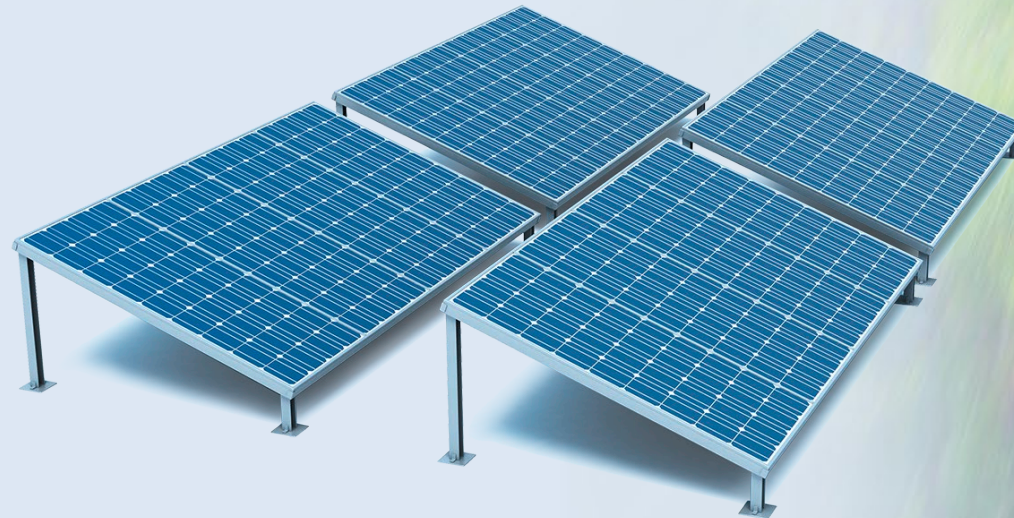


Attracting Tomorrow



Power electronic capacitors for low power (PEC LP MKP)



TDK Electronics AG
Aluminum & Film Capacitors Business Group
Munich, Germany
November 2023



Aluminum & Film Capacitors Business Group at a glance

Attracting Tomorrow

L2: Internal use only


Key data

Headquarters	Munich, Germany
Number of plants	8
Employees total	6600
Management	Karl Stoll CEO Bernhard Koch Deputy General Manager Auxi Fernandez CFO

Portfolio

Aluminum electrolytic capacitors

- Screw terminals
- Snap-in / Multi pin / Large size
- Axial-lead / Soldering star
- Single-ended
- Hybrid polymer aluminum electrolytic capacitors
 - SMD
 - Axial-lead / Soldering star

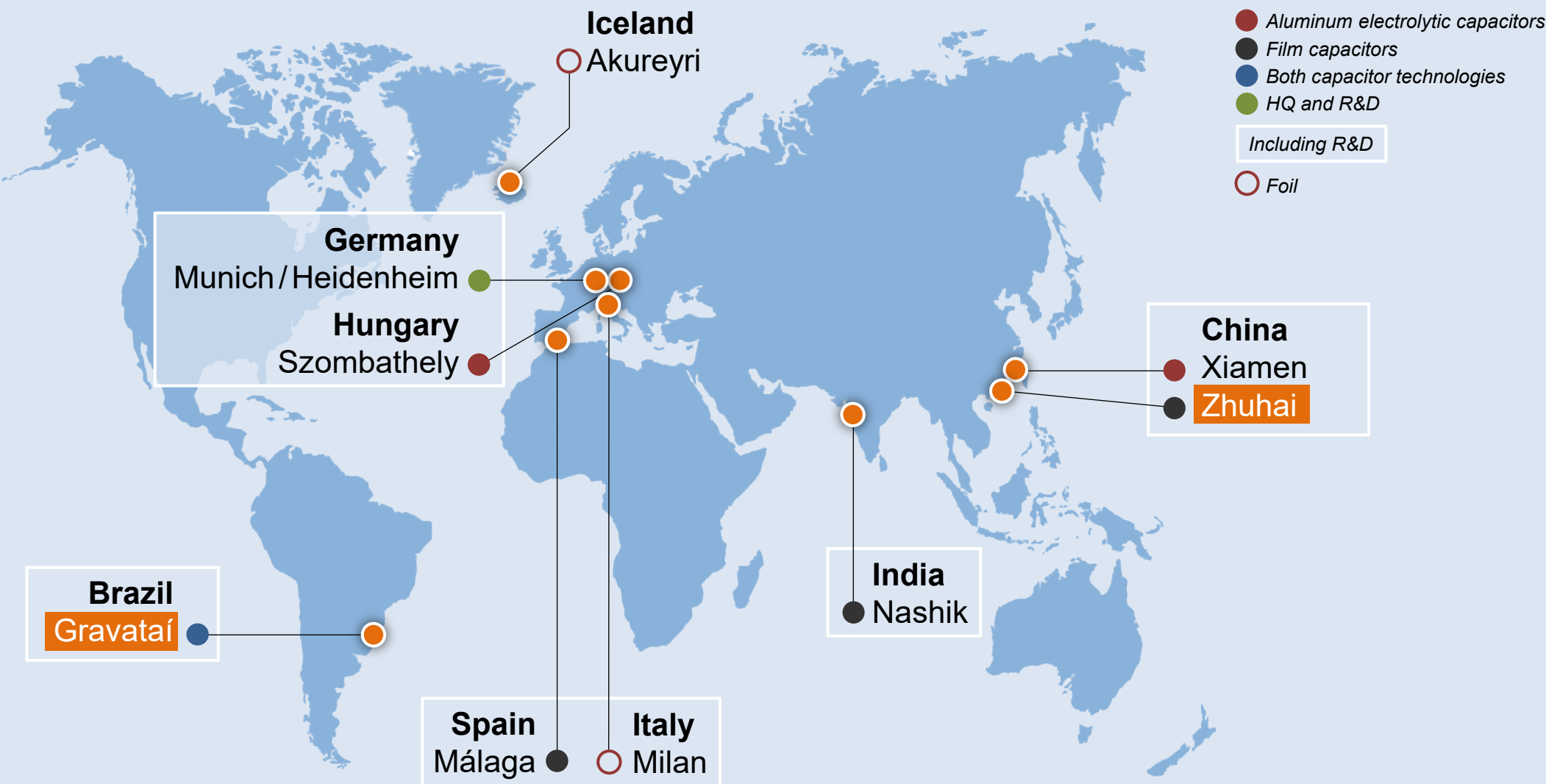
Film capacitors for Industrial and for Automotive

- DC capacitors
- AC capacitors
- Power capacitor chips for low power (PCC LP)

Film capacitors for Energy Solutions

- Power electronic capacitors for high power (PEC HP)
- **Power electronic capacitors for low power (PEC LP MKP)**
- Power factor correction (PFC) capacitors and key components for low and medium voltage (LV, MV)
- Power quality solutions (PQS)

Our Aluminum & Film Capacitors Business Group has a global manufacturing presence



Plant in Zhuhai, China

Product range

Aluminum & Film Capacitors BG

Film capacitors

- DC capacitors
- Power capacitor chips for low power (PCC LP)
- Power electronic capacitors for low power (PEC LP MKP)
- Power factor correction (PFC) capacitors and key components for low voltage (LV)
- Power quality solutions (PQS)

Piezo & Protection Devices BG

- Disk, Energy, Strap and Block varistors
- SMD disc varistors (CU)
- Inrush current limiters (ICLs)
- PTC thermistors



85,000 m²

Founded in 1998

Certification

- ISO 9001
- ISO 14001
- ISO 45001
- IATF 16949

Plant in Gravataí, Brazil

Product range

Aluminum & Film Capacitors BG

- Aluminum electrolytic capacitors
 - Axial-lead/Soldering star
 - Single-ended
 - Screw terminals
 - Snap-in/Multi pin
- Hybrid polymer aluminum electrolytic capacitors
 - SMD

Film capacitors

- DC capacitors
- AC capacitors
- Power factor correction (PFC) capacitors and key components for low voltage (LV)
- Power electronic capacitors for defibrillators (MKP)



43,000 m²
Founded in 1954

Certification

- ISO 9001
- ISO 14001
- ISO 45001
- IATF 16949

PEC MKP capacitors portfolio

MKP AC / MKD AC



Input / Output filter

MKP DC



DC link

Defibrillator



Defibrillator

Power capacitors for a wide range of applications

Solar inverters	Wind power plants	Drives	Traction	UPS	EV chargers	Hydrogen

Defibrillator capacitors for medical applications



Series
B32365*

Features

- Capacitance range 30 to 200 μF , voltage up to 5 kV
- Cylindrical and oval design (plastic or metal case)
- Terminals cable design upon request (straight/flag fast-on & stripped)
- Temperatures up to 60 °C hotspot

Applications

- AED (Automated External Defibrillator) and MED (Manual External Defibrillator)

Benefits

- Self-healing properties
- Low leakage current; high charge and discharge pulse capability
- Life expectancy up to 10,000 cycles

AC filter capacitors for industrial applications 1/2



Series
B32361* & B32362*

Standard solution

- 1-phase
- 20 to 600 μF
- 250 to 480 V_{RMS}



Series
B3237X*E/F

Improved resin filled design (portfolio extension)

- 1 & 3 Ph
- 5 to 600 μF
- 250 to 1000 V_{RMS}
- Metal cover
- Tightly sealed



Q4/2023

Series
B3237*G

New gas filled design – robust series for high requirements

- 1 & 3Ph
- 5 to 600 μF
- 250 to 1000 V_{RMS}
- Metal cover
- Long lifetime

AC filter capacitors for industrial applications 2/2



Series
B32361*
B32362*

Features

- Capacitance range 20 to 600 μF , 250 to 480 V_{RMS}
- IEC 61071-, GB/T17702- and UL 810- compliant
- Temperatures up to 85 °C hotspot
- Single-phase (1 Ph) capacitors

Applications

- Capacitors for AC input/output filtering for industrial applications, converters, UPS, drives and wind/solar inverters

Benefits

- Self-healing properties
- Overpressure disconnecter (tear-off fuse)

MKD AC filter capacitors product range



- Series
- B32370*
 - B32371*
 - B32373*
 - B32374*
 - B32375*
 - B32376*
 - B32377*
 - B32378*

	Rated AC V_{RMS} [V]	C_R [μ F] tolerance +/- 5%	Diameter [mm]	Height [mm]	Others
Single phase	600	5	50	64.5	B3237* series <ul style="list-style-type: none"> • Overpressure disconnecter • Available with fast-on terminals, screw terminals (M6 and M10) and clamp terminals
	
	1000	600	136	245	
Three phase	250	3 x 5	50	163	Delta connection: B32375* series (fast on terminal), B32376* series (screw terminal), B32377* series (clamp on terminal) Star connection: B32378* series (only in the market) <ul style="list-style-type: none"> • Overpressure disconnecter
	
	1000	3 x 600	136	350	

Single phase (1P2W)



3-phase/3 wires (3P3W) & 3-phase/4 wires (3P4W)



DC-link filter capacitors for industrial applications



Series

B2568* **New**

B2569* **New**

B2562*

B2563xB*

B2563xE* **New**

Features

- Capacitance range 40 4000 μ F, 500 to 3000 V DC
- Low ESR <1 m Ω & low ESL <12 nH (B2563*E series, ultra low ESL design)
- Temperatures up to 105 °C hotspot
- IEC 61071, RoHS-compliant and UL 810-compliant

Applications

- DC link for renewable energy inverters, industrial drives, e-mobility, medical and traction

Benefits

- Tightly sealed (metal top B2568* series)
- Self-healing properties
- 85 °C/85% RH V_N 1000 h (metal top B2568*/resin top B2569* series)
- Life expectancy up to 100,000 hours at hot spot temperature +75 °C

MKP DC filter capacitors product range

	Rated DC V _R DC [V]	C _R [μF] tol. +/- 10%	Diameter [mm]	Height H _c [mm]	Features
Standard	700	40	85	70	B2562* series • DC link for renewable energies, industrial drives and traction
	
	3000	4000	116	345	
Low LSI ULSI HF	500	50	85	50	B2563* series • L _s <13 nH • DC link for e-mobility
	
	2000	400	85	65	
Heavy duty	900	60	85	99	B2568* series • Metal top, tightly sealed • L _S <14 nH with 4T
	
	3000	4000	136	368	
High PD	700	45	75	95	B2569* series • Resin top, high humidity resistance and partial discharge
	
	3000	5500	136	370	

B2562* series



B2563* series



B2568* series



- Tightly sealed for operations in harsh environment
- Fire and smoke classification according to EN 45545
- Ultra low ESL (4 terminals upon request)
- Customized designs (high frequency and segmented film) upon request

B2569* series




- Resin top with improved partial discharge capabilities
- High humidity resistance 1.3 V_N, 85 °C/85%/500 hours
- Improved high partial discharge (PD) extinction voltage >1.6 kV AC (10 pC)

Power capacitors in round can for DC applications applications

MKP DC standard	MKP DC HF (EVO design)	MKP DC Metal top	MKP DC 4T	MKP DC HT 105 °C	MKP DC ULSI
B2562/B2569		B2568	B25689	B25695	B2563*E
<p>40 µF 5500 µF</p>	<p>Ramping up Q42023 Samples upon request</p>	<p>40 µF 4000 µF</p>	<p>80 µF 3000 µF</p>	<p>40 µF 4000 µF</p>	<p>20 µF 270 µF</p>
<p>700 V DC 3 kV DC</p>	<p>700 V DC 3 kV DC</p>	<p>900 V DC 3 kV DC</p>	<p>900 V DC 3 kV DC</p>	<p>900 V DC 2 kV DC</p>	<p>700 V DC 2 kV DC</p>
<p>HF customized version available</p>	<p>High frequency Si and SiC designs 20% lower ESL 10% lower ESR than standard</p>	<p>Tight Sealed Specially for traction applications</p>	<p>Special types Very low ESL <10 nH 65% lower ESL than standard Hermetically sealed</p>	<p>New</p>	<p>Very low ESL <12 nH High frequency design Ready for SiC</p>

Available sizes

MKP DC LSI/ULSI	2T MKP DC	4T MKP DC
 <p>D 85 mm</p> <p>H 50,65 mm</p> <p>C: from 20 μF to 270 μF V: from 700 V to 2 kV</p>	 <p>D: 75, 85, 90, 100, 116, 136 mm</p> <p>H is flexible</p> <p>C: from 40 μF to 6 mF V: from 700 V to 3 kV</p>	 <p>D: 116 mm</p> <p>H is flexible</p> <p>C: from 40 μF to 4 mF V: from 700 V to 3 kV</p>

- 6 diameters available for all MKP DC
- D 85, 100 and 116 mm are the high runners
- Big flexibility in height due to big range of film width
- **1, 2 or 3 windings inside depending on the the specification needed to be achieve**
- Standard film widths 50 mm, 62.5 mm, 75 mm, 100 mm
- D 85 mm available for ULSI/LSI
- Example of design of 2 windings



Recommendations for EV charging

High-power density

- Trend to develop high-power density converters using SiC semiconductors
- Capacitors with high current capability, ultra low ESL and lower ESR at high frequencies are requested



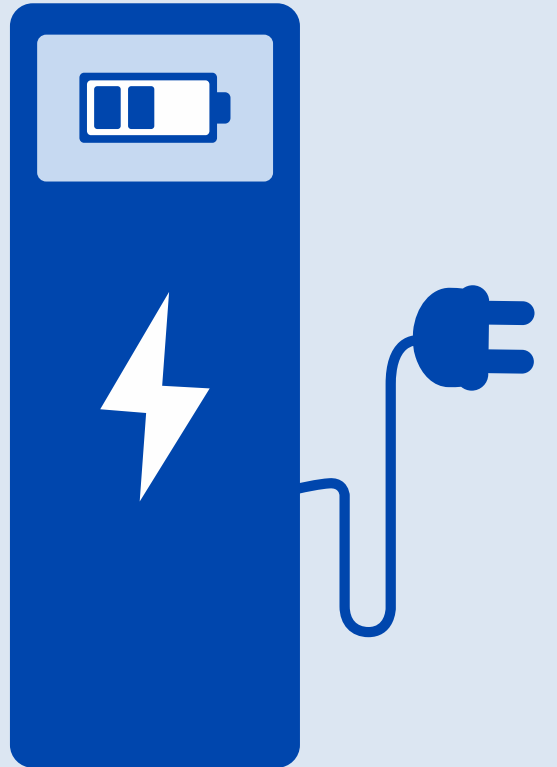
MKP DC ultra low inductance (ULSI) Series B2563*E ultra low ESL <13 nH

Main applications

- DC fast charging
- Solar string inverters
- Induction heating
- Traction
- High-speed switching applications

Product description

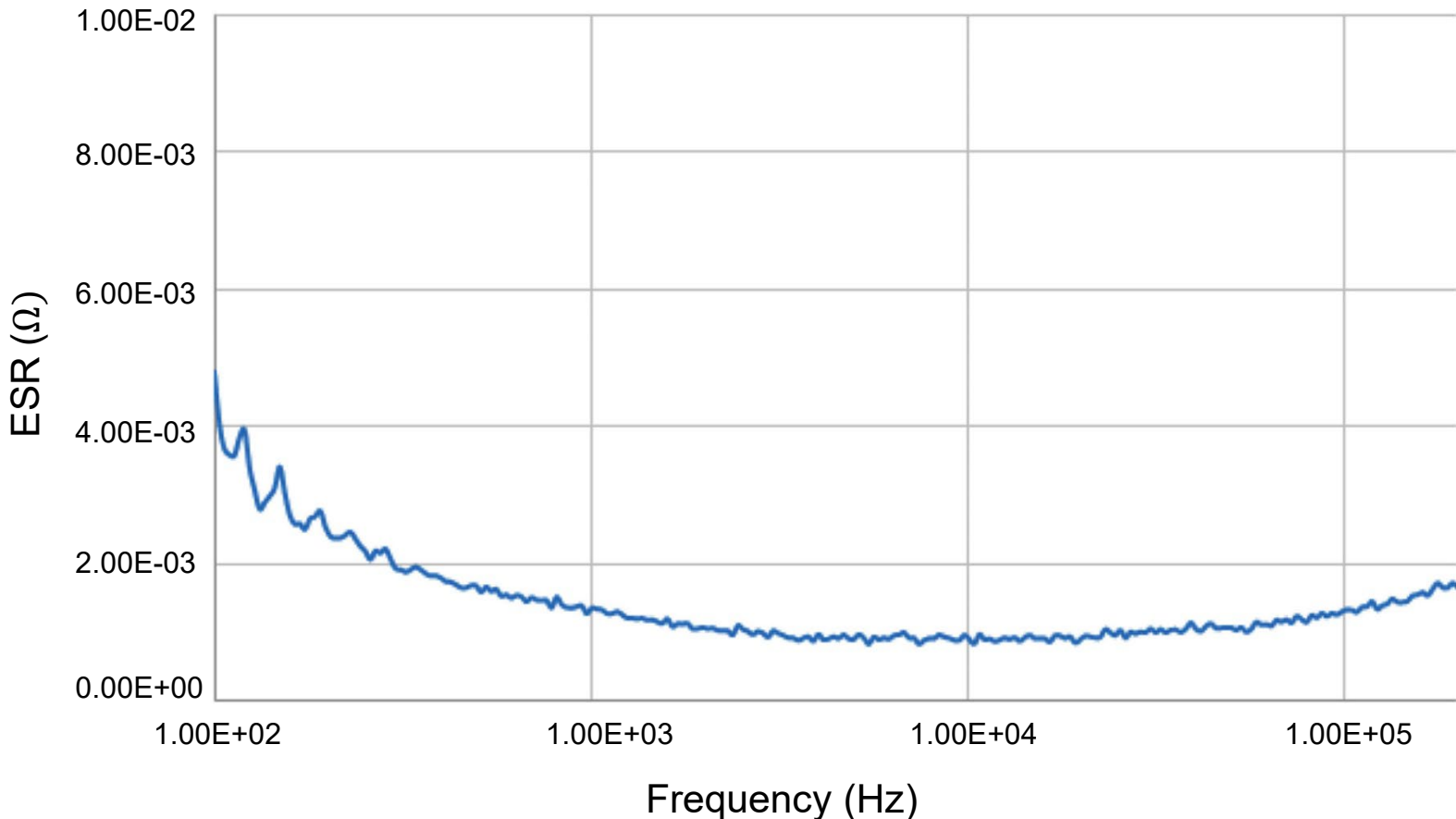
- Capacitance range 20 to 270 μF ; V DC: 700 V to 2 KV
- **ESL <13 nH**
- **Low ESR** over frequency
- Diameter: 85 mm
- Height: 50 and 65 mm
- Male (M8) or female (M5) terminals
- High current capability
- DC link for SiC power modules and Si modules with high-speed switching
- For 85 °C HS, (samples available at higher temperatures)



MKP DC ULSI HF

ESR versus frequency

B25632E117K000 (110 μ F, 1000 V DC)



Typical switching frequency power module

20 kHz to 40 kHz, so it is important to characterize the capacitor to low/stable ESR values until several hundreds kHz and consider all the harmonics for the thermal considerations

110 μ F, 1000 V DC

10 kHz: 1.18 m Ω

100 kHz: 1.38 m Ω

160 kHz: 1.5 m Ω

Low ESR in the working frequency range

MKP DC metal top series B2568*

Tightly sealed MKP DC series with metal top disk (B2568*)

- **Range:** 900 V to 3 kV, 50 μ F to 4 mF
- Main DC link voltage for traction: 1 kV for 1.7 kV IGBTs and 2 kV for 3.3 kV IGBTs
- **Target applications**
 - Traction inverters
 - Commercial agricultural vehicles (CAV)
 - Medium-voltage drives (MVD)
- **Humidity:** 85 °C/85% RH 1000 hours
- **Fire & smoke classification acc. to EN 45545:** R22: HL3 R23,; HL2
- **Dimensions:** \varnothing 85, \varnothing 116 and \varnothing 136 mm; height 74 mm to 368 mm
- **Light weight** (aluminum)
- Good cooling (normally stacked 2 windings)
- Ultra low ESL with 4 terminals (4T) design (<14 nH, in some cases <10 nH possible)

Standard datasheet available under

www.tdk-electronics.tdk.com/en/power_capacitors



**For harsh operating conditions
especially traction applications**

MKP DC 4T metal top series B25689*

The tightly sealed DC capacitors with ultra low ESL

Tightly sealed MKP DC series with 4 terminals (4T)
for ESL <14 nH (B25689* series)

- **Range:** 900 V to 3 kV, 50 μ F to 3 mF
- Main DC link voltage for traction: 1 kV for 1.7 kV IGBTs and 2 kV for 3.3 kV IGBTs
- **Target applications**
 - Traction inverters
 - All high-speed switching applications
- **Humidity:** 85 °C/85% RH 1000 hours
- **Fire & smoke classification acc. to EN 45545:** R22: HL3 R23: HL2
- **Dimensions:** \varnothing 116; height: 74 to 345 mm
- **Light weight** (aluminum)
- Good cooling (normally stacked 2 windings)
- Approx. **60% less ESL** than standard capacitor with 2T
- Typical ESL 12 to 15 nH (special designs with 10 nH possible)
- Lifetime up to 200,000 hours
- Samples available

Standard datasheet available under www.tdk-electronics.tdk.com/en/power_capacitors



**For harsh
operating conditions
especially traction
applications**

MKP DC metal top series B2568*

Modular approach comparison 2T vs 4T

Typical values requested – diameter = 116 mm

Hc (mm)	1000 V DC (1.7 kV power modules)	1800 V DC (3.3 kV power modules)	2000 V DC (3.3 kV power modules)	ESL 2 terminals	ESL 4 terminals
75	360 μ F	100 μ F	80 μ F	32	13
100	550 μ F	165 μ F	130 μ F	25	10
179	1100 μ F	330 μ F	260 μ F	34	14
229	1500 μ F	450 μ F	360 μ F	38	15

Typical values requested – diameter = 85 mm:

Hc (mm)	1000 V DC (1.7 kV power modules)	1800 V DC (3.3 kV power modules)	2000 V DC (3.3 kV power modules)	ESL (typical nH)
179	550 μ F	160 μ F	130 μ F	22 nH
229	740 μ F	220 μ F	180 μ F	25 nH
252	810 μ F	240 μ F	195 μ F	28 nH

* Special types with even lower ESL upon request



**Same mechanical
approach for all platforms**

MKP DC HF EVO: The DC link for the next generation power converters

- **Lower ESL** than standard MKP DC (around 20% lower)
- **Lower ESR** compared with standard MKP DC (around 5 to 10% lower)
- Overlapped busbars for **homogeneous current distribution**
- **Internal resonances avoided**
- To be used in combination with SiC or when there is a considerable current at high frequencies
- In final approval stage; series from September 2023
- Datasheet available end of Q2/2023; samples from June 2023
- Applications: Solar & wind inverters, industrial drives, traction aux. inverters

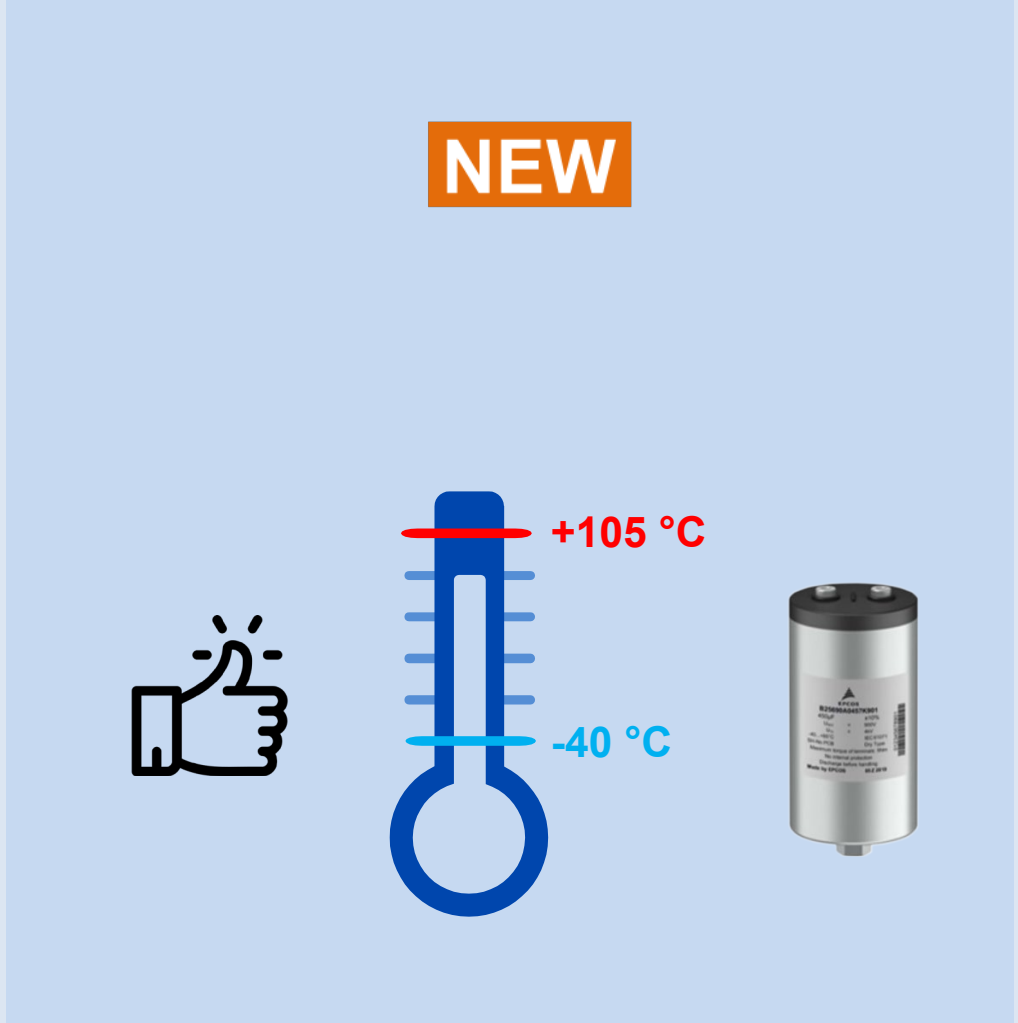


NEW

MKP DC 105 °C series B25695*

Improving the DC link performance

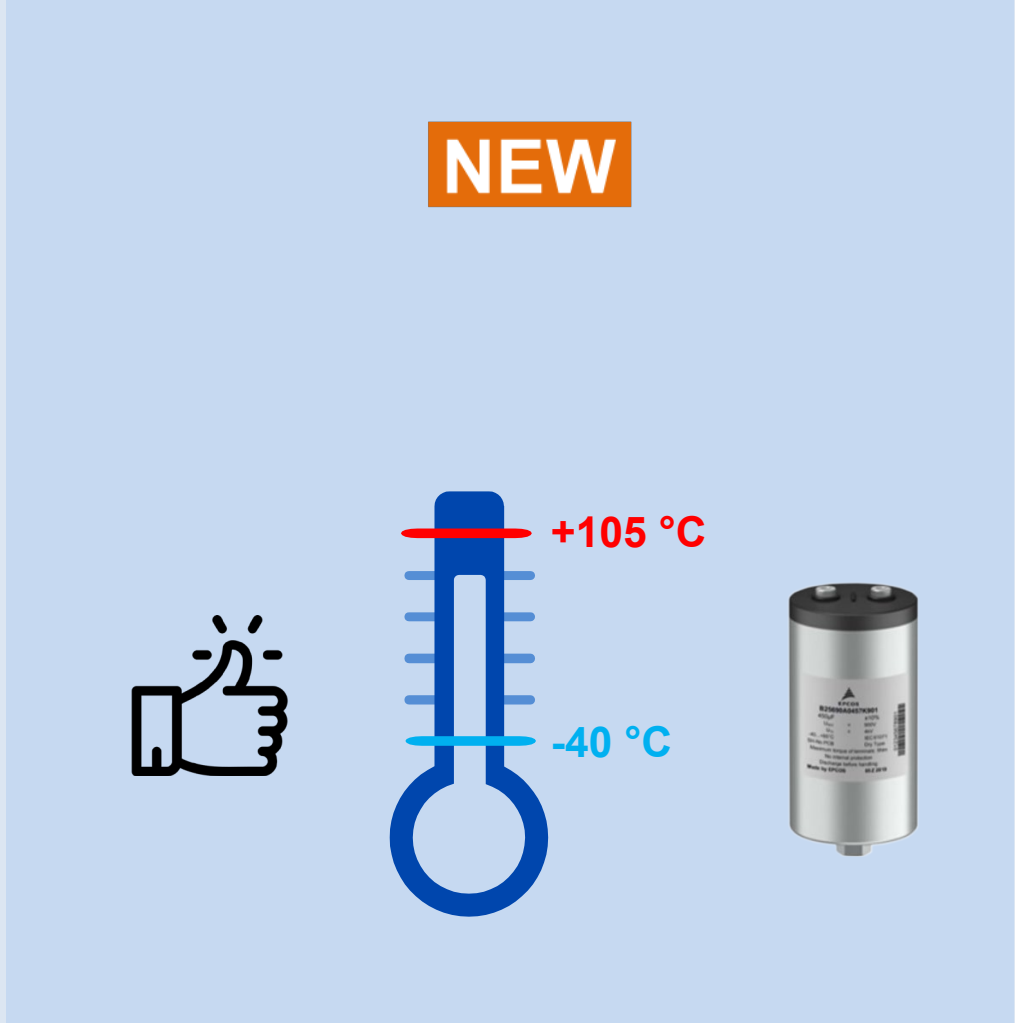
- Datasheet available in April 2024
- Diameters 85, 116 mm; voltages from 900 V to 1.6 kV
- Lifetime will be specified for 95 °C and 105 °C HS
- Design-in upon request, samples available
- Epoxy resin instead of PU, improved process
- Applications: Solar & wind inverters, industrial drives, traction inverters



MKP DC 105°C series B25695*

Series advantages

- Higher current capability (higher self-heating allowed)
- Higher ambient temperature possible (e.g. less cooling)
- Hot spot allowed till 105 °C (derating to be considered)
- Solution could be done more compact



MKP-DC battery – CFD simulations

Overview & boundary conditions

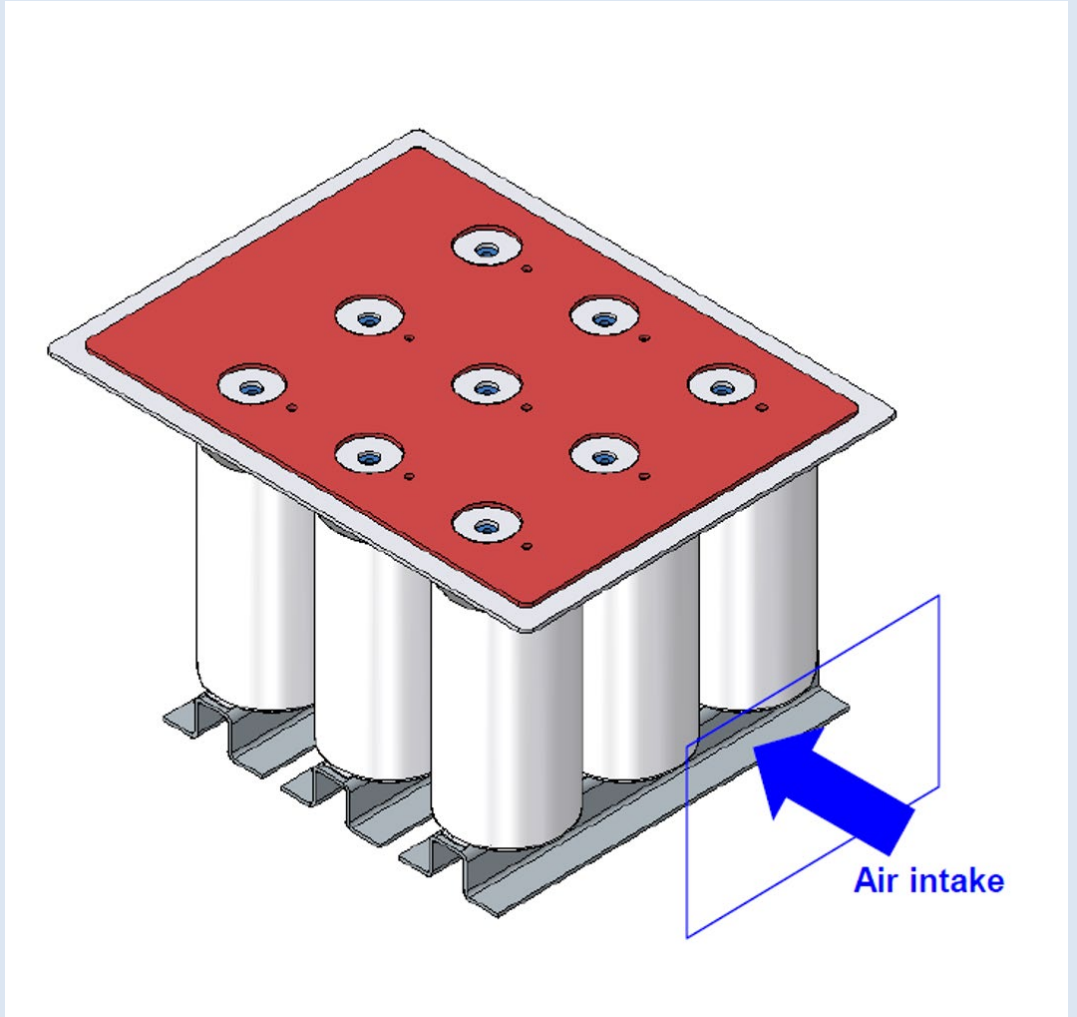
- We offer CFD simulations to customers
- Depending e.g. on distance between capacitors and velocity of air we can change self-heating of the capacitor

General data

- P/N: B25620B0757K881
- Capacitance: 6.75 mF
- Voltage: 900 VDC
- I_{total} : 600 A_{RMS}

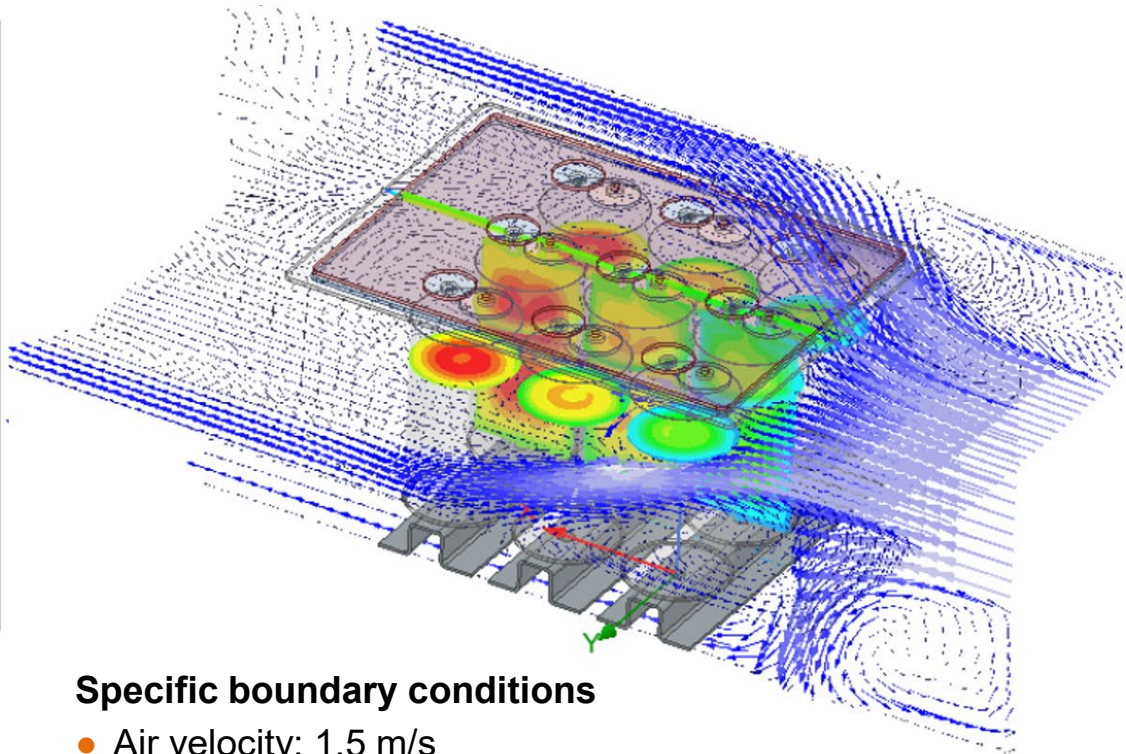
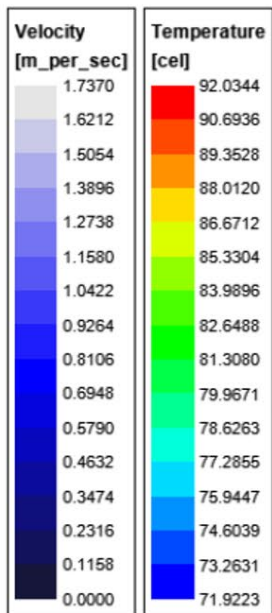
Common boundary conditions

- Ambient temperature: 70 °C
- Losses: 7 W/capacitor
- Busbar losses: 16 W
- Air direction: from right to left
- Active cooling temperature (when present): 65 °C



MKP-DC battery – CFD simulations

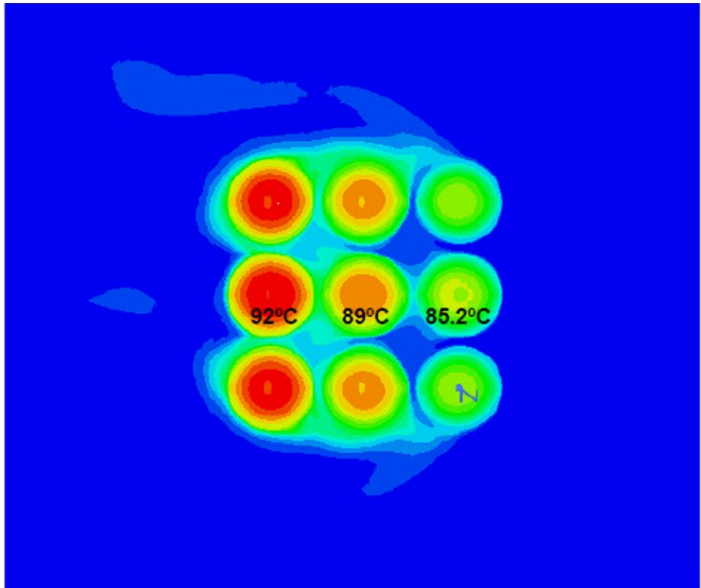
Forced convection



Specific boundary conditions

- Air velocity: 1.5 m/s
- Separation between capacitors: 10 mm
- No active cooling considered

Top winding half-height cross section



Results (hotspot temperatures)

- First row: 85.2 °C → -12.9 K
- Second row: 89 °C → -18.4 K
- Third row: 92 °C → -21.9 K

Recommendations for renewable energies

Solar & wind applications

Better efficiency

- **Solar** Since PV is strongly influenced by cost pressure then new inverters are forced to offer very high efficiency (97 to 98%) with longer maintenance periods.
- Application is demanding cost-optimized standard products with higher nominal voltages and reduced ESR/ESL. Capacitors should be optimized to work at higher frequencies
- **Wind** is as well strongly influenced by cost pressure with a trend to increase the output power specially in off-shore applications
- Both applications are demanding higher current densities



Semikron SkiiP4 module
with our resin top DC link series



Full SiC String inverter using our
ULSI capacitors family

Recommendations for traction applications

High power density

- In light train applications, the use of light and low volume converters is a must, so standardization of components (modular platforms) together compact designs is highly appreciated
- Becoming more popular the use of fast switching IGBTs and SiC semiconductors with higher switching frequencies

This requires low ESL capacitors; two good series are our MKP 4 terminal capacitors with ESL as low as 10 nH





www.tdk-electronics.tdk.com