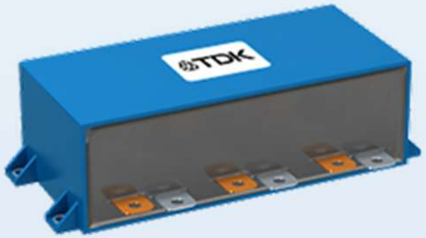
We are working in the power application field in
- Automotive
- Industrial
- Marine (Electric Boat)

with more than 30 years experience.

We have more than 10 Global Patents

We have technical benefit and preview because we are involved inside
- largest Power Semiconductor Manufacturer
- leading Passive Components Manufacturer

We can include all mechanical topics as well as software…



Content

EU – Capacitors and DUAL USE

Please note that the EU and other countries restricted the Im- and Export of so called DUAL USE products, machineries, Software aso.

Capacitors*

may fall underneath the

EU(Regulation (EU) No. 2021/821 (EU Dual-Use Regulation)
Energy Storage Device

*- Voltage rating greater than **750 V**,
- capacitance greater than **0.25 µF**
- and series inductance less than **10nH**. (Status: 2023)

→ **Check yourself whether your capacitor (application) falls under the DUAL USE regulation and always check its current status!**

Disclaimer

Please note that these <u>compilation</u> uses pictures which may not be state of the art, to prevent copies. All pictures in this presentation are already available to the public.

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Thank you for your attention!

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