Film Capacitors

EMI Suppression Capacitors (MKP)

Series/Type: **B32922P/Q ... B32924P/Q**

Date: April 2024

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Typical applications

- X2 class for interference suppression
- "Across the line" application
- Severe ambient conditions
- Automotive application

Climatic

- Max. operating temperature: 125 °C
- Climatic category (IEC 60068-1): 40/125/56

Features

- Small dimensions
- Good self-healing properties
- AEC-Q200 compliant
- RoHS-compatible
- Halogen-free capacitors available on request

Construction

- Dielectric: polypropylene (MKP)
- Plastic case (UL 94 V-0)
- Epoxy resin sealing (UL 94 V-0)

Terminals

- Parallel wire leads, lead-free tinned
- Special lead lengths available on request

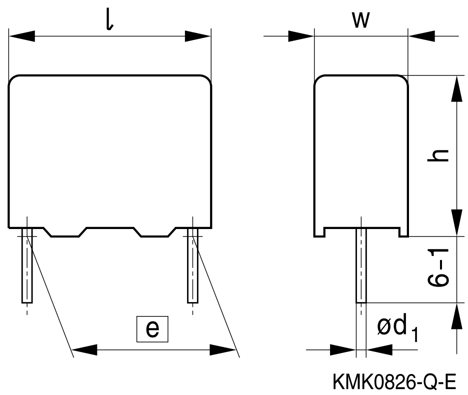
Marking

Manufacturer's logo, lot number, date code, rated capacitance (coded), capacitance tolerance (code letter), rated AC voltage (IEC), series number, sub-class (X2), dielectric code (MKP), climatic category, passive flammability category, approvals

Delivery mode

- Bulk
- Taped (Ammo pack or reel)
  For taping details, refer to chapter "Taping and packing".

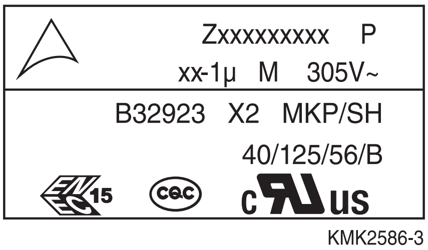
Dimensional drawing



Dimensions in mm

Lead spacing e ±0.4	Lead diameter d_1 ±0.05	Type
15	0.8	B32922P/Q
22.5	0.8	B32923P/Q
27.5	0.8	B32924P/Q

Marking example



Approvals

Approval marks	Standards	Certificate
ENEC 15	EN 60384-14:2014 IEC 60384-14:2013	ENEC-04096 (approved by UL)
cULus	UL 60384-14:2014 CSA E60384-14:2013	E97863 (approved by UL)
CQC	GB/T6346.14-2015	CQC20001257420

Overview of available types

Lead spacing	15 mm	22.5 mm	27.5 mm
Type	B32922P/Q	B32923P/Q	B32924P/Q
C_R (µF)			
0.033			
0.039			
0.047			
0.056			
0.068			
0.082			
0.10			
0.12			
0.15			
0.18			
0.22			
0.27			
0.33			
0.39			
0.410			
0.47			
0.56			
0.68			
0.82			
1.0			
1.2			
1.5			
1.8			
2.0			
2.2			
2.7			
3.3			
3.9			
4.7			
5.6			

Ordering codes and packing units

Lead spacing mm	C_R µF	Max. dimensions w × h × l mm	Ordering code (composition see below)	Ammo pack pcs./MOQ	Reel pcs./MOQ	Untaped pcs./MOQ
15	0.033	5.0 × 10.5 × 18.0	B32922P3333+***	4680	5200	4000
	0.039	5.0 × 10.5 × 18.0	B32922P3393+***	4680	5200	4000
	0.047	5.0 × 10.5 × 18.0	B32922P3473+***	4680	5200	4000
	0.056	5.0 × 10.5 × 18.0	B32922P3563+***	4680	5200	4000
	0.068	5.0 × 10.5 × 18.0	B32922P3683+***	4680	5200	4000
	0.082	5.0 × 10.5 × 18.0	B32922P3823+***	4680	5200	4000
	0.10	5.0 × 10.5 × 18.0	B32922P3104+***	4680	5200	4000
	0.12	6.0 × 12.0 × 18.0	B32922P3124+***	3840	4400	4000
	0.15	6.0 × 12.0 × 18.0	B32922P3154+***	3840	4400	4000
	0.18	7.0 × 12.5 × 18.0	B32922P3184+***	3320	3600	4000
	0.22	7.0 × 12.5 × 18.0	B32922P3224+***	3320	3600	4000
	0.27	8.0 × 14.0 × 18.0	B32922P3274+***	2920	3000	2000
	0.33	8.0 × 14.0 × 18.0	B32922P3334M***	2920	3000	2000
	0.33	8.5 × 14.5 × 18.0	B32922Q3334+***	2720	2800	2000
	0.39	9.0 × 17.5 × 18.0	B32922P3394+***	2560	2800	2000
	0.47	9.0 × 17.5 × 18.0	B32922P3474+***	2560	2800	2000
	0.56	11.0 × 18.5 × 18.0	B32922P3564+***	–	2200	1200
	0.68	11.0 × 18.5 × 18.0	B32922P3684M***	–	2200	1200

MOQ = Minimum Order Quantity, consisting of 4 packing units.
Further intermediate capacitance values on request.

Composition of ordering code

+ = Capacitance tolerance code:
M = ±20%
K = ±10%

*** = Packaging code
289 = Straight terminals, Ammo pack
189 = Straight terminals, Reel
003 = Straight terminals, untaped (lead length 3.2 ±0.3 mm)
000 = Straight terminals, untaped (lead length 6.0 –1.0 mm)

Ordering codes and packing units

Lead spacing mm	C_R µF	Max. dimensions w × h × l mm	Ordering code (composition see below)	Ammo pack pcs./MOQ	Reel pcs./MOQ	Untaped pcs./MOQ
22.5	0.22	6.0 × 15.0 × 26.5	B32923P3224+***	2720	2800	2880
	0.27	6.0 × 15.0 × 26.5	B32923P3274+***	2720	2800	2880
	0.33	6.0 × 15.0 × 26.5	B32923P3334M***	2720	2800	2880
	0.33	7.0 × 16.0 × 26.5	B32923Q3334+***	2320	2400	2520
	0.39	7.0 × 16.0 × 26.5	B32923P3394+***	2320	2400	2520
	0.41	8.5 × 16.5 × 26.5	B32923P3414+***	1920	2000	2040
	0.47	8.5 × 16.5 × 26.5	B32923P3474+***	1920	2000	2040
	0.56	8.5 × 16.5 × 26.5	B32923P3564M***	1920	2000	2040
	0.68	10.5 × 16.5 × 26.5	B32923P3684+***	1560	1600	2160
	0.82	10.5 × 18.5 × 26.5	B32923P3824+***	1560	1600	2160
	1.0	11.0 × 20.5 × 26.5	B32923P3105+***	1480	1400	2040
	1.2	12.0 × 22.0 × 26.5	B32923P3125+***	1320	1200	1800
	1.5	14.5 × 29.5 × 26.5	B32923P3155+***	–	–	1040
	1.8	14.5 × 29.5 × 26.5	B32923P3185+***	–	–	1040
	2.0	14.5 × 29.5 × 26.5	B32923P3205+***	–	–	1040
	2.2	14.5 × 29.5 × 26.5	B32923P3225+***	–	–	1040

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Ordering codes and packing units

Lead spacing mm	C_R µF	Max. dimensions w × h × l mm	Ordering code (composition see below)	Ammo pack pcs./MOQ	Reel pcs./MOQ	Untaped pcs./MOQ
27.5	0.68	11.0 × 19.0 × 31.5	B32924P3684+***	–	1400	1280
	0.82	11.0 × 19.0 × 31.5	B32924P3824+***	–	1400	1280
	1.0	11.0 × 19.0 × 31.5	B32924P3105+***	–	1400	1280
	1.2	11.0 × 19.0 × 31.5	B32924P3125M***	–	1400	1280
	1.2	12.5 × 21.5 × 31.5	B32924Q3125+***	–	1200	1120
	1.5	12.5 × 21.5 × 31.5	B32924P3155+***	–	1200	1120
	1.8	13.5 × 23.0 × 31.5	B32924P3185+***	–	1000	1040
	2.2	14.0 × 24.5 × 31.5	B32924P3225M***	–	1000	1040
	2.7	18.0 × 27.5 × 31.5	B32924P3275+***	–	–	800
	3.3	16.0 × 32.0 × 31.5	B32924Q3335+***	–	–	880
	3.3	18.0 × 27.5 × 31.5	B32924P3335M***	–	–	800
	3.9	18.0 × 33.0 × 31.5	B32924P3395+***	–	–	800
	3.9	21.0 × 31.0 × 31.5	B32924Q3395+***	–	–	720
	4.7	18.0 × 33.0 × 31.5	B32924P3475M***	–	–	800
	4.7	21.0 × 31.0 × 31.5	B32924Q3475M***	–	–	720
	5.6	22.0 × 36.5 × 31.5	B32924P3565+***	–	–	784

MOQ = Minimum Order Quantity, consisting of 4 packing units.
Further intermediate capacitance values on request.

Composition of ordering code

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Technical data and specifications

Reference standard: UL / IEC 60384-14:2013/AMD1:2016 and AEC-Q200D.
All data given at T = 20 °C unless otherwise specified

Rated AC voltage (IEC 60384-14)	305 V AC (50/60 Hz)			
Maximum continuous DC voltage V_{DC} (≤ 110 °C)	630 V DC			
Max. operating temperature $T_{op,max}$ (T_{op} = T_A + self-heating)	+125 °C			
DC operating derating between 110 °C and 125 °C	1.33% / °C of V_{DC} derating compared to V_{DC} at 110 °C			
DC test voltage[1]	Between terminals: 1312 V DC, 2 s			
Dissipation factor tan δ (in 10^{-3}) at 20 °C (upper limit values)	at	C ≤ 0.1 µF	0.1 µF < C_R ≤ 2.2 µF	C_R > 2.2 µF
	1 kHz	1.0	1.0	3.0
	100 kHz	5.0	–	–
Insulation resistance R_{ins} (in GΩ) or time constant τ = C_R • R_{ins} (in s) at 100 V DC, 20 °C, rel. humidity ≤ 65% and for 60 s (minimum as-delivered values)	C_R ≤ 0.33 µF		C_R > 0.33 µF	
	15 GΩ		5000 s	
Passive flammability category	B			
Operating voltage V_{op} at high temperature	T_{op} ≤ 125 °C T_{op} ≤ 125 °C		V_{op} = V_{AC} (continuously) V_{op} = 1.25 • V_{AC} (1000 h)	
Biased humidity test 1	Temperature: Relative humidity (RH): Voltage value: Test duration:		+40 °C ±2 °C 93% ±3% 305 V AC, 50 Hz 1000 hours	
Biased humidity test 2	Temperature: Relative humidity (RH): Voltage value: Test duration:		+85 °C ±2 °C 85% ±2% 240 V AC, 50 Hz 500 hours	
Limit values after damp heat test	Capacitance change |ΔC/C|: Dissipation factor change |Δtan δ|: Insulation resistance R_{ins}			≤ 10% < 0.005 ≥ 200 MΩ
Temperature cycling, 30 min maximum dwell time at each temperature extreme. 1 min. maximum transition time.	–55 °C ... +125 °C / 100 cycles Capacitance change |ΔC/C| ≤ 5% No visible damage			

1) The repetition of this DC voltage test may damage the capacitor. Special care must be taken in case of use several capacitors in a parallel configuration.

Pulse handling capability

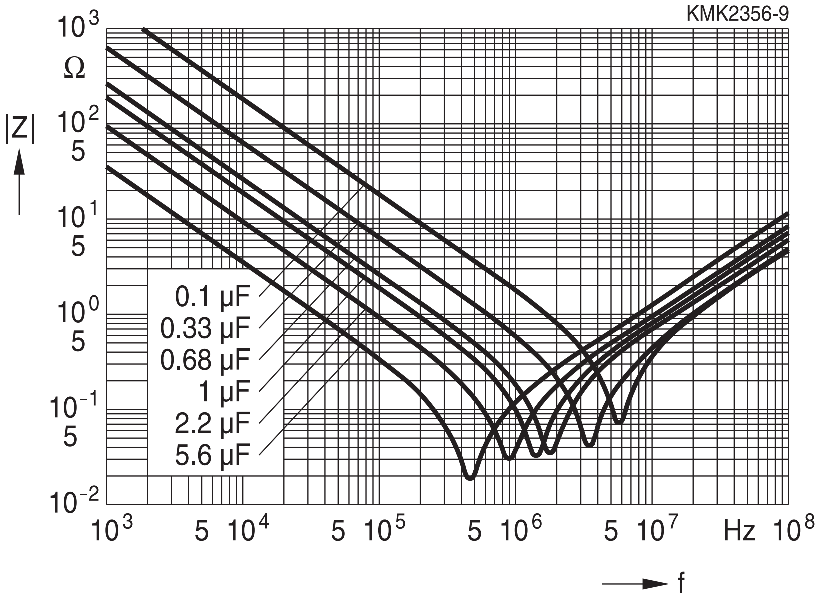
"dV/dt" represents the maximum permissible voltage change per unit of time for non-sinusoidal voltages, expressed in V/µs.
"k_0" represents the maximum permissible pulse characteristic of the waveform applied to the capacitor, expressed in V^2/µs.

Note:
The values of dV/dt and k_0 provided below must not be exceeded in order to avoid damaging the capacitor.

dV/dt and k_0 values

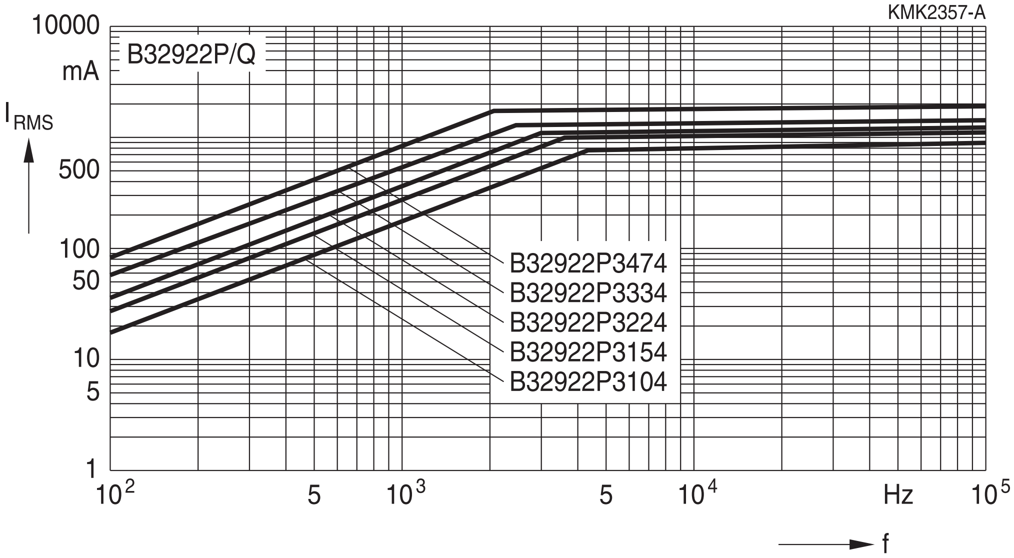
Lead spacing (mm)	15	22.5	27.5
dV/dt (V/µs)	340	170	80
k_0 (V^2/µs)	292400	146200	69000

Impedance Z versus frequency f
(typical values)

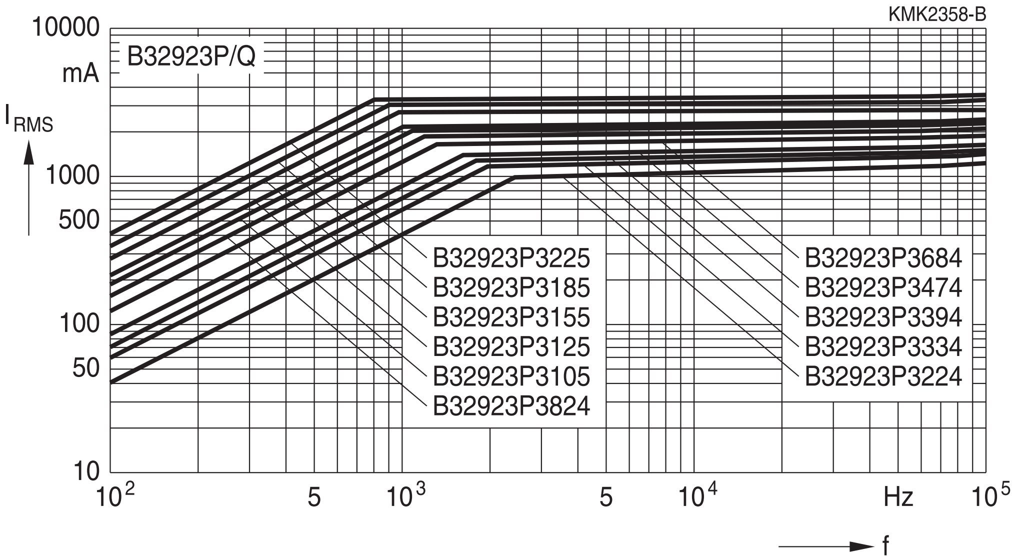


Permissible AC current I_{RMS} versus frequency f
(for sinusoidal waveforms $T_A \leq 90$ °C and ΔESR <100% from receipt condition)

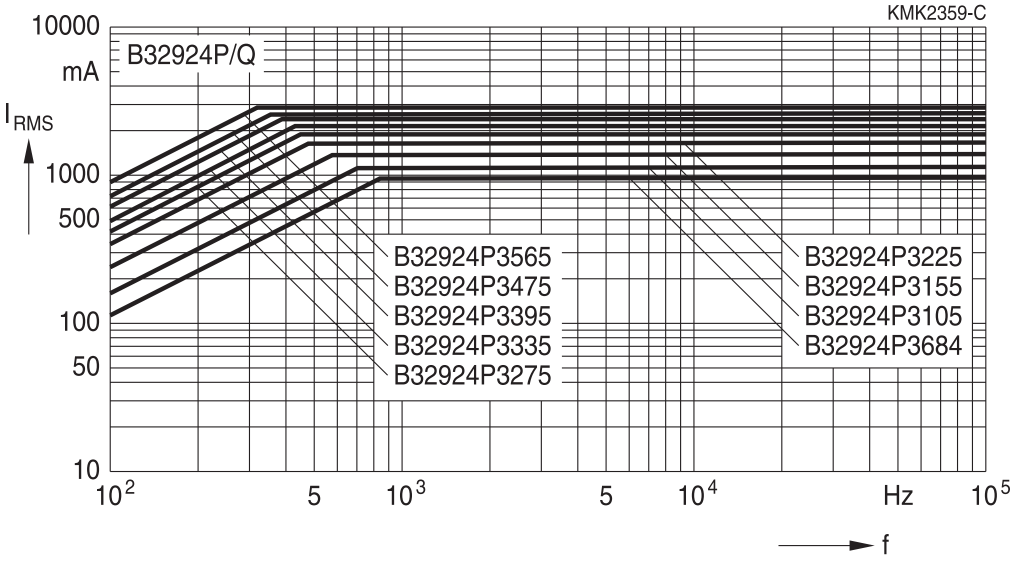
Lead spacing 15 mm



Lead spacing 22.5 mm



Lead spacing 27.5 mm



Testing and Standards

Test	Reference	Conditions of test		Performance requirements
Electrical parameters	IEC 60384-14	Voltage Proof: Between terminals: 4.3 × V_R (DC), 1min Terminals and enclosure: 2 V_R + 1500 V AC, 1 min Insulation resistance, R_{ins} Capacitance, C Dissipation factor, tan δ		Within specified limits
Robustness of terminations	IEC 60068-2-21	Tensile strength (test Ua1)		Capacitance and tan δ within specified limits
		Wire diameter	Tensile force	
		$0.5 < d_1 \leq 0.8$ mm	10 N	
		$0.8 < d_1 \leq 1.25$ mm	20 N	
Resistance to soldering heat	IEC 60068-2-20, test Tb, method 1A	Solder bath temperature at 260 ±5 °C, immersion for 10 seconds		$\Delta C/C_0 \leq 5\%$ tan δ within specified limits
Rapid change of temperature	IEC 60384-14	T_A = lower category temperature T_B = upper category temperature Five cycles, duration t = 30 min		No visible damage $\|\Delta C/C_0\| \leq 5\%$ tan δ within specified limits

Test	Reference	Conditions of test	Performance requirements
Vibration	IEC 60384-14	Test F_C: vibration sinusoidal Displacement: 0.75 mm Acceleration: 98 m/s^2 Frequency: 10 Hz ... 500 Hz Test duration: 3 orthogonal axes, 2 hours each axe	No visible damage
Bump	IEC 60384-14	Test Eb: Total 4000 bumps with 400 m/s^2 mounted on PCB 6 ms duration	No visible damage $\lvert\Delta C/C_0\rvert \leq 5\%$ tan δ within specified limits
Damp heat, steady state	IEC 60384-14	Test Ca 40 °C / 93% RH / 56 days	No visible damage $\lvert\Delta C/C_0\rvert \leq 5\%$ $\lvert\Delta \tan \delta\rvert \leq 0.008$ for C ≤ 1 µF $\lvert\Delta \tan \delta\rvert \leq 0.005$ for C > 1 µF Voltage proof $R_{ins} \geq 50\%$ of initial limit
Impulse test Endurance	IEC 60384-14	3 impulses T_B / 1.25 V_R / 1000 hours, 1000 V_{RMS} for 0.1 s every hour	No visible damage $\lvert\Delta C/C_0\rvert \leq 10\%$ $\lvert\Delta \tan \delta\rvert \leq 0.008$ for C ≤ 1 µF $\lvert\Delta \tan \delta\rvert \leq 0.005$ for C > 1 µF Voltage proof $R_{ins} \geq 50\%$ of initial limit
Charge and discharge	IEC 60384-14	dv/dt = 100 V/µs Cycles = 10000	$\lvert\Delta C/C_0\rvert \leq 10\%$ $\lvert\Delta \tan \delta\rvert \leq 0.008$ for C ≤ 1 µF $\lvert\Delta \tan \delta\rvert \leq 0.005$ for C > 1 µF Voltage proof $R_{ins} \geq 50\%$ of initial limit
Passive flammability	IEC 60384-14	Flame applied for a period of time depending on capacitor volume	B
Active flammability	IEC 60384-14	20 discharges at 2.5 kV + V_R	The cheesecloth shall not burn with a flame
Biased humidity 1		85 °C / 85% relative humidity / 500 h / 240 V AC, 50Hz	No visible damage $\lvert\Delta C/C_0\rvert \leq 10\%$ Dissipation factor change $\lvert\Delta \tan \delta\rvert \leq 0.005$ Insulation resistance $R_{ins} \geq 200\ M\Omega$
High temperature exposure (storage)	AEC-Q200	125 °C for 1000 hrs	No visible damage $\lvert\Delta C/C_0\rvert \leq 10\%$ $\lvert\Delta \tan \delta\rvert \leq 0.008$ Insulation resistance $R_{ins} \geq 50\%$ of initial limit

Test	Reference	Conditions of test	Performance requirements
Temperature cycling	AEC-Q200	T_A = –55 °C T_B = upper category temperature 1000 cycles, duration t = 30 min	No visible damage $\lvert\Delta C/C_0\rvert \leq 5\%$
Biased humidity 2	AEC-Q200	40 °C / 93% relative humidity / 1000 h / 305 V AC, 50 Hz	No visible damage $\lvert\Delta C/C_0\rvert \leq 10\%$ $\lvert\Delta \tan \delta\rvert \leq 0.005$ Insulation resistance $R_{ins} \geq 200\ M\Omega$
Operating life	AEC-Q200	Rated voltage / 125 °C / 1000 h	No visible damage $\lvert\Delta C/C_0\rvert \leq 10\%$ $\lvert\Delta \tan \delta\rvert \leq 0.008$ $R_{ins} \geq 50\%$ of initial limit
Physical dimension	AEC-Q200	As per user and supplier specification (length, width, height, lead length, lead space)	No visible damage Within specification
Resistance to soldering heat	AEC-Q200	260 ± 5 °C for 10 s	No visible damage $\lvert\Delta C/C_0\rvert \leq 5\%$ $\lvert\Delta \tan \delta\rvert \leq 0.001$
Solderability	AEC-Q200	J-STD-002, For both leaded and SMD Electrical test not required Magnification 50 × Conditions: leaded; method A at 235 °C, category 3	A minimum of 95% of each of the surface being tested shall be exhibit good wetting. The balance of the surface may contain only small pin holes, dewetted areas, and rough spots provided such defects are not concentrated in one area. There shall be no nonwetting or exposed base metal within the evaluated area.
Moisture resistance	AEC-Q200	MIL-STD-202 Method 106, t = 24 h/cycle Note: Steps 7a and 7b not required Unpowered Measurement at 24 ±4 h after test conclusion	No visible damage $\lvert\Delta C/C_0\rvert \leq 5\%$ $\lvert\Delta \tan \delta\rvert \leq 0.005$ $R_{ins} \geq 50\%$ of initial limit
Electrical characterization	AEC-Q200	Temp A: –40 °C, Temp B: +125 °C, Temp C: +25 °C	No visible damage Summary to show Min, Max, Mean and Standard deviation at room as well as min. and max. operating temperatures

Test	Reference	Conditions of test	Performance requirements
Terminal strength (leaded)	AEC-Q200	MIL-STD-202 Method 211, Test leaded device lead integrity only Conditions: A (2.27 kg), C (227 g)	No visible damage $\|\Delta C/C_0\| \leq 2\%$ $\|\Delta \tan \delta\| \leq 0.0015$ $R_{ins} \geq 50\%$ of initial limit
Resistance to solvent	AEC-Q200	MIL-STD-202 Method 215, Notes: Also aqueous wash chemical - Okemclean or equivalent Do not use banned solvents	No visible damage $\|\Delta C/C_0\| \leq 2\%$ $\|\Delta \tan \delta\| \leq 0.0015$ $R_{ins} \geq 50\%$ of initial limit
Mechanical shock	AEC-Q200	MIL-STD-202 method 213, Figure 1 of method 213 Condition C	No visible damage $\|\Delta C/C_0\| \leq 3\%$ $\|\Delta \tan \delta\| \leq 0.004$ $R_{ins} \geq 50\%$ of initial limit
Vibration	AEC-Q200	5 g's for 20 min, 12 cycles each of 3 orientations Use 8" × 5" PCB, .031" thick. 7 secure points on one 8" side and 2 secure points at corners of opposite sides Parts mounted within 2" from any secure point. Test from 10-2000 Hz	No visible damage

Mounting guidelines

1 Soldering

1.1 Solderability of leads

The solderability of terminal leads is tested to IEC 60068-2-20, test Ta, method 1.

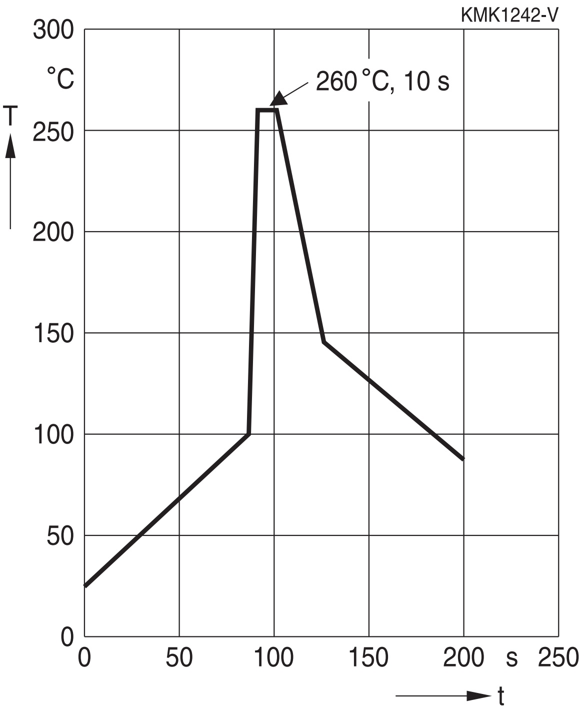
Before a solderability test is carried out, terminals are subjected to accelerated ageing (to IEC 60068-2-2, test Ba: 4 h exposure to dry heat at 155 °C). Since the ageing temperature is far higher than the upper category temperature of the capacitors, the terminal wires should be cut off from the capacitor before the ageing procedure to prevent the solderability being impaired by the products of any capacitor decomposition that might occur.

Solder bath temperature	235 ±5 °C
Soldering time	2.0 ±0.5 s
Immersion depth	2.0 +0/–0.5 mm from capacitor body or seating plane
Evaluation criteria:	
Visual inspection	Wetting of wire surface by new solder ≥90%, free-flowing solder

1.2 Resistance to soldering heat

Resistance to soldering heat is tested to IEC 60068-2-20, test Tb, method 1.
Conditions:

Series		Solder bath temperature	Soldering time
MKT	boxed (except 2.5 × 6.5 × 7.2 mm) coated uncoated (lead spacing >10 mm)	260 ±5 °C	10 ±1 s
MFP MKP	 (lead spacing >7.5 mm)		
MKT	boxed (case 2.5 × 6.5 × 7.2 mm)		5 ±1 s
MKP MKT	(lead spacing ≤7.5 mm) uncoated (lead spacing ≤10 mm) insulated (B32559)		<4 s recommended soldering profile for MKT uncoated (lead spacing ≤ 10 mm) and insulated (B32559)



Immersion depth	2.0 +0/–0.5 mm from capacitor body or seating plane
Shield	Heat-absorbing board, (1.5 ±0.5) mm thick, between capacitor body and liquid solder
Evaluation criteria:	
Visual inspection	No visible damage
$\Delta C/C_0$	2% for MKT/MKP/MFP 5% for EMI suppression capacitors
tan δ	As specified in sectional specification

1.3 General notes on soldering

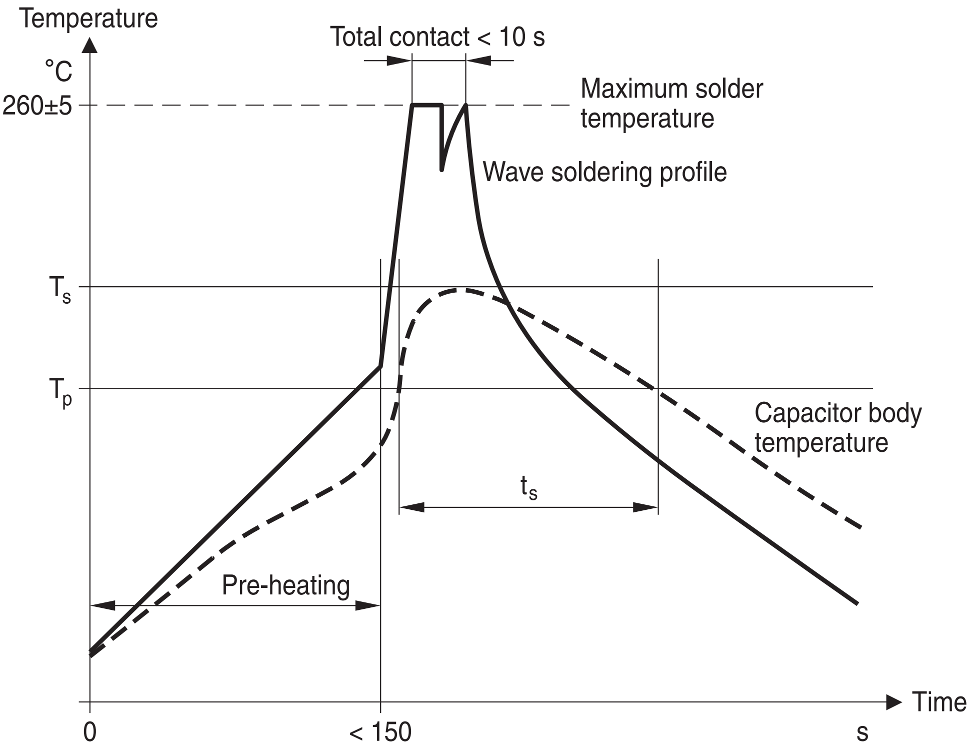
Permissible heat exposure loads on film capacitors are primarily characterized by the upper category temperature T_{max}. Long exposure to temperatures above this type-related temperature limit can lead to changes in the plastic dielectric and thus change irreversibly a capacitor's electrical characteristics. For short exposures (as in practical soldering processes) the heat load (and thus the possible effects on a capacitor) will also depend on other factors like:

- Pre-heating temperature and time
- Forced cooling immediately after soldering
- Terminal characteristics:
- diameter, length, thermal resistance, special configurations (e.g. crimping)
- Height of capacitor above solder bath
- Shadowing by neighboring components
- Additional heating due to heat dissipation by neighboring components
- Use of solder-resist coatings

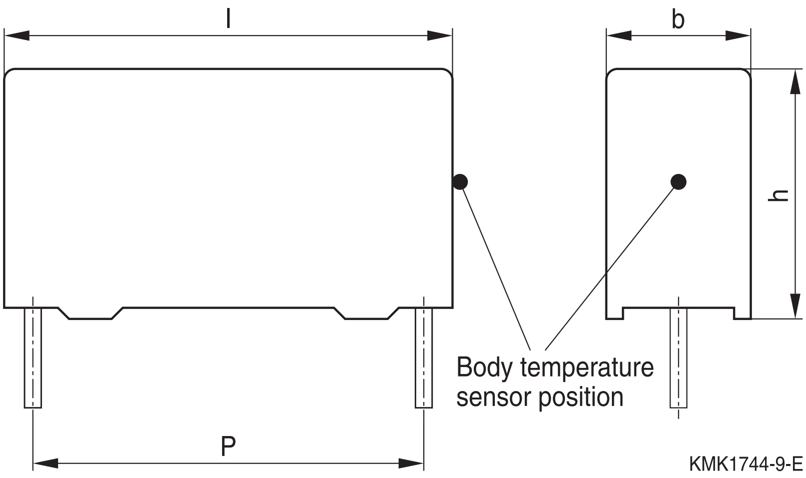
The overheating associated with some of these factors can usually be reduced by suitable countermeasures. For example, if a pre-heating step cannot be avoided, an additional or reinforced cooling process may possibly have to be included.

Recommendations

As a reference, the recommended wave soldering profile for our film capacitors is as follows:



T_s: Capacitor body maximum temperature at wave soldering
T_p: Capacitor body maximum temperature at pre-heating KMK1745-A-E



Body temperature should follow the description below:

- MKP capacitor
  During pre-heating: $T_p \leq 110$ °C
  During soldering: $T_s \leq 120$ °C, $t_s \leq 45$ s
- MKT capacitor
  During pre-heating: $T_p \leq 125$ °C
  During soldering: $T_s \leq 160$ °C, $t_s \leq 45$ s

When SMD components are used together with leaded ones, the film capacitors should not pass into the SMD adhesive curing oven. The leaded components should be assembled after the SMD curing step.
Leaded film capacitors are not suitable for reflow soldering.
In order to ensure proper conditions for manual or selective soldering, the body temperature of the capacitor (T_s) must be ≤120 °C.
One recommended condition for manual soldering is that the tip of the soldering iron should be <360 °C and the soldering contact time should be no longer than 3 seconds.
For uncoated MKT capacitors with lead spacings ≤10 mm (B32560/B32561) the following measures are recommended:

- pre-heating to not more than 110 °C in the preheater phase
- rapid cooling after soldering

Please refer to our Film Capacitors Data Book in case more details are needed.

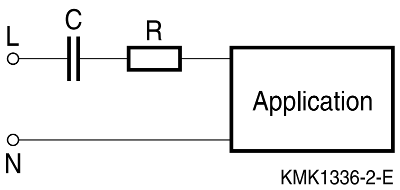
Application note for the different possible X1 / X2 positions

In series with the powerline (i.e. capacitive power supply)

Typical Applications:

- Power meters
- ECUs for white goods and household appliances
- Different sensor applications
- Severe ambient conditions

Basic circuit



Required features

- High capacitance stability over the lifetime
- Narrow tolerances for a controlled current supply

Recommended product series

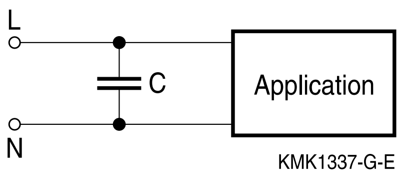
- B3293* (305 V AC) heavy duty with EN approval for X2 (UL Q1/2010)
- B3265* MKP series
  standard MKP capacitor without safety approvals
- B3267*L MKP series
  standard MKP capacitor without safety approvals
- B3292*H/J (305 V AC), severe ambient condition, approved as X2

In parallel with the powerline

Typical Applications:

Standard X2 are used parallel over the mains for reducing electromagnetic interferences coming from the grid. For such purposes they must meet the applicable EMC directives and standards.

Basic circuit



Required features

- Standard safety approvals
  (ENEC, UL, CSA, CQC)
- High pulse load capability
- Withstand surge voltages

Recommended product series

- B3292*C/D (305 V AC)
  standard series, approved as X2
- B3291* (330 V AC), approved as X1
- B3291* (530 V AC), approved as X1
- B3291* (550 V AC), approved as X1
- B3292*H/J (305 V AC), severe ambient condition, approved as X2

Cautions and warnings

- Do not exceed the upper category temperature (UCT).
- Do not apply any mechanical stress to the capacitor terminals.
- Avoid any compressive, tensile or flexural stress.
- Do not move the capacitor after it has been soldered to the PC board.
- Do not pick up the PC board by the soldered capacitor.
- Do not place the capacitor on a PC board whose PTH hole spacing differs from the specified lead spacing.
- Do not exceed the specified time or temperature limits during soldering.
- Avoid external energy inputs, such as fire or electricity.
- Avoid overload of the capacitors.
- Consult us if application is with severe temperature and humidity condition.
- There are no serviceable or repairable parts inside the capacitor. Opening the capacitor or any attempts to open or repair the capacitor will void the warranty and liability of TDK Electronics.
- Please note that the standards referred to in this publication may have been revised in the meantime.

The table below summarizes the safety instructions that must always be observed. A detailed description can be found in the relevant sections of the chapters "General technical information" and "Mounting guidelines".

Topic	Safety information	Reference chapter "General technical information"
Storage conditions	Make sure that capacitors are stored within the specified range of time, temperature and humidity conditions.	4.5 "Storage conditions"
Flammability	Avoid external energy, such as fire or electricity (passive flammability), avoid overload of the capacitors (active flammability) and consider the flammability of materials.	5.3 "Flammability"
Resistance to vibration	Do not exceed the tested ability to withstand vibration. The capacitors are tested to IEC 60068-2-6:2007. TDK Electronics offers film capacitors specially designed for operation under more severe vibration regimes such as those found in automotive applications. Consult our catalog "Film Capacitors for Automotive Electronics".	5.2 "Resistance to vibration"
Soldering	Do not exceed the specified time or temperature limits during soldering.	1 "Soldering"
Cleaning	Use only suitable solvents for cleaning capacitors.	2 "Cleaning"
Embedding of capacitors in finished assemblies	When embedding finished circuit assemblies in plastic resins, chemical and thermal influences must be taken into account. Caution: Consult us first, if you also wish to embed other uncoated component types!	3 "Embedding of capacitors in finished assemblies"

Design of our capacitors

Our EMI capacitors use polypropylene (PP) film metalized with a thin layer of Zinc (Zn). The following key points have made this design suitable to IEC/UL testing, holding a minimum size.

- Overvoltage AC capability with very high temperature Endurance test of IEC 60384-14:2013 (4^{th} edition) / UL 60384-14:2014 (2^{nd} edition) must be performed at 1.25 × V_R at maximum temperature, during 1000 hours, with a capacitance drift less than 10%.
- Higher breakdown voltage withstanding if compared to other film metallizations, like Aluminum. IEC 60384-14:2013 (4th edition) / UL 60384-14:2014 (2nd edition) establishes high voltage tests performed at 4.3 × VR – 1 minute, impulse testing at 2500 V for C = 1 µF and active flammability tests.
- Damp heat steady state: 40 °C/ 93% RH / 56 days. (without voltage or current load)

Effect of humidity on capacitance stability

Long contact of a film capacitor with humidity can produce irreversible effects. Direct contact with liquid water or excess exposure to high ambient humidity or dew will eventually remove the film metallization and thus destroy the capacitor. Plastic boxed capacitors must be properly tested in the final application at the worst expected conditions of temperature and humidity in order to check if any parameter drift may provoke a circuit malfunction.

In case of penetration of humidity through the film, the layer of Zinc can be degraded, specially under AC operation (change of polarity), accelerated by the temperature, provoking an increment of the serial resistance of the electrode and eventually a reduction of the capacitance value.

For DC operation, the parameter drift is much less.

Plastic boxes and resins can not protect 100% against humidity. Metal enclosures, resin potting or coatings or similar measures by customers in their applications will offer additional protection against humidity penetration.

Display of ordering codes for TDK Electronics products

The ordering code for one and the same product can be represented differently in data sheets, data books, other publications, on the company website, or in order-related documents such as shipping notes, order confirmations and product labels. The varying representations of the ordering codes are due to different processes employed and do not affect the specifications of the respective products.

Detailed information can be found on the Internet under www.tdk-electronics.tdk.com/orderingcodes.

Correlation of data sheet values and modelling tool outputs

Data sheet values and results of design tools may deviate as they have not been derived in the same context.

While data sheets show individual parameter statements without considering a possible dependency to other parameters. Tools model a complete given scenario as input and processed inside the tool.

Furthermore as we constantly strive to improve our models, the results of tools can change over time and be a non-binding indication only.

Symbols and terms

Symbol	English	German
α	Heat transfer coefficient	Wärmeübergangszahl
α_C	Temperature coefficient of capacitance	Temperaturkoeffizient der Kapazität
A	Capacitor surface area	Kondensatoroberfläche
β_C	Humidity coefficient of capacitance	Feuchtekoeffizient der Kapazität
C	Capacitance	Kapazität
C_R	Rated capacitance	Nennkapazität
ΔC	Absolute capacitance change	Absolute Kapazitätsänderung
$\Delta C/C$	Relative capacitance change (relative deviation of actual value)	Relative Kapazitätsänderung (relative Abweichung vom Ist-Wert)
$\Delta C/C_R$	Capacitance tolerance (relative deviation from rated capacitance)	Kapazitätstoleranz (relative Abweichung vom Nennwert)
dt	Time differential	Differentielle Zeit
Δt	Time interval	Zeitintervall
ΔT	Absolute temperature change (self-heating)	Absolute Temperaturänderung (Selbsterwärmung)
$\Delta \tan \delta$	Absolute change of dissipation factor	Absolute Änderung des Verlustfaktors
ΔV	Absolute voltage change	Absolute Spannungsänderung
dV/dt	Time differential of voltage function (rate of voltage rise)	Differentielle Spannungsänderung (Spannungsflankensteilheit)
$\Delta V/\Delta t$	Voltage change per time interval	Spannungsänderung pro Zeitintervall
E	Activation energy for diffusion	Aktivierungsenergie zur Diffusion
ESL	Self-inductance	Eigeninduktivität
ESR	Equivalent series resistance	Ersatz-Serienwiderstand
f	Frequency	Frequenz
f_1	Frequency limit for reducing permissible AC voltage due to thermal limits	Grenzfrequenz für thermisch bedingte Reduzierung der zulässigen Wechselspannung
f_2	Frequency limit for reducing permissible AC voltage due to current limit	Grenzfrequenz für strombedingte Reduzierung der zulässigen Wechselspannung
f_r	Resonant frequency	Resonanzfrequenz
F_D	Thermal acceleration factor for diffusion	Therm. Beschleunigungsfaktor zur Diffusion
F_T	Derating factor	Deratingfaktor
i	Current (peak)	Stromspitze
I_C	Category current (max. continuous current)	Kategoriestrom (max. Dauerstrom)
I_{RMS}	(Sinusoidal) alternating current, root-mean-square value	(Sinusförmiger) Wechselstrom
i_z	Capacitance drift	Inkonstanz der Kapazität
k_0	Pulse characteristic	Impulskennwert
L_S	Series inductance	Serieninduktivität
λ	Failure rate	Ausfallrate

Symbol	English	German
λ_0	Constant failure rate during useful service life	Konstante Ausfallrate in der Nutzungsphase
λ_{test}	Failure rate, determined by tests	Experimentell ermittelte Ausfallrate
P_{diss}	Dissipated power	Abgegebene Verlustleistung
P_{gen}	Generated power	Erzeugte Verlustleistung
Q	Heat energy	Wärmeenergie
ρ	Density of water vapor in air	Dichte von Wasserdampf in Luft
R	Universal molar constant for gases	Allg. Molarkonstante für Gas
R	Ohmic resistance of discharge circuit	Ohmscher Widerstand des Entladekreises
R_i	Internal resistance	Innenwiderstand
R_{ins}	Insulation resistance	Isolationswiderstand
R_P	Parallel resistance	Parallelwiderstand
R_S	Series resistance	Serienwiderstand
S	severity (humidity test)	Schärfegrad (Feuchtetest)
t	Time	Zeit
T	Temperature	Temperatur
τ	Time constant	Zeitkonstante
tan δ	Dissipation factor	Verlustfaktor
tan δ_D	Dielectric component of dissipation factor	Dielektrischer Anteil des Verlustfaktors
tan δ_P	Parallel component of dissipation factor	Parallelanteil des Verlfustfaktors
tan δ_S	Series component of dissipation factor	Serienanteil des Verlustfaktors
T_A	Temperature of the air surrounding the component	Temperatur der Luft, die das Bauteil umgibt
T_{max}	Upper category temperature	Obere Kategorietemperatur
T_{min}	Lower category temperature	Untere Kategorietemperatur
t_{OL}	Operating life at operating temperature and voltage	Betriebszeit bei Betriebstemperatur und -spannung
T_{op}	Operating temperature, $T_A + \Delta T$	Beriebstemperatur, $T_A + \Delta T$
T_R	Rated temperature	Nenntemperatur
T_{ref}	Reference temperature	Referenztemperatur
t_{SL}	Reference service life	Referenz-Lebensdauer
V_{AC}	AC voltage	Wechselspannung
V_C	Category voltage	Kategoriespannung
$V_{C,RMS}$	Category AC voltage	(Sinusförmige) Kategorie-Wechselspannung
V_{CD}	Corona-discharge onset voltage	Teilentlade-Einsatzspannung
V_{ch}	Charging voltage	Ladespannung
V_{DC}	DC voltage	Gleichspannung
V_{FB}	Fly-back capacitor voltage	Spannung (Flyback)

Symbol	English	German
V_i	Input voltage	Eingangsspannung
V_o	Output voltage	Ausgangssspannung
V_{op}	Operating voltage	Betriebsspannung
V_p	Peak pulse voltage	Impuls-Spitzenspannung
V_{pp}	Peak-to-peak voltage Impedance	Spannungshub
V_R	Rated voltage	Nennspannung
$\hat{V}_R$	Amplitude of rated AC voltage	Amplitude der Nenn-Wechselspannung
V_{RMS}	(Sinusoidal) alternating voltage, root-mean-square value	(Sinusförmige) Wechselspannung
V_{SC}	S-correction voltage	Spannung bei Anwendung "S-correction"
V_{sn}	Snubber capacitor voltage	Spannung bei Anwendung "Beschaltung"
Z	Impedance	Scheinwiderstand
e	Lead spacing	Rastermaß

Important notes

The following applies to all products named in this publication:

1 Some parts of this publication contain **statements about the suitability of our products for certain areas of application**. These statements are based on our knowledge of typical requirements that are often placed on our products in the areas of application concerned. We nevertheless expressly point out **that such statements cannot be regarded as binding statements about the suitability of our products for a particular customer application**. As a rule we are either unfamiliar with individual customer applications or less familiar with them than the customers themselves. For these reasons, it is always ultimately incumbent on the customer to check and decide whether a product with the properties described in the product specification is suitable for use in a particular customer application.

2 We also point out that **in individual cases, a malfunction of electronic components or failure before the end of their usual service life cannot be completely ruled out in the current state of the art, even if they are operated as specified**. In customer applications requiring a very high level of operational safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health (e.g. in accident prevention or life-saving systems), it must therefore be ensured by means of suitable design of the customer application or other action taken by the customer (e.g. installation of protective circuitry or redundancy) that no injury or damage is sustained by third parties in the event of malfunction or failure of an electronic component.

3 **The warnings, cautions and product-specific notes must be observed**.

4 In order to satisfy certain technical requirements, **some of the products described in this publication may contain substances subject to restrictions in certain jurisdictions (e.g. because they are classed as hazardous)**. Useful information on this will be found in our Material Data Sheets on the Internet (www.tdk-electronics.tdk.com/material). Should you have any more detailed questions, please contact our sales offices.

5 We constantly strive to improve our products. Consequently, **the products described in this publication may change from time to time**. The same is true of the corresponding product specifications. Please check therefore to what extent product descriptions and specifications contained in this publication are still applicable before or when you place an order.
We also **reserve the right to discontinue production and delivery of products**. Consequently, we cannot guarantee that all products named in this publication will always be available. The aforementioned does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.

6 Unless otherwise agreed in individual contracts, **all orders are subject to our General Terms and Conditions of Supply**.

7 **Our manufacturing sites serving the automotive business apply the IATF 16949 standard**. The IATF certifications confirm our compliance with requirements regarding the quality management system in the automotive industry. Referring to customer requirements and customer specific requirements (“CSR”) TDK always has and will continue to have the policy of respecting individual agreements. Even if IATF 16949 may appear to support the acceptance of unilateral requirements, we hereby like to emphasize that **only requirements mutually agreed upon can and will be implemented in our Quality Management System**. For clarification purposes we like to point out that obligations from IATF 16949 shall only become legally binding if individually agreed upon.

8 The trade names EPCOS, CarXield, CeraCharge, CeraDiode, CeraLink, CeraPad, CeraPlas, CSMP, CTVS, DeltaCap, DigiSiMic, FilterCap, FormFit, InsuGate, LeaXield, MediPlas, MiniBlue, MiniCell, MKD, MKK, ModCap, MotorCap, PCC, PhaseCap, PhaseCube, PhaseMod, PhiCap, PiezoBrush, PlasmaBrush, PowerHap, PQSine, PQvar, SIFERRIT, SIFI, SIKOREL, SilverCap, SIMDAD, SiMic, SIMID, SineFormer, SIOV, SurfIND, ThermoFuse, WindCap, XieldCap are **trademarks registered or pending** in Europe and in other countries. Further information will be found on the Internet at www.tdk-electronics.tdk.com/trademarks.

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