Film Capacitors - Power Electronic Capacitors

General purpose applications

Series/Type: **FilterCap MKD AC – Three phases**
Ordering code: **B3237X Series**

Date: 2019-05-14
Version: 03

Construction and general data

General data	
Dielectric	Metallized polypropylene film
Resin filling	Non PCB, soft polyurethane
Safety device	Overpressure disconnector, self-healing technology
Mounting and grounding	Stud on bottom of aluminum can
Cooling	Naturally air-cooled (or forced air cooling)
Degree of protection	Indoor mounting IP20 (IP54 upon request)
Discharge resistor	Upon request
Reference standards	IEC 61071, GB/T 17702, optional IEC 60831, UL 810
Safety approvals	**For B32377 type A, and B32378 type A series:** UL 810, CSA C22.2, No 190, Max.600 V_{RMS} (Line voltage), 50/60 Hz, “Protected”, 10 k AFC, Max. 70 °C. **For B32377 type B, and B32377 type C series:** UL 810, CSA C22.2, No 190, Max.1000 V_{RMS} (Line voltage), 50/60 Hz, “Protected”, 10 k AFC, Max. 70 °C. **File no.: E487229, CCN:CYWT2/8**
Terminals	B32377 Type A, Type B and B32378: M5 screw clamp terminals B32377 Type C: M6 screw clamp terminals

B32377 Type A **B32377 Type B** **B32377 Type C** **B32378 Type D/E**

Figure 1: Capacitor MKD-AC series B32377* and B32378*

Specifications and characteristics

Rated capacitance C_R: 3x10 … 3x600 µF (for ≥400 µF customized design), Tolerance: ±5%

Voltage V_{RMS} (line to line)	Rated AC voltage V_R (line to line)	DC voltage V_{RDC}
250	350	675
330	460	900
420	590	1050
480	680	1200
530	750	1350
600	850	1500
660	935	1650
720	1020	1800
780	1100	1950
850	1200	2100
900	1270	2250
1000	1415	2475

Test data	
Voltage between terminals V_{TT}	2.15 • V_{RMS}, 2 s
Voltage between terminals and Case V_{TC}	4000 V AC,10 s
Dissipation factor tan δ at 100Hz	≤1.0 •10^{-3}
Life test	According to IEC 61071
Life expectancy*	100000 hours for V_{RMS}, $|\Delta C/C|$ ≤3%

Climatic category 40/70/21	
T_{stg}**	−40 ...+85 °C
T_{min}	−40 °C
T_{max}***	+70 °C
T_{hs}****	+85 °C
Max. permissible humidity	95% (test = 21 days)
Max. permissible altitude	2000 m above sea level

Mechanical characteristics	
Terminal cross section	*B32377 Type A, B32377 Type B and B32378: 25 mm²* *B32377 Type C: 35 mm²*
Max. torque (case)	M12: 12 Nm
Max. torque (for screw terminal)	B32377 Type A, B32377 Type B and B32378: 2 Nm B32377 type C: 3.5 Nm

* Note that this life expectancy occurs for the worst case with a maximum temperature hot-spot of +85° Celsius degree. For other operation temperatures please check the life time curve for further details.

**:T_{stg} – Storage temperature.
***:T_{max}– Maximum operation ambient temperature.
****:T_{hs}– Maximum temperature allowed at the capacitors hot spot. Considering mounting position with terminals to the top. For other mounting positions, please request evaluation.

Design data	
Dimensions (D x H)	According to specification table
Weight approx.	According to specification table
Max. terminal current	Screw clamp terminal: 50 A (B32377 type A) 80 A (B32377 type B) 100 A (B32377 type C) 50 A (B32378)

Electrical characteristics: Clearance and creepage distances

Series	Diameter	Terminal to terminal		Terminal to case	
	Mm	Min. clearance mm	Min. creepage mm	Min. clearance mm	Min. creepage mm
B32377 Type A	75/85/96/116/136	Not applicable	12.7	9.5	12.7
B32377 Type B	96/116/136	Not applicable	12.7	9.5	12.7
B32377 Type C	116/136	Not applicable	19.1	19.1	19.1
B32378 Type D	116/136	Not applicable	12.7	9.5	12.7
B32378 Type E	116/136	Not applicable	19.1	19.1	19.1

Capacitor catalog number (type or series designation)

FilterCap MKD AC series					A	B	C	D		E	F	G	H	I
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B	3	2	3	7	7	A	3	4	0	7	J	0	3	0

A. Indicates termination type
6 = M10 (3x) Screw terminals (delta connection)
7 = M5 (3x) Clamp terminals (type A and B, delta connection)
7 = M6 (3x) Clamp terminals (type C, delta connection)
8 = M5 (4x) Clamp terminals (star connection)

B. Indicates revision status (any letter), in case of S letter it means customized design

C. Indicates first number of voltage V_{RMS} value (any digit)

D. Indicates first and second figure of capacitance value (any two digits)

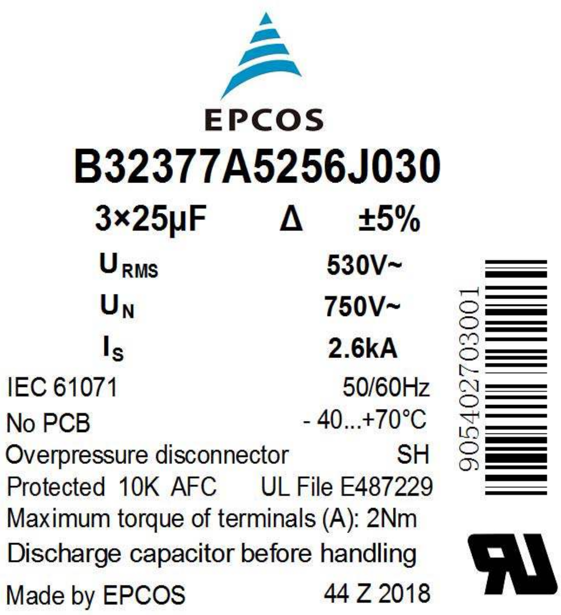
E. Indicates exponent used as multiplier (any digit)

F. Indicates capacitor tolerance for PEC AC capacitor
J = ±5 %; K = ± 10 %;

G. Indicates coded capacitance value

H. Indicates second number of voltage V_{RMS} value (any digit)

I. Indicates Accessories (any digit)



Label information
Date code explanation
WW Z YYYY
WW Z YYYY: production weeks (e.g.: 49)
WW **Z** YYYY: produced in Zhuhai (China)
WW Z **YYYY**: production year (e.g.: 2018)

Bar code explanation
Bar code consists of batch number and serial number.
Batch number: 9 digits (e.g.: 123456789)
Serial number: 3 digits (e.g.: 001)

Terminal type explanation
Terminals (A): type A terminals
Terminals (B): type B terminals
Terminals (C): type C terminals
Terminals (D): type D terminals
Terminals (E): type E terminals

Dimensional drawings

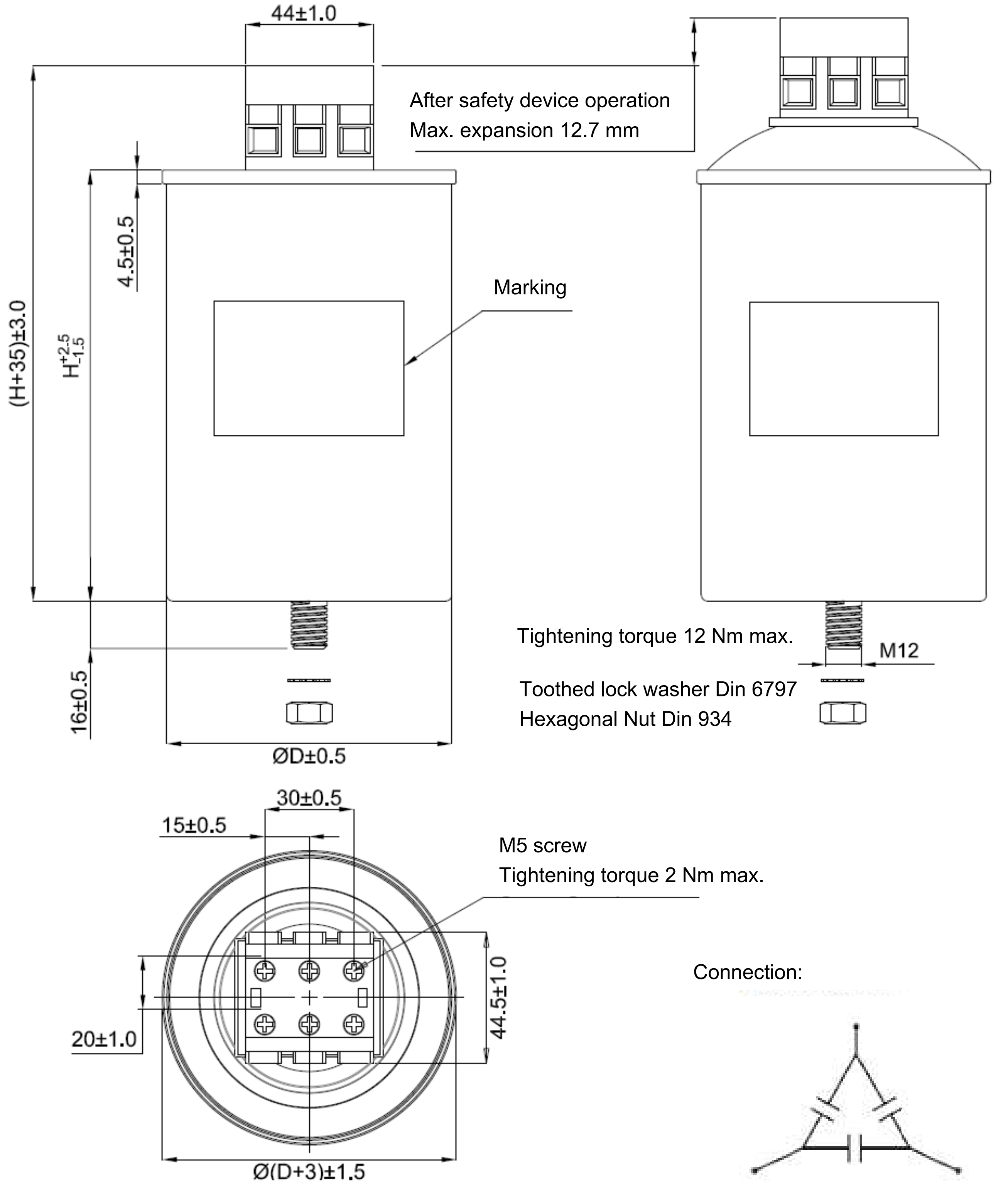


Figure 2: Series B32377* (Delta connection type A)

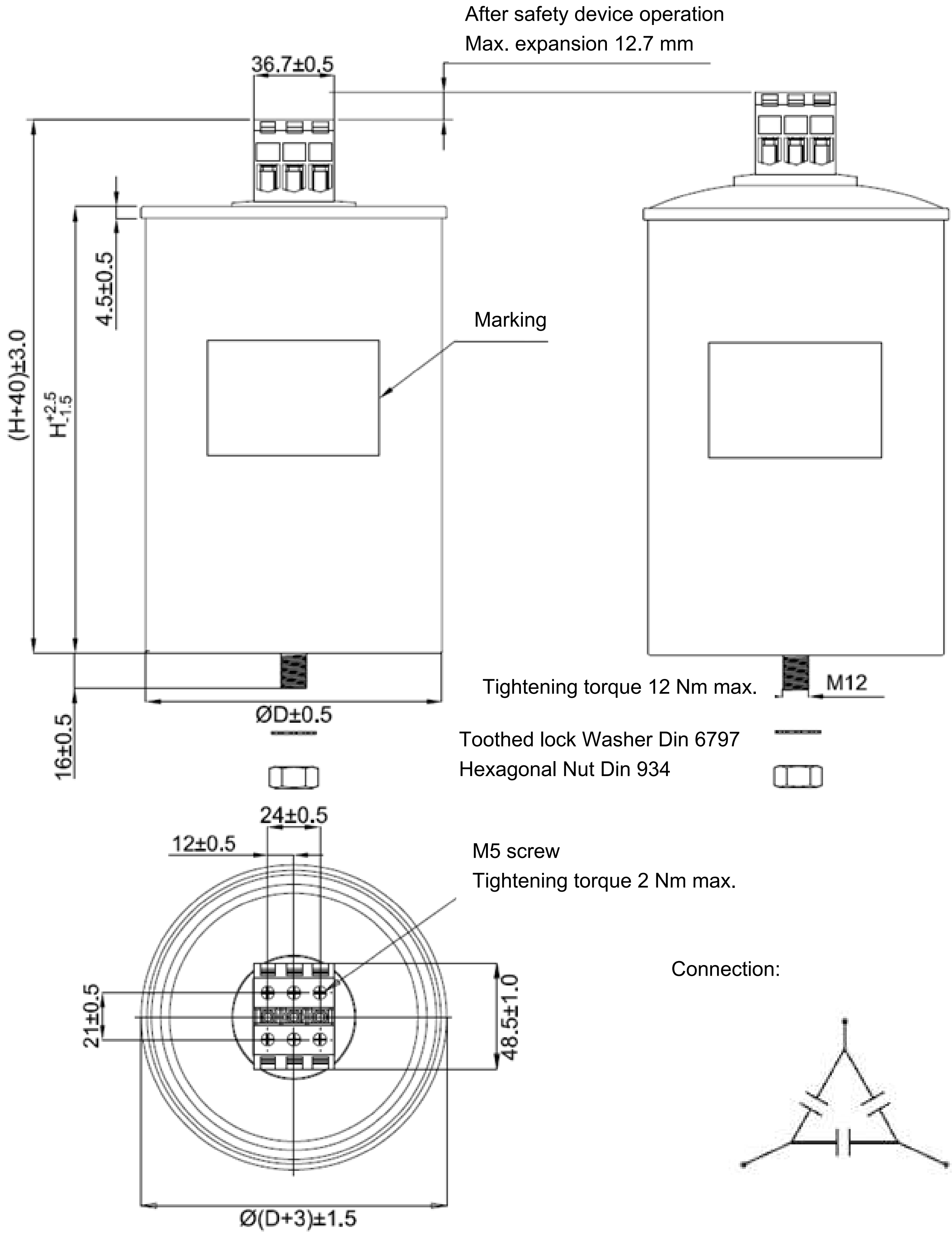


Figure 3: Series B32377* (Delta connection type B)

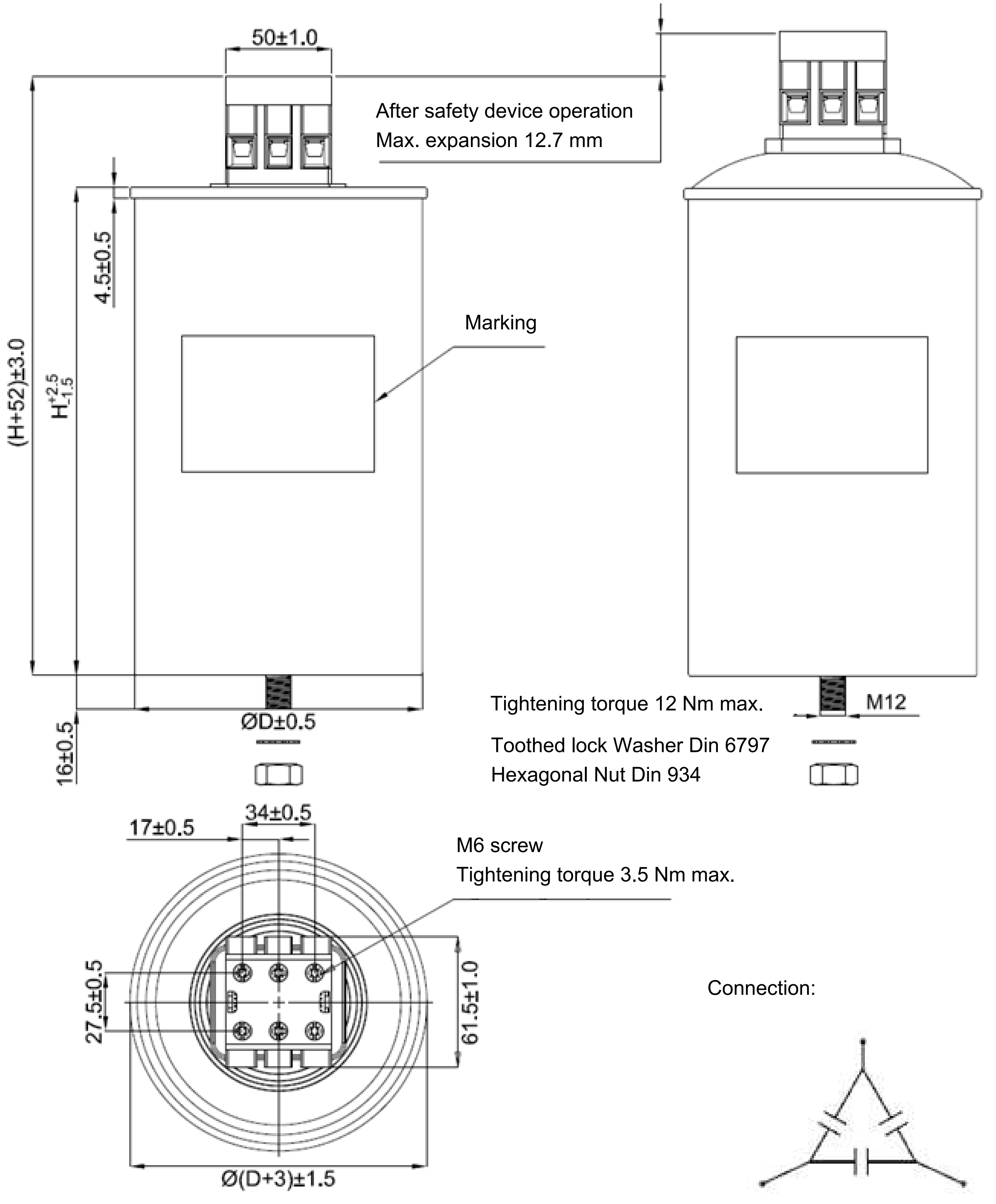


Figure 4: Series B32377* (Delta connection type C)

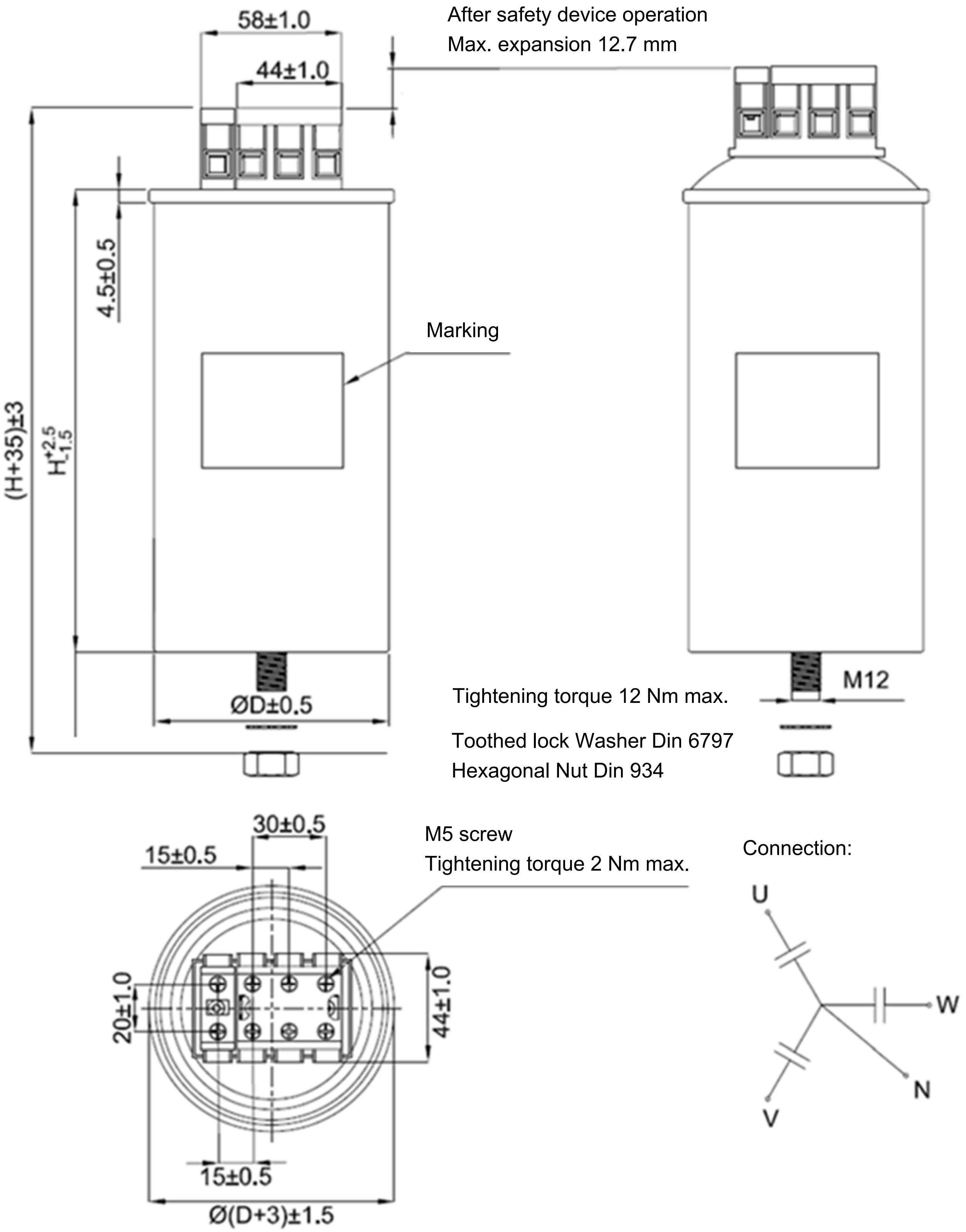


Figure 5: Series B32378* (Star connection with neutral type D)

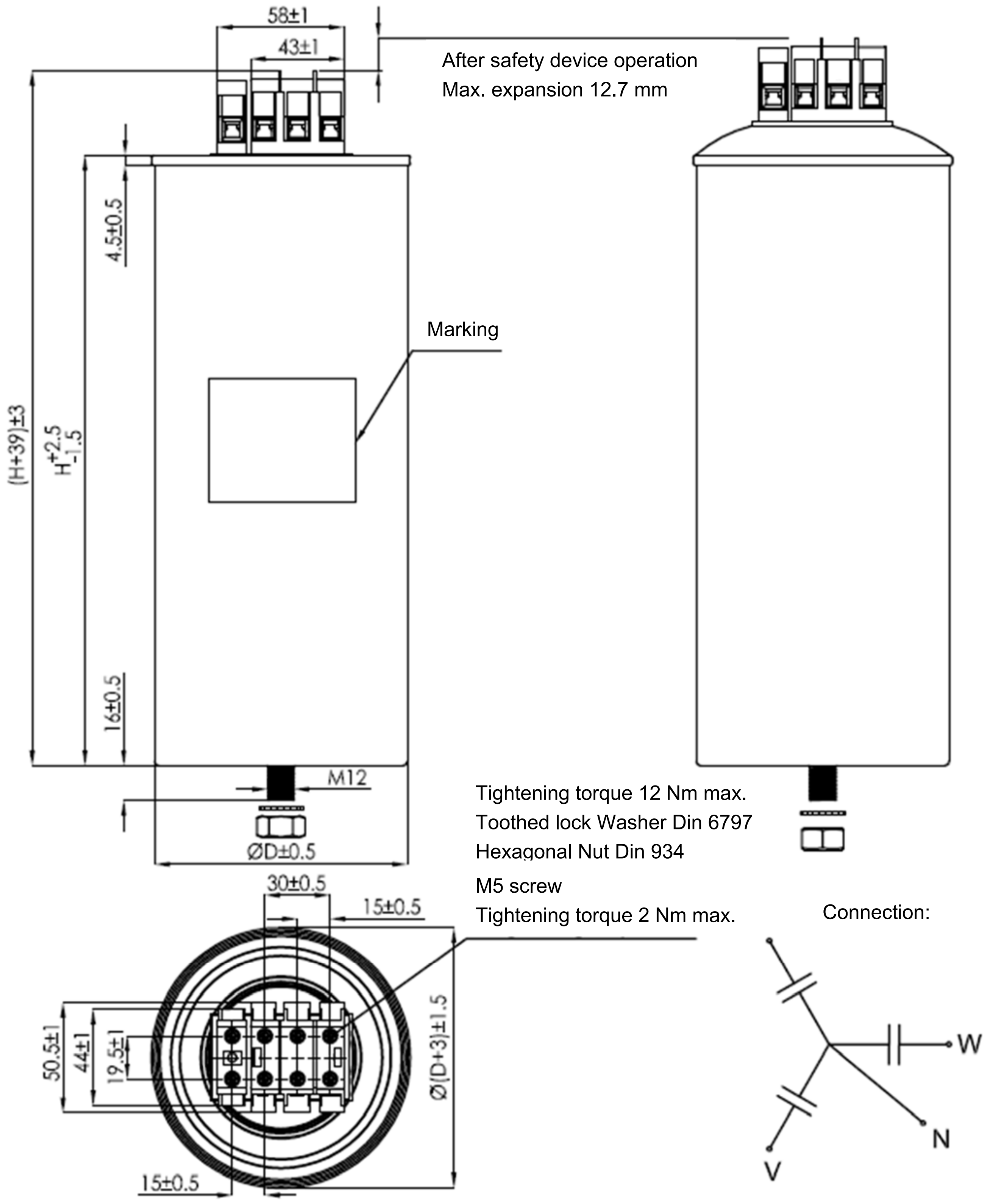


Figure 6: Series B32378* (Star connection with neutral type E)

Installation space requirements

1) A minimum distance of 20 mm between the capacitors is necessary to maintain sufficient cooling.

2) Keep at least 20 mm space above the capacitor and do not attach any mounting components at the crimp or on top. This gap will allow a longitudinal extension of the can in order to ensure that the over-pressure disconnector can fully extend.

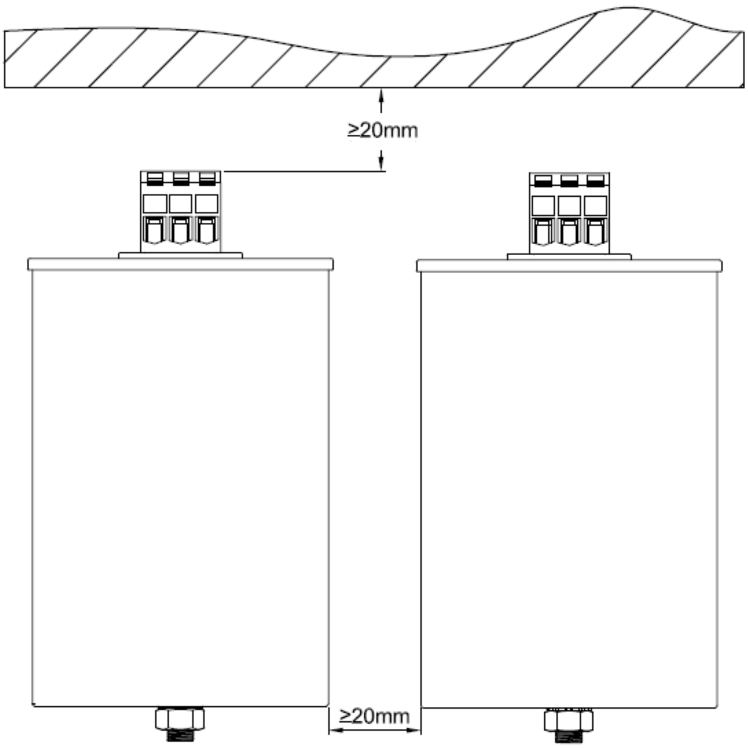


Figure 7: Installation space requirements

Note: For further details, please check installation manual for MKD-AC capacitors.

Technical data of standard products

B32377 series - UL certification up to 600 V_{RMS} (V_R/V_{RMS} line to line voltage)

V_R/V_{RMS} V	C_R µF	Ordering code	I_{max} A	Î A	D mm	H mm	Terminal type	Weight kg	Packing Unit
350/ 250	3×50	B32377A2506J050	21	1300	75	163	A	0.8	6
	3×60	B32377A2606J050	24	1500	75	163	A	0.8	6
	3×70	B32377A2706J050	26	1800	75	163	A	0.8	6
	3×84	B32377A2846J050	28	1900	75	163	A	0.8	6
	3×100	B32377A2107J050	30	1800	75	200	A	1.0	6
	3×150	B32377A2157J050	35	2100	75	230	A	1.2	6
	3×160	B32377A2167J050	37	2200	75	230	A	1.2	6
	3×200	B32377A2207J050	42	3000	96	236	B	2.0	4
	3×250	B32377A2257J050	45	3000	96	281	B	2.2	4
	3×300	B32377A2307J050	54	4500	116	236	B	2.8	4
	3×330	B32377A2337J050	56	5000	116	236	B	2.8	4
	3×400	B32377A2407J050	60	4800	116	281	B	3.2	4
460/ 330	3×50	B32377A3506J030	23	1500	75	163	A	0.8	6
	3×60	B32377A3606J030	26	1400	75	200	A	1.0	6
	3×70	B32377A3706J030	29	1500	75	200	A	1.0	6
	3×80	B32377A3806J030	30	1500	75	230	A	1.2	6
	3×100	B32377A3107J030	33	1400	75	275	A	1.4	6
	3×120	B32377A3127J030	38	2000	85	245	A	1.6	4
	3×150	B32377A3157J030	42	2500	96	245	A	2.0	4
	3×200	B32377A3207J030	50	3600	116	236	B	2.8	4
	3×250	B32377A3257J030	54	4200	116	281	B	3.2	4
	3×300	B32377A3307J030	60	5500	136	236	B	3.7	4
	3×330	B32377A3337J030	63	6000	136	236	B	3.7	4
590/ 420	3×50	B32377A4506J020	25	1300	75	200	A	1.0	6
	3×60	B32377A4606J020	28	1300	75	230	A	1.2	6
	3×70	B32377A4706J020	30	1500	75	245	A	1.2	6
	3×80	B32377A4806J020	31	1300	75	275	A	1.4	6
	3×100	B32377A4107J020	36	1700	85	275	A	1.8	4
	3×150	B32377A4157J020	46	3200	116	236	B	2.8	4
	3×200	B32377A4207J020	52	3360	116	281	B	3.2	4
	3×250	B32377A4257J020	60	4880	136	251	B	3.9	4

B32377 series - UL certification up to 600 V_{RMS} (V_R/V_{RMS} line to line voltage)

V_R/V_{RMS} V	C_R µF	Ordering code	I_{max} A	Î A	D mm	H mm	Terminal type	Weight kg	Packing Unit
680/ 480	3×30	B32377A4306J080	20	900	75	200	A	1.0	6
	3×40	B32377A4406J080	24	1200	75	200	A	1.0	6
	3×50	B32377A4506J080	27	1100	75	245	A	1.2	6
	3×60	B32377A4606J080	30	1200	75	275	A	1.4	6
	3×70	B32377A4706J080	33	1500	85	245	A	1.6	4
	3×74	B32377A4746J080	35	1600	96	230	A	1.9	4
	3×80	B32377A4806J080	35	2000	85	275	A	1.8	4
	3×100	B32377A4107J080	40	2000	96	275	A	2.2	4
	3×130	B32377A4137J080	47	3200	116	251	B	3.0	4
	3×138	B32377B4137J880	49	3200	116	251	B	3.0	4
	3×150	B32377A4157J080	50	2900	116	281	B	3.2	4
	3×170	B32377A4177J080	54	4200	136	236	B	3.7	4
	3×200	B32377A4207J080	59	4465	136	251	B	3.9	4
750/ 530	3×20	B32377A5206J030	17	950	75	163	A	0.8	6
	3×25	B32377A5256J030	20	850	75	200	A	1.0	6
	3×30	B32377A5306J030	23	900	75	230	A	1.2	6
	3×40	B32377A5406J030	28	900	75	275	A	1.4	6
	3×45	B32377A5456J030	30	1000	75	275	A	1.4	6
	3×50	B32377A5506J030	32	1700	96	206	B	1.7	4
	3×62	B32377A5626J030	36	2800	116	206	B	2.5	4
	3×70	B32377A5706J030	40	2600	116	206	B	2.5	4
	3×75	B32377A5756J030	41	2550	116	206	B	2.5	4
	3×80	B32377A5806J030	44	3150	136	206	B	3.2	4
	3×100	B32377A5107J030	44	2700	116	236	B	2.8	4
	3×120	B32377A5127J030	52	3500	136	236	B	3.7	4
	3×133	B32377B5137J330	55	3500	136	251	B	3.9	4
	3×150	B32377A5157J030	58	2840	136	281	B	4.3	4
850/ 600	3×15	B32377A6156J000	14	780	75	163	A	0.8	6
	3×20	B32377A6206J000	18	1100	85	163	A	1.0	4
	3×25	B32377A6256J000	21	1300	96	163	A	1.0	4
	3×30	B32377A6306J000	24	1600	96	163	A	1.4	4
	3×38	B32377A6386J000	29	1440	96	200	A	1.7	4
	3×50	B32377A6506J000	34	1400	85	275	A	1.8	4
	3×50	B32377B6506J000	36	1700	96	230	A	1.9	4
	3×70	B32377A6706J000	40	1300	85	350	A	2.2	4
	3×83	B32377A6836J000	45	3600	136	206	B	3.2	4
	3×90	B32377A6906J000	48	3000	136	236	B	3.7	4
	3×100	B32377A6107J000	52	2700	136	236	B	3.7	4
	3×130	B32377A6137J000	72	3400	136	281	B	4.3	4

B32377 series - UL certification up to 1000 V_{RMS} (V_R/V_{RMS} line to line voltage)

V_R/V_{RMS} V	C_R µF	Ordering code	I_{max} A	Î A	D mm	H mm	Terminal type	Weight Kg	Packing Unit
935/ 660	3×40	B32377A6406J060	32	1800	116	200	C	2.5	4
	3×50	B32377A6506J060	36	1900	116	230	C	2.8	4
	3×60	B32377A6606J060	36	2000	116	245	C	3.2	4
	3×70	B32377A6706J060	43	2300	116	275	C	3.2	4
	3×75	B32377A6756J060	43	2300	116	275	C	3.2	4
	3×80	B32377A6806J060	44	2400	116	275	C	3.2	4
	3×90	B32377A6906J060	50	3200	136	245	C	3.9	4
	3x100	B32377A6107J060	54	3400	136	245	C	3.9	4
	3x110	B32377A6117J060	55	3200	136	275	C	4.3	4
1020/ 720	3×25	B32377A7256J020	25	1300	96	206	B	1.7	4
	3×30	B32377A7306J020	28	1400	96	206	B	1.7	4
	3×34	B32377A7346J020	33	1400	96	236	B	1.9	4
	3×38	B32377A7386J020	35	2000	116	200	C	2.5	4
	3×40	B32377A7406J020	36	2000	116	200	C	2.5	4
	3×50	B32377A7506J020	38	2100	116	230	C	2.8	4
	3×56	B32377A7566J020	40	2100	116	245	C	3.0	4
	3×60	B32377A7606J020	42	2200	116	275	C	3.2	4
	3×65	B32377A7656J020	44	2000	116	275	C	3.2	4
	3×75	B32377A7756J020	48	3000	136	230	C	3.7	4
	3x100	B32377B7107J020	56	3200	136	275	C	4.3	4
1100/ 780	3x25	B32377A7256J080	25	1100	96	236	B	1.9	4
	3x29	B32377A7296J080	28	1200	96	251	B	2.0	4
	3x30	B32377A7306J080	30	1400	116	200	C	2.5	4
	3x35	B32377A7356J080	31	1900	116	200	C	2.5	4
	3x40	B32377A7406J080	35	1800	116	230	C	2.8	4
	3x47	B32377A7476J080	38	1860	116	245	C	3.0	4
	3×50	B32377A7506J080	40	1740	116	275	C	3.2	4
	3×56	B32377A7566J080	42	1740	116	275	C	3.2	4
	3×60	B32377A7606J080	44	2000	136	230	C	3.7	4
	3×70	B32377A7706J080	48	2800	136	245	C	3.9	4
	3×75	B32377A7756J080	50	2500	136	275	C	4.3	4
1200/ 850	3×10	B32377A8106J050	17	750	96	169	B	1.4	4
	3×15	B32377A8156J050	21	900	96	206	B	1.7	4
	3×20	B32377A8206J050	23	1100	96	236	B	1.9	4
	3×25	B32377A8256J050	26	1400	116	200	C	2.5	4
	3×31	B32377A8316J050	30	1800	116	200	C	2.5	4
	3×35	B32377A8356J050	33	1600	116	230	C	2.8	4
	3×42	B32377B8426J050	37	2500	136	200	C	3.2	4
	3×50	B32377A8506J050	41	2400	136	230	C	3.7	4
	3×55.8	B32377A8566J050	43	2600	136	230	C	3.7	4
	3×60	B32377A8606J050	45	2200	136	245	C	3.9	4
	3×70	B32377A8706J050	50	2500	136	275	C	4.3	4

B32377 series - UL certification up to 1000 V_{RMS} (V_R/V_{RMS} line to line voltage)

V_R/V_{RMS} V	C_R µF	Ordering code	I_{max} A	Î A	D mm	H mm	Terminal type	Weight kg	Packing Unit
1270/ 900	3×20	B32377A9206J000	30	1200	116	200	C	2.5	4
	3×25	B32377A9256J000	34	1400	116	200	C	2.5	4
	3×30	B32377A9306J000	36	1600	116	230	C	2.8	4
	3×35	B32377A9356J000	42	1900	116	245	C	3.0	4
	3×40	B32377A9406J000	46	2100	136	230	C	3.7	4
	3×45	B32377A9456J000	50	2300	136	245	C	3.9	4
	3×50	B32377A9506J000	54	2200	136	275	C	4.3	4
	3×56	B32377A9566J000	56	2400	136	275	C	4.3	4
	3×60	B32377A9606J000	60	2200	136	305	C	4.7	4
1415/ 1000	3×15	B32377A1156J000	26	1200	116	200	C	2.5	4
	3×20	B32377A1206J000	31	1300	116	200	C	2.5	4
	3×25	B32377A1256J000	37	1500	116	245	C	3.0	4
	3×30	B32377A1306J000	42	2000	136	230	C	3.7	4
	3×35	B32377A1356J000	44	2000	136	245	C	3.9	4
	3×40	B32377A1406J000	49	2000	136	275	C	4.3	4
	3×45	B32377A1456J000	53	2200	136	275	C	4.3	4
	3×50	B32377A1506J000	56	2100	136	305	C	4.7	4
	3×56	B32377B1566J000	66	2000	136	350	C	5.5	4

B32378 series - UL certification up to 600 V_{RMS} (V_R/V_{RMS} line to line voltage)

V_R/V_{RMS} V	C_R µF	Ordering code	I_{max} A	Î A	D mm	H mm	Terminal type	Weight kg	Packing Unit
590/ 420	3×150	B32378A4157J020	27	4500	116	146	D	1.9	4
	3×200	B32378A4207J020	31	4700	116	169	D	2.1	4
	3×250	B32378A4257J020	34	4300	116	206	D	2.5	4
680/ 480	3×100	B32378A4127J080	25	4000	116	146	D	1.9	4
	3×150	B32378A4157J080	28	5100	116	146	D	1.9	4
	3×200	B32378A4207J080	32	3800	116	206	D	2.5	4
750/ 530	3×80	B32378A5806J030	22	3000	116	146	D	1.9	4
	3×100	B32378A5107J030	24	3700	116	146	D	1.9	4
	3×120	B32378A5127J030	27	4500	116	146	D	1.9	4
	3×150	B32378A5157J030	30	4300	116	169	D	2.1	4
850/ 600	3×80	B32378A6806J000	23	3300	116	146	D	1.9	4
	3×100	B32378A6107J000	25	4000	116	146	D	1.9	4
	3×120	B32378A6127J000	28	3700	116	169	D	2.1	4
	3×150	B32378A6157J000	31	3400	116	206	D	2.5	4

B32378 series - UL certification pending (V_R/V_{RMS} line to line voltage)

V_R/V_{RMS} V	C_R µF	Ordering code	I_{max} A	Î A	D mm	H mm	Terminal type	Weight kg	Packing Unit
935/ 660	3×80	B32378A6806J060	24	3500	116	146	E	1.9	4
	3×100	B32378A6107J060	26	3400	116	169	E	2.1	4
	3×120	B32378A6127J060	29	3000	116	206	E	2.5	4
1020/ 720	3×60	B32378A7606J020	20	2800	116	146	E	1.9	4
	3×70	B32378A7706J020	23	3300	116	146	E	1.9	4
	3×80	B32378A7806J020	25	2900	116	169	E	2.1	4
	3×100	B32378A7107J020	25	3600	116	169	E	2.1	4
	3×120	B32378A7127J020	30	3600	116	206	E	2.5	4
1100/ 780	3×50	B32378A7506J080	19	2700	116	146	E	1.9	4
	3×60	B32378A7606J080	22	2500	116	169	E	2.1	4
	3×70	B32378A7706J080	24	2900	116	169	E	2.1	4
	3×80	B32378A7806J080	26	2400	116	206	E	2.5	4
	3×100	B32378A7107J080	30	3000	116	206	E	2.5	4
1200/ 850	3×50	B32378A8506J050	21	2500	116	169	E	2.1	4
	3×60	B32378A8606J050	23	3000	116	169	E	2.1	4
	3×70	B32378A8706J050	26	2400	116	206	E	2.5	4
	3×80	B32378A8806J050	28	2700	116	206	E	2.5	4
	3×100	B32378A8107J050	32	2700	116	236	E	2.8	4
1270/ 900	3×40	B32378A9406J000	21	2200	116	169	E	2.1	4
	3×60	B32378A9606J000	23	2600	116	206	E	2.5	4
	3×80	B32378A9806J000	30	2500	116	236	E	2.8	4
1415/ 1000	3×30	B32378A1306J000	17	2000	116	169	E	2.1	4
	3×60	B32378A1606J000	28	2500	116	236	E	2.8	4
	3×80	B32378A1806J000	31	2500	116	251	E	3.0	4

Remark: just for the series B32378 star connection applies the formula for transformation of voltage line-neutral to line to line. The conversion relationship is defined as (line to line voltage) $\mathbf{V_{ll}} = \sqrt{\mathbf{3}} \cdot \mathbf{V_{ln}}$ (phase voltage, line-neutral).

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.

Terms

Design

The winding element of the MKD capacitor consists of metallized polypropylene film. This winding construction achieves low losses and a high pulse-current withstand capability. Soft PU resin is used for impregnation of the capacitor.

Contacting

The end faces of the windings are contacted by metal spraying to ensure a reliable and low-inductance connection between the leads and layers. The leads are welded or soldered to these end faces, brought out through insulating elements (plastic) and soldered to the terminals.

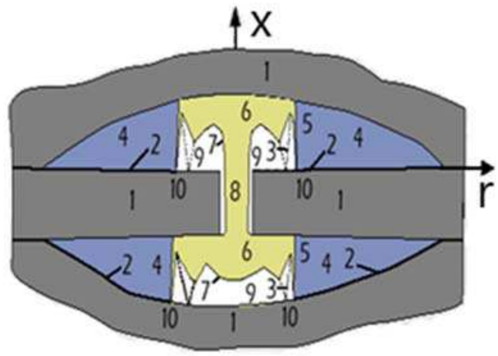
Impregnation

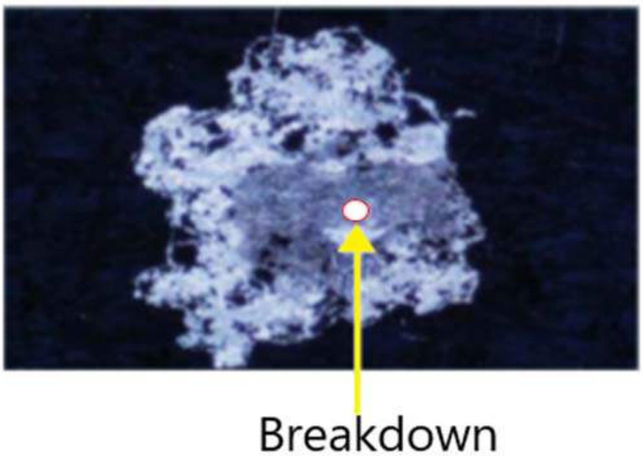
All hollows between the windings and between the windings and the case are filled with an impregnating agent. Besides increasing dielectric strength, this improves heat dissipation from inside a capacitor. The impregnating agents that we use are free of PCB and halogens.

Self-healing

All MKD capacitors are self-healing, i. e. voltage breakdowns heal in a matter of microseconds and hence do not produce a short circuit.

Breakdowns can occur under heavy electrical load as a result of weaknesses or pores in the dielectric. The integrity of self-healing capacitors is not affected by such breakdowns.





1. Dielectric (Polypropylene)
2. Metallization
3. Material-displacing shock wave
4. Air gap with metal vapor
5,6. Plasma zone
7. Boundary layer between gas-phase dielectric and plasma zones
8. Puncture channel
9. Gas-phase dielectric
10. Zone of displaced metallization and dielectric

Figure 8: Description of Self-healing technology

When a breakdown occurs, the dielectric in a breakdown channel is broken down into its atomic components by the electric arc that forms between the electrodes. At the high temperatures of as much as 6000 K, a plasma is created that explodes out of the channel region and pushes the dielectric layers apart. The actual self-healing process starts with the continuation of the electric arc in the propagating plasma. Here the metal layers are removed from the metal edges by evaporation. Insulation areas are formed. The rapid expansion of the plasma beyond the areas of insulation and its cooling in the areas of less field strength allow the discharge to extinguish after a few microseconds.

The area of insulation that is created is highly resistive and voltage-proof for all operating requirements of the capacitor. The self-healing breakdown is limited in current and so it does not represent a short circuit. The self-healing process is so brief and low in energy that the capacitor also remains fully functional during the breakdown.

Characteristics

Equivalent circuit diagram

Any real capacitor can be modelled by the following schematic:

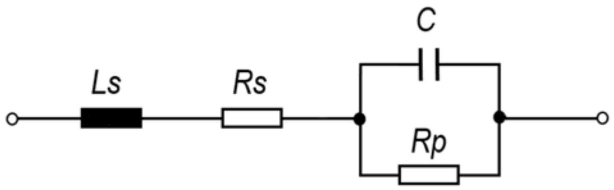


Figure 9: Equivalent circuit diagram

Symbol	Description	Unit
Ls	Series inductance	H
Rs	Series resistance, due to contacts(leads, sprayed metal and film metallization	Ω
Rp	Parallel resistance, due to insulation resistance	Ω
C	Capacitance	F

C, R_S and L_S are magnitudes that vary in the frequency domain (AC).
R_P is a magnitude defined in DC (insulation resistance).

Rated capacitance C_R

It is referred to a test temperature of +20 ℃ and a measuring frequency range of 50 Hz to 1 kHz.

Capacitance tolerance range

It is the range within which the actual capacitance may differ from rated capacitance. The actual capacitance is to be measured at a temperature of +20 ℃. This range results from variances in materials and manufacturing processes. The standard manufacturing tolerance for PP film capacitors is ±10% or ‘K’ tolerance or ±5%, ‘J’ tolerance.

Temperature dependence of capacitance

The capacitance variation in the permissible temperature range is not linear, but it is reversible, the characteristic change in capacitance ΔC/C as a function of test temperature is shown as follows:

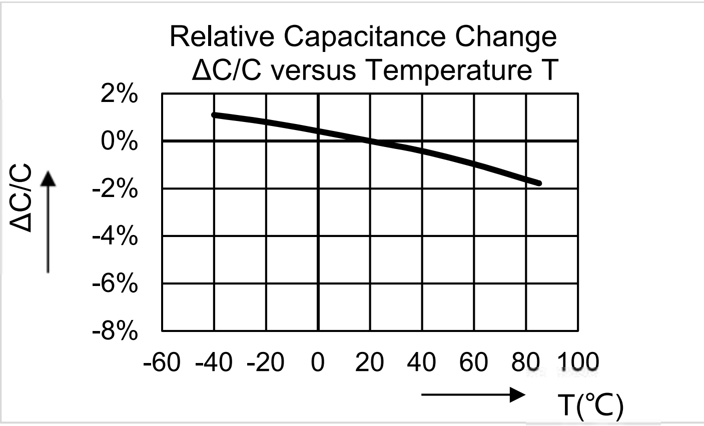


Figure 10: Temperature dependence of capacitance

Capacitance drift

Capacitance is subject to irreversible in addition to reversible changes, i.e. capacitance drift, the sum of all time-dependent, irreversible changes of capacitance during operating life. This variation is stated in percent of the value at delivery. The typical figure is +1/−3%.

Rated AC voltage V_R

The maximum operating peak recurrent voltage of either polarity of a reversing type waveform for which the capacitor has been designed.
Unlike what is common in other standard (e.g. B32304* 3–phase capacitor series for PFC application) therefore, the rated voltage **V_R is not the RMS** value, but the maximum or peak value of the capacitor voltage. The voltage at which the capacitor may be operated is dependent on other factors (especially current and frequency) besides rated voltage.

Voltage V_{RMS}

It is the Root Mean Square (RMS) voltage of maximum permissible value of sinusoidal AC voltage in continuous operation.

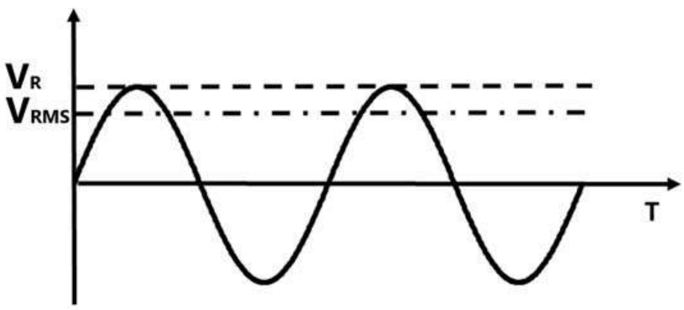


Figure 11: Voltage V_{RMS}

Rated DC voltage V_{RDC}

It is the maximum operating peak voltage of either polarity but of non-reversing type waveform, for which the capacitor has been designed, for continuous operation.

Non-recurrent surge voltage V_S

A peak voltage induced by a switching or any other disturbance of the system which is allowed for a limited number of times and for durations shorter than the basic period.

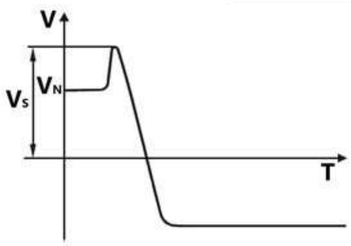


Figure 12: Non-recurrent surge voltage V_S

Maximum duration: 50 ms/pulse
Maximum number of occurrences: 1000 (during load)

Max. Recurrent peak voltage $\hat{u}$

This is the permissible, max. recurrent peak voltage that may appear for max.1% of the period.

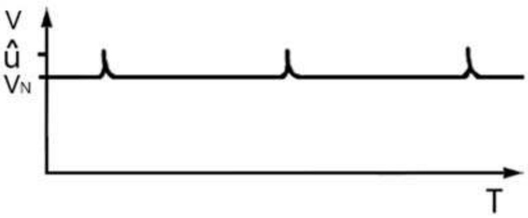


Figure 13: Max. Recurrent peak voltage $\hat{u}$

Symmetric alternating voltage $\hat{u}_{ac}$

The peak values of a symmetrical alternating voltage applied to the capacitor is a decisive factor for the dielectric losses.

For AC capacitors: $\hat{u}_{ac} = V_R$

Insulation voltage V_i

It is the rms rated value of the insulation voltage of capacitive elements and terminals to case or earth. If not specified, the rms value of the insulating voltage is equivalent to the rated voltage divided by $\sqrt{2}$.

Maximum current I_{max}

It is the maximum rms current for continuous operation, but could not be higher than maximum terminal current. A higher current than proposal I_{max} value could be possible in lower ambient temperature.

Maximum peak current $\hat{I}$

It is the maximum current amplitude which occurs instantaneously during continuous operation. The maximum peak current and the maximum rate of voltage rise $(dV/dt)_{max}$ on a capacitor are related as follows:

$$\hat{I} = C_R \cdot \left(\frac{dV}{dt}\right)_{max}$$

Maximum surge current I_s

It is the peak non-repetitive current induced by switching or any other disturbance of the system permitted for a limited number of times, at durations shorter than the basic period.

$$I_s = C_R \cdot \left(\frac{dV}{dt}\right)_s$$

Maximum duration: 50 ms/pulse
Maximum number of occurrences: 1000 (during load)

Self-inductance L_{self}

The self-inductance is produced by the inductance of the terminals and the windings. Because of the special kind of contacting in self-healing capacitors (large area metal spraying covering all windings), the self-inductance is particularly low. It allows the resonance frequency to be determined:

$$f = \frac{1}{2\pi\sqrt{L_{self} \cdot C_R}}$$

The resonance frequency is high for all capacitors accordingly.

Insulation Resistance (R_{ins})

The dielectric of a capacitor has a large area and a short length. Even if the material is a good isolator there always flows a certain current between the charged electrodes (the current increases exponentially with the temperature). This leakage can be described as a parallel resistance with a high value, an Insulation Resistance.

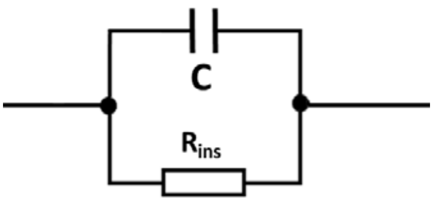


Figure 14: Insulation Resistance (R_{ins})

Insulation resistance and self-discharge time constant

The insulation values for the individual components according to the capacitance are stated as an insulation resistance R_{ins} in MΩ or a self-discharge time constant τ in seconds.

$$\tau = R_{ins} \cdot C_R$$

Series resistance R_S

Resistive losses occur in the electrodes in the contacting and in the inner wiring. These are comprised in the series resistance R_S of a capacitor.
The series resistance R_S generates the ohmic losses ($I^2 \times R_S$) in a capacitor. It is largely independent of frequency. The figures stated in selection charts apply to +20℃ capacitor temperature.

Dissipation factor tan δ

The equivalent circuit diagram used for the losses in a capacitor can be shown as follows:

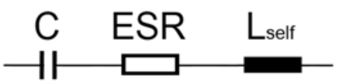


Figure 15: Simplified equivalent circuit diagram of a capacitor

Symbol	Description	Unit
C	Capacitor	F
L_{self}	Self-inductance	H
ESR	Equivalent series resistance, representing the entire active power in capacitor	Ω

The self-inductance and capacitance of a capacitor produce its resonance frequency (natural frequency).

$$\tan\delta(f) = \tan\delta_0 + Rs \cdot \omega \cdot C$$

From the frequency dependence of the equivalent series resistance can be derived:

$$ESR = \frac{\tan\delta}{\omega \cdot C} = Rs + \frac{\tan\delta_0}{\omega \cdot C}$$

Symbol	Description	Unit
tan δ	Dissipation factor of capacitor	-
$\tan\delta_0$	Dissipation factor of dielectric	-
R_S	Series resistance	Ω

Dielectric dissipation factor tan δ_0

The dissipation factor tan δ_0 of the dielectric is assumed to be constant for all capacitors in their frequency range of use. The figures stated in data sheets apply to rated operation.

Expected Fit rate λ

The FIT (Failure In Time) of a component is defined as the number of expected failures in 10^9 hours of operation.

The FIT rate is calculated on the basis of the number of components operating in the field and the estimated hours of operation. All the reports of failures are taken into consideration for this calculation, which is updated every year. The other values in the graph are given as indication and calculated based on acceleration factors.

The failure criterion is capacitance drop higher than 3%.

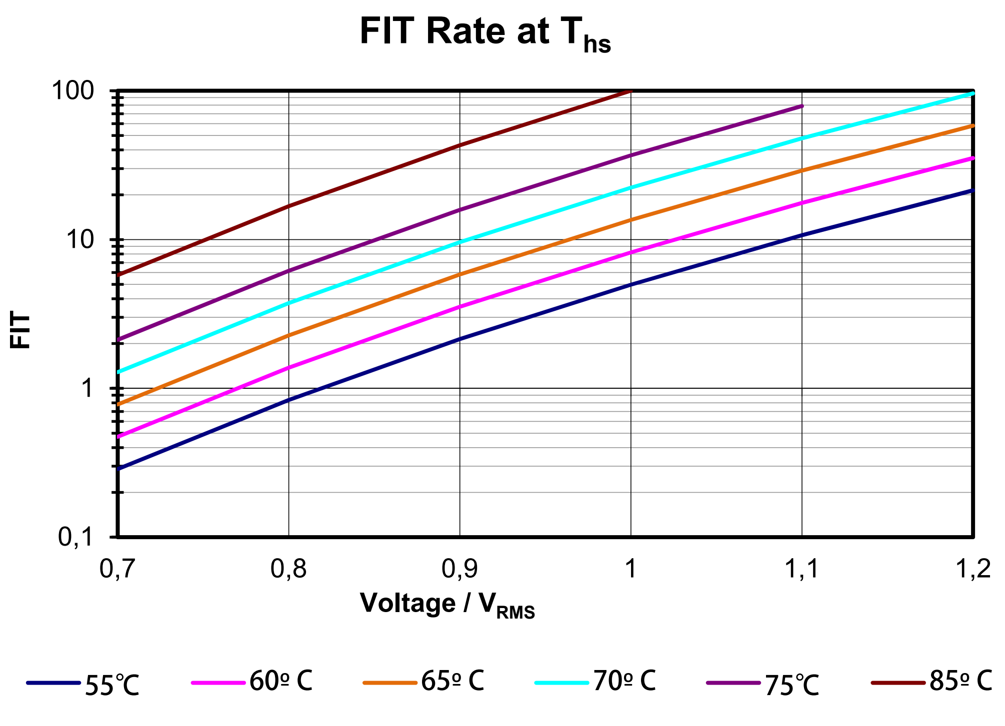


Figure 16: Expected Fit rate λ

Thermal design

In order to scale a capacitor correctly for a particular application, the permissible ambient temperature has to be determined. This can be taken from the diagram "Permissible ambient temperature TA vs total power dissipation P" after calculating the power dissipation (for further details please check individual data sheets).

Calculation of power dissipation P

The total power dissipation P is composed of the dielectric losses (P_D) and the resistive losses (P_R). Generally a secondary sinusoidal AC voltage can be used for calculating with sufficient accuracy.

$$P = P_D + P_R$$

$$P_D = \hat{u}_{ac}^2 \cdot \pi \cdot f_0 \cdot C \cdot \tan \delta_0$$

Symbol	Description	Unit
$\hat{u}_{ac}$	Peak value of symmetrical AC voltage applied to capacitor	V
f_0	Fundamental frequency	Hz
C	Capacitance	F
tan δ_0	Dissipation factor of dielectric	-

$$P_R = I^2 \cdot R_S$$

Symbol	Description	Unit
I	RMS value of capacitor current	A
R_S	Series resistance at maximum hot-spot temperature	Ω

The R_S figure at maximum hot-spot temperature is used to calculate the resistive losses. In selection charts and data sheets the figure is stated for 20 ℃ capacitor temperature. The conversion factor is as follows:

$$R_{s85^\circ} = 1.25 \cdot R_{s20^\circ}$$

Thermal resistance R_{th}

The thermal resistance is defined as the ratio of a temperature difference and the power dissipation produced in a capacitor. The decisive factor here is ΔTcap where the temperature difference between an external reference point of the coolant (e.g. air) surrounding the capacitor and the hot spot (zone with highest temperature occurring in the component). In a steady state:

$$R_{th} = \frac{\Delta T_{cap}}{P}$$

Symbol	Description	Unit
R_{th}	Thermal resistance	K/W
ΔTcap	Temperature difference between hot-spot and ambient	K
P	Power dissipation	W

The temperature difference depends on a large number of different factors. The thermal resistance is a function of several parameters such as the working temperature and the power dissipation of the capacitor.

After installation of the capacitor, it is necessary to verify that maximum hot-spot temperature is not exceeded at extreme service conditions. For detail calculations please refer to single datasheet part number for further details.

Life expectancy t_{LD}

The life expectancy t_{LD} is based on the exclusive effect of Voltage and Temperature (hot-spot T_{hs}) applied to the capacitor dielectric and electrodes (other factors are not considered in the model such as environmental or mechanical effects).

Hot Spot Temperature (T_{hs}): as the sum of ambient temperature plus the heating induced by the current (I_{RMS}) in the dielectric which is measured inside of capacitor. Current is an indirect parameter under consideration which affects the temperature T_{hs}.

Lifetime estimation formula as follows:

$$t_2 = t_1 \cdot e^{(T_1 - T_2)/A} \left(\frac{V_1}{V_2}\right)^n$$

Symbol	Description	Unit
t_2	Estimated lifetime at temperature T_2 and Voltage V_2	hour
t_1	Reference life expectancy (e.g. 100,000 hours for V_R ∣ΔC/C∣≤3%)	hour
V_2	Variable Voltage (Rated AC voltage)	VAC
V_1	Reference Voltage (Rated AC voltage)	VAC
T_1	Reference temperature (e.g. 70℃)	℃
T_2	Variable temperature	℃
A	Acceleration factor of temperature	-
n	Acceleration factor of voltage	-

Lifetime Expectancy Graphs

The lifetime estimations below shows the standard expected lifetime of 100,000 hours (at +85 °C hot-spot) are only theoretical calculations based on endurance test results performed according to IEC61071 standard.

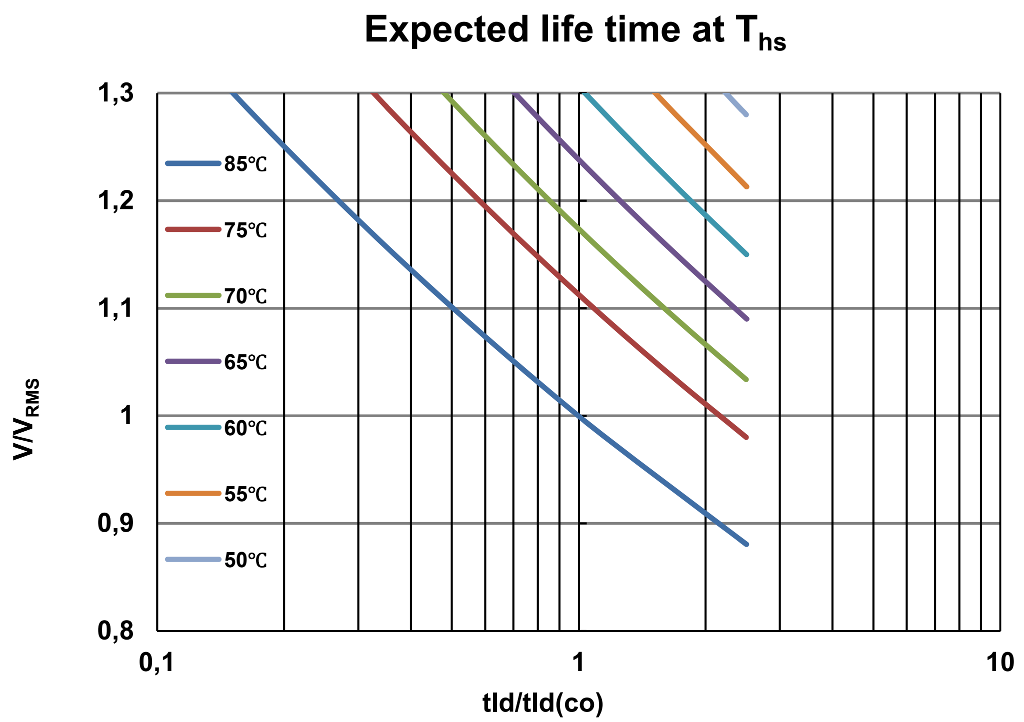


Figure 17: Service life t_{LD} at different hot-spot temperature (T_{hs}) and voltage V_{RMS}.

Cautions and warnings

- Capacitors with dents of more than 1 mm depth or any other mechanical damage must not be used.
- Check the tightness of the connections / terminals periodically.
- The energy stored in capacitors may be lethal. To prevent any risk of shock, the capacitors must be discharged and short-circuited before handling.
- Failure to follow cautions may result in the worst case in premature failure, bursting and fire.

Safety

- Electrical or mechanical misapplication of capacitors may be hazardous. Personal injury or property damage may result from bursting of the capacitor or expulsion of molten material due to mechanical disruption of the capacitor.
- Ensure good, effective grounding for capacitor enclosures.
- Observe appropriate safety precautions during operation (self-recharging phenomena and the high energy stored in capacitors).
- Handle capacitors carefully, as they may still be charged even after disconnection.
- The terminals of capacitors, connected busbars and cables as well as other devices may also be energized.
- Follow good engineering practice.
- The maximum permissible fault current (AFC) of 10 kA in accordance with the UL 810 standard must be assured by the application.

Thermal load

- After installing the capacitor, verify that the maximum hot-spot temperature is not exceeded under extreme operating conditions.

Mechanical protection

- The capacitor has to be installed to assure that no mechanical damage or dents in the case occur.

Storage and operating conditions

- Do not use or store capacitors in corrosive atmospheres, especially where chloride gas, sulfide gas, acid, alkali, salt or the like are present. In dusty environments, regular maintenance and cleaning, especially of the terminals, is required to avoid creating a conductive path between phases and/or phases and ground.

Overpressure disconnector

- To ensure full functionality of an overpressure safety disconnector, the following points must be observed:
  1. The elastic elements must not be hindered, i.e.
     - Connecting lines must be flexible leads (cables)
     - There must be sufficient space (min.15 mm) for expansion above the connections
     - The metal cover must not be retained by rigid parts such as busbars.
  2. The stress parameters of the capacitor must be within the IEC 61071 specification.

Service life expectancy

- Electrical components do not have an unlimited service life expectancy: this also applies to self-healing capacitors. The maximum service life expectancy may vary depending on the application in which the capacitor is used.

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.

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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, CeraCharge, CeraDiode, CeraLink, CeraPad, CeraPlas, CSMP, CTVS, DeltaCap, DigiSiMic, ExoCore, FilterCap, FormFit, LeaXield, MiniBlue, MiniCell, MKD, MKK, MotorCap, PCC, PhaseCap, PhaseCube, PhaseMod, PhiCap, PowerHap, PQSine, PQvar, SIFERRIT, SIFI, SIKOREL, SilverCap, SIMDAD, SiMic, SIMID, SineFormer, SIOV, ThermoFuse, WindCap 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.

Release 2018-10