1 General

Capacitors for power electronics are components for equipment and installations that are operated at high power. They are used to convert and control this power. A major feature of their application is that they are capable of carrying peak currents which are much higher than rms currents.

Standards IEC 1071-1 and 2, which are identical to EN 61071-1 and 2 as well as to VDE 0560, parts 120 and 121, apply to capacitors for power electronics.

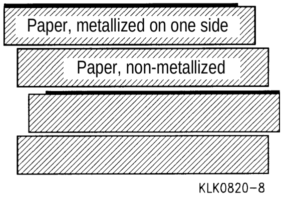
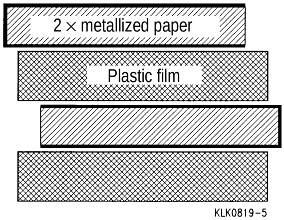
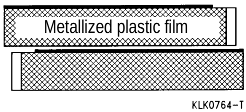
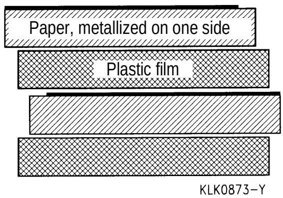
Standards IEC 831-1 and 2, which are identical to EN 60831-1 and 2 as well as to VDE 0560, parts 46 and 47, apply to capacitors for power factor correction.

1.1 Versions

EPCOS produces the following kinds of capacitor:

MP capacitors for DC voltage (MP – metallized paper)
MKV capacitors for AC voltage (MKV – metallized plastic film, low-loss)
MKK-AC capacitors for AC voltage (MKK – metallized plastic film, compact)
MKK-DC capacitors for DC voltage (MKK – metallized plastic film, compact)
MPK capacitors for DC voltage (MPK – metallized paper and plastic film)

All capacitors are self-healing, i. e. voltage breakdowns heal in a matter of microseconds and so produce no short circuit.

Version	Electrode	Impregnation	Dielectric
MP capacitors	Metal layer vapor-deposited on one side of paper.	Hard wax and oil	
MKV capacitors	Metal layer vapor-deposited on two sides of paper. Paper is not within electric field.	Oil	
MKK capacitors	Metal layer vapor-deposited on one side of plastic film.	Dry (filled with neither liquid nor solid impregnating agents)	
MPK capacitors	Metal layer vapor-deposited on one side of paper.	Oil	

1.2 Self-healing

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.

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.

1.3 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 (ceramic or plastic) and soldered to the terminals.

MKK capacitors have a special end face design (wave cut).

1.4 Impregnation

1.4.1 Solid and liquid impregnating agents

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. They consist of mineral oil, hard wax and pure synthetic hydrocarbons that partly contain small quantities of conventional additives (stabilizers). For waste disposal refer to section 11 “End of use and disposal”.

1.4.2 Gaseous impregnating agents

In this case, all hollow spaces are filled with inert insulating gases. The impregnating gas is filled into the capacitor after vacuum drying has been completed.

2 Characteristics

The following definitions apply to power capacitors according to IEC 1071. For capacitors for power factor correction refer to page 297.

2.1 Capacitance

2.1.1 Rated capacitance C_R

This is referred to a test temperature of 20 °C and a measuring frequency range of 50 to 120 Hz.

2.1.2 Capacitance tolerance range

This 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 °C.

2.1.3 Temperature dependence of capacitance

The capacitance variation in the permissible temperature range is not linear, but it is reversible. Bild 1 shows the characteristic change in capacitance ΔC/C as a function of test temperature for MP, MKV and MKK capacitors. No uniform curve is possible for MPK capacitors because of the combined paper/film dielectric.

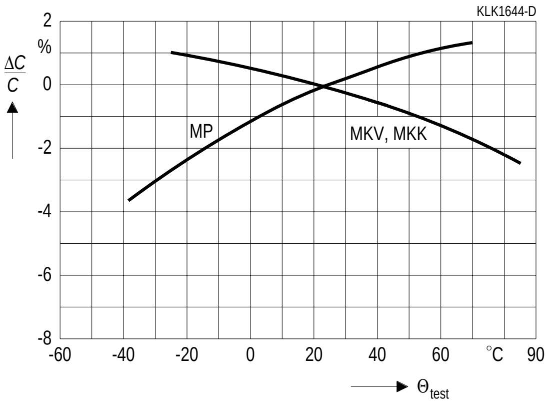


Bild 1

Relative capacitance change ΔC/C versus test temperature T_{test}

2.1.4 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 %.

2.2 Voltages

2.2.1 Rated AC voltage U_R

The maximum operating recurrent peak voltage of either polarity of a reversing type waveform for which the capacitor has been designed.

Unlike what is common in other standards therefore, the rated voltage U_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.

2.2.2 Rated DC voltage U_R

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

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

The peak values of a symmetrical alternating voltage $\hat{u}_{ac}$ applied to the capacitor is a decisive factor for the dielectric losses (also refer to chapter “Thermal Design of Capacitors for Power Electronics”).

$$(P_D = \hat{u}_{ac}^2 \cdot \pi \cdot f_0 \cdot C \cdot \tan \delta_0) \tag{1}$$

The thermal data sheet information (diagram P_D versus f_0) applies to the following $\hat{u}_{ac}$ values:

Figure 2a for DC capacitors:
$\hat{u}_{ac} = 0{,}1 \cdot U_R$ (DC)
(peak value of the superimposed ripple voltage is 10 % of the rated DC voltage)

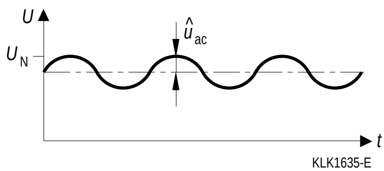


Figure 2b for AC capacitors:
$\hat{u}_{ac} = U_R$ (AC)
(peak value of the applied AC voltage is the rated AC voltage)

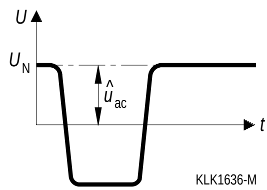
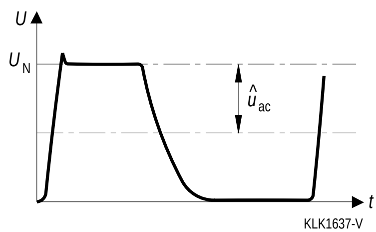


Figure 2c for GTO snubber capacitors:
$\hat{u}_{ac} = U_R$ (DC) / 2
(peak value of the symmetrical AC voltage is equal to half the rated DC voltage)



2.2.4 Max. recurrent peak voltage û

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

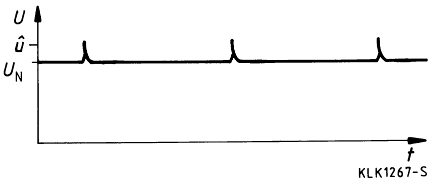


Bild 3

Permissible, max. recurrent peak voltage $\hat{u}$

2.2.5 Insulation voltage U_{ins}

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 $\sqrt{2}$.

The value is stated in the selection tables and the individual data sheets.

2.2.6 Non-recurrent surge voltage u_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.

Max. duration: 50 ms/pulse
Max. count: 1000 (during load)

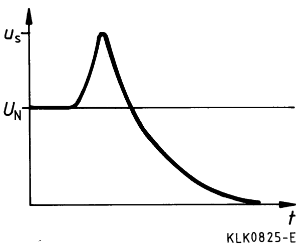


Bild 4

Surge voltage u_s
DC capacitors

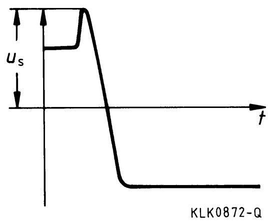


Bild 5

Surge voltage u_s
AC capacitors

2.2.7 Testing of dielectric strength

Voltage test between terminals U_{TT}

Every capacitor shall be subjected for 10 s to either test of the following table. The choice is left to the manufacturer. During the test neither puncture nor flashover shall occur. Self-healing breakdowns are permitted. In the case of units with all elements in parallel, operation of internal element fuse(s) is permitted, provided the capacitance tolerances are still met.

	AC capacitors (self-healing)	DC capacitors (self-healing)
AC test voltage rms value	1,25 U_R	–
DC test voltage	1,75 U_R	1,5 U_R

Notes

- The duration may be reduced to 2 s provided the voltage is increased by 10%.
- The AC test voltage may be 50 Hz or 60 Hz.
- The test voltage indicated in the above table can be reduced if capacitors are intended for intermittend duty or for short service duration; the new values shall be agreed upon between manufacturer and purchaser.

AC voltage test between terminals and case U_{TC}

Units having all terminals insulated from the case shall be subjected for 10 s to a voltage applied between the terminals (joined together) and the case.

The test voltage values are the following:

U_{TC} = 2 U_{ins} + 1000 V or 2000 V whichever is the highest value where U_i is the insulation voltage.

The insulation voltage of the capacitor shall be specified by the user. The insulating voltage is equal to the nominal voltage of the capacitor, divided by $\sqrt{2}$ unless otherwise specified. During the test, neither puncture nor flashover shall occur. The test shall be performed, even if one of the terminals is intended to be connected to the case in service. Units having one terminal permanently connected to the case shall not be subjected to this test.

The test is omitted for single-pole capacitors on which a terminal is firmly connected to the metal case (e.g. B25835) and for capacitors with a fully insulated case (e.g. B25856).

2.3 Currents

2.3.1 Maximum current I_{max}

The maximum rms current for continuous operation.

2.3.2 Maximum peak current î

The maximum current amplitude which occurs instantaneously during continuous operation.

The maximum peak current and the maximum rate of voltage rise $(du/dt)_{max}$ on a capacitor are related as follows:

$$\hat{i} = C \cdot (\mathrm{d}u/\mathrm{d}t)_{max} \quad (2)$$

î is stated in selection charts and data sheets.

2.3.3 Maximum surge current I_S

The admissible peak current induced by a switching or any other disturbance of the system which is allowed for a limited number of times.

$$I_S = C \cdot (du/dt)_S \tag{3}$$

Max. duration: 50 ms/pulse
Max. count: 1000 (during load)

The value is stated in selection charts and data sheets.

2.3.4 Rate of voltage rise du/dt

The rate of voltage rise du/dt is limited by the peak current handling capability of the contacts or the self-inductance of a capacitor.

$$\frac{du}{dt} = \frac{I}{C} \tag{4}$$

2.4 Energy content W_N

The energy content is calculated from the rated capacitance and rated voltage values.

$$W_N = {}^1/_2\, C_N \cdot U_N^2 \tag{5}$$

W_N	energy content	Ws
C_N	rated capacitance	F
U_N	rated voltage	V

2.5 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.

The resonance frequency is accordingly high for all capacitors.

2.6 Insulation resistance R_{ins} and self-discharge time constant •

The insulation values for the individual components, according to the capacitance, are stated as an insulation resistance in MΩ or a self-discharge time constant τ in seconds. In this data book minimum figures at delivery are stated.

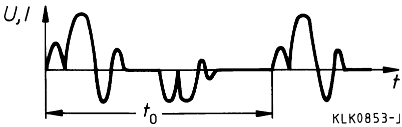
$$\tau = R_{ins} \cdot C \tag{6}$$

2.7 Time and frequency

2.7.1 Duration of fundamental t_0

This is the duration of the fundamental oscillation after which all processes are cyclically repeated. The duration of the fundamental (t_0) and the fundamental frequency (f_0) are related:

$$f_0 = \frac{1}{t_0} \tag{7}$$



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Duration of fundamental t_0 (cyclic)

2.8 Capacitor losses

2.8.1 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 ($I^2 \cdot R_S$) in a capacitor. It is largely independent of frequency. The figures stated in selection charts apply to 20 °C capacitor temperature.

The R_S figure at maximum hot-spot temperature is used to calculate ohmic losses. For conversion factors, see chapter “Thermal Design of Capacitors for Power Electronics”.

2.8.2 Dielectric dissipation factor tan •$_0$

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.

2.8.3 Dissipation factor tan •

The equivalent circuit diagram used for the losses in a capacitor can be shown as in figure 7.

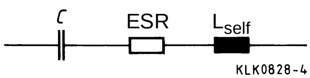

Bild 7

Simplified equivalent circuit diagram of a capacitor

L_{self} = self-inductance

ESR = equivalent series resistance, representing entire active power in capacitor.

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

The relation of the dissipation factor to the frequency is illustrated by the following example:

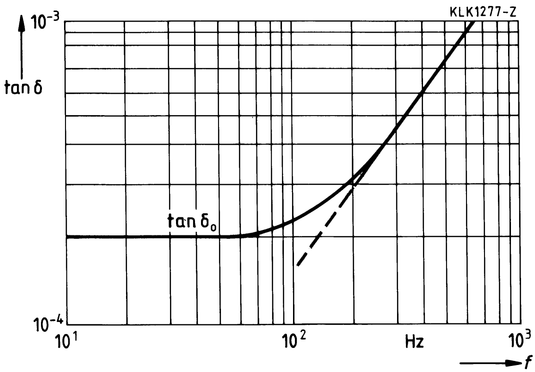

Bild 8

Dissipation factor tan δ versus frequency f

This curve corresponds to:

$$\tan\delta\,(f) = \tan\delta_0 + R_S \cdot \omega \cdot C \tag{8}$$

$\tan\delta$	dissipation factor of capacitor	
$\tan\delta_0$	dissipation factor of dielectric	
C	capacitance	F
R_S	series resistance	Ω

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

$$ESR = \frac{\tan\delta}{\omega \cdot C} = R_S + \frac{\tan\delta_0}{\omega \cdot C} \tag{9}$$

ESR equivalent series resistance Ω

2.8.4 Thermal resistance R_{th}

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

In a steady state:

$$R_{th} = \frac{\Delta T_{cap}}{P} \tag{10}$$

R_{th}	thermal resistance	K/W
ΔT_{cap}	temperature difference between hot spot and ambient	K
P	power dissipation	W

The temperature difference depends on a large number of different factors. Among other things the thermal resistance is a function of the working temperature or power dissipation of the capacitor. The qualitative nature of this factor is shown in figure 9 for an exemplary capacitor.

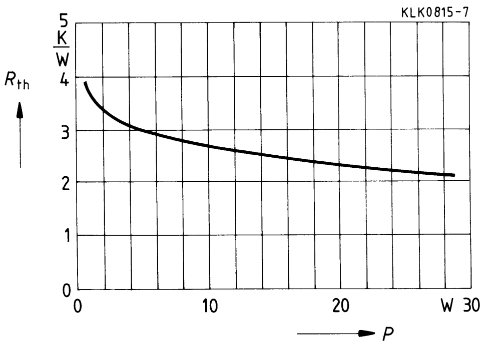

Bild 9

Thermal resistance R_{th} versus capacitor power dissipation P

The calculations are checked on high-power test inverters. Here the capacitors can be subjected to the following loads in a unipolar and bipolar mode:

Rated voltages	up to 7000 V
Rms currents	up to approx. 1000 A
Max. peak currents	up to 2000 A
Fundamental frequencies	up to 2000 Hz

2.8.5 Thermal time constant •$_{th}$

The thermal time constant τ_{th} can be calculated with sufficient accuracy for our capacitors from the specific thermal capacitance (approx. 1.3 Ws/K · g), the capacitor mass stated in the selection charts and the thermal resistance at the operating point:

$$\tau_{th} = m \cdot c_{thcap} \cdot R_{th} \tag{11}$$

τ_{th}	thermal time constant	s
R_{th}	thermal resistance	K/W
m	capacitor mass (weight)	g
c_{thcap}	specific thermal capacitance	Ws/K ·g

2.8.6 Power dissipation P

The power dissipation P is the sum of all active power produced in a capacitor, i.e.:

$$P = \hat{u}_{ac}^2 \cdot \pi \cdot f_0 \cdot C \cdot \tan\delta_0 + I^2 \cdot R_S \tag{12}$$

$\hat{u}_{ac}$	peak value of symmetrical AC voltage applied to capacitor	
f_0	fundamental frequency	Hz
C	capacitance	F
$\tan\delta_0$	dissipation factor of dielectric	
I	rms value of capacitor current	A
R_S	series resistance at maximum hot-spot temperature	Ω

For power dissipation and permissible ambient temperature, see the calculation example in chapter "Thermal Design of Capacitors for Power Electronics".

2.9 Self-heating

The power dissipated in the operation of capacitors leads to an increase in temperature in the capacitor. The temperature conditions that occur are difficult to anticipate (influence of ambient temperature and special cooling measures; radiation and heat conduction). In cases of doubt the user should make a type test to make sure capacitors remain within the permissible temperature range.

Observe the following in such a test:

a) The provisional, experimental configuration must match the final or mass-produced equipment environment.

b) The temperature should not be measured until thermal equilibrium has been established, which may take hours (much longer than $5 \cdot \tau_{th}$).

3 Operating modes

3.1 Continuous operation (co)

Time of operation (>> 5 · τ_{th}) until the capacitor is at thermal equilibrium for most of the time.

3.2 Intermittent operation (io)

Periods of operation alternate – usually in a regular sequence of identical pulses – with pauses in which the capacitor is off load. The pauses can be so short that the capacitor does not cool down to the temperature of the surrounding coolant.

The sum of on time and off time is called cycle duration.

The ratio of on time to cycle duration is the duty factor. This is stated in percent of the cycle duration.

3.3 Short-term operation (sto)

In short-term operation the on time is so short (<< 5 · τ_{th}) that the capacitor will **not** reach thermal equilibrium. The pause in which no voltage is applied to the capacitor is so long that it practically cools down to the temperature of the coolant.

For pure DC voltage only the duration of voltage load is considered. For certain individual models (DC capacitors) the voltage for short-term operation is also stated in this data book.

4 Safety

The technical and constructional measures implemented in power capacitors from EPCOS guarantee extremely high standards of safety.

These standards are in part due to a special burst chamber in which exceptional fault occurrences can be simulated at high levels of power so that the response of capacitors can be examined.

4.1 Protection against electric shock

All capacitors are subjected to a voltage test. This test is made between the terminals and the accessible case with a voltage U_{TC} according to the requirements.

VDE 0100 requires grounding of the capacitor case. This can be done with the terminals provided for this purpose (labeled in accordance with DIN 40 011) or with a metal clamp (section 10.5 “Grounding”).

4.2 Safety in case of overload and failure

Many capacitor designs are equipped with an overpressure disconnector (see data sheets). This prevents the capacitor from bursting if the pressure inside it becomes too high through overloading or at the end of its service life.

The excess internal pressure either expands the folded crimps on the aluminum case or pushes the bottom of the case outwards.

The disconnector is separated at its break point and the current to the windings in the capacitor is interrupted.

To ensure correct operation of the overpressure disconnector, observe the mounting instructions on page 39.

5 Climatic stress

The following definitions apply to power capacitors according to IEC 1071. For capacitors for power factor correction refer to page 297.

5.1 Temperature and cooling

Ambient temperature T_A

The ambient temperature T_A is measured at 10 cm distance and at $^2/_3$ of the case height of the capacitor.

Operating temperature T_C

The temperature of the hottest point on the case of the capacitor in thermal equilibrium.

Lowest operating temperature T_{min}

The lowest temperature at which the capacitor may be energized.

Maximum operating temperature T_{max}

The highest temperature of the case at which the capacitor may be operated.

Test temperature T_{test}

The uniform temperature of all parts of a capacitor.

Hot-spot temperature T_{hs}

The zone with the highest temperature occurring in a capacitor is called the hot spot.

Maximum hot-spot temperature T_{HS}

This is the maximum permissible hot-spot temperature for a particular capacitor type.

MP and MKK capacitors:	T_{HS} = 70 °C
MKV and MPK capacitors:	T_{HS} = 85 °C

Steady-state condition

Thermal equilibrium attained by the capacitor at constant output and at constant cooling-air temperature.

Storage and transport temperature T_{stg}

Storage and transport temperatures are temperatures outside the operating-temperature range at which a capacitor is not operational but does not suffer lasting damage. Capacitors are only subjected to transport temperatures temporarily.

Natural cooling

The capacitor is cooled by natural movement of the air and by heat emission.

Forced cooling

The capacitor is cooled by forced ventilation of its environment.

Note:

The figures T_{stg}, T_{min} and T_{max} are stated for the individual models and in the data sheets. The permissible ambient temperature Θ_A as a function of total power dissipation should be taken from the diagrams (see individual data sheets).

5.2 Climatic category to IEC 68

The climatic category (test category) is stated in accordance with IEC 68, part 1 by three groups of numbers separated by slashes.

Example:	40/070/56
1st group:	Lower category temperature T_{min} as test temperature for test Aa (cold) to IEC 68, part 2-1
2nd group:	Upper category temperature T_{max} as test temperature for test Ba (dry heat) to IEC 68, part 2-2
3rd group:	Number of days as duration for test Ca (damp heat, steady state) to IEC 68, part 2-3 at (93 + 2 / – 3) % relative humidity and 40 °C ambient temperature

6 Mechanical stress

The following definitions apply to power capacitors according to IEC 1071. For capacitors for power factor correction refer to page 297.

6.1 Mechanical robustness of terminals

The terminals satisfy the following test conditions to IEC 68, part 2-21:

Tensile strength	test Ua (20 N)
Bending strength	test Ub two bends in opposite directions – for tab connectors – for terminal bolts
Torsional strength of axial leads	test Uc; severity 2 (two rotations)
Torsional strength of threaded bolts	test Ud

6.2 Vibration resistance

The resistance to vibration of capacitors with diameters of ≤ 60 mm and heights of ≤ 160 mm corresponds to IEC 68, part 2-6.
The following conditions are satisfied (figures for larger capacitors upon enquiry):

Test duration	6 h	corresponding to max. 98,1 m/s^2 or 10 *g*
Frequency range	10 … 55 Hz	
Displacement amplitude	0.75 mm	

These figures apply to the capacitor alone.

Because the fixing and the terminals may influence the vibration properties, it is necessary to check stability when a capacitor is built in and exposed to vibration.
Irrespective of this, you are advised not to locate capacitors where vibration amplitude reaches its maximum in strongly vibrating appliances.

6.3 Shock testing

This is carried out in accordance with IEC 68, part 2-27: test Ea. Figures on request.

The figures are dependent on the size and mass of a capacitor. The maximum figures for small capacitors, for instance, are about 30 *g*.

7 Low air pressure

The following definitions apply to power capacitors according to IEC 1071. For capacitors for power factor correction refer to page 297.

Shelf life at low air pressure

Capacitors of humidity ≤ 95 %: max. altitude 20000 m = approx. 40 hP
Capacitors of humditiy ≤ 75 %: max. altitude 8500 m = approx. 300 hP

Operation at low air pressure

To IEC 68, part 2-13: test M (figures on request).

8 Labeling of capacitors

The following example illustrates how a capacitor is labeled.

	Manufacturer (manufacturer‘s logo)
EPCOS B25832-C6106-K009	Ordering code
MKV 10 µF ± 10 % SH	Version, rated capacitance, tolerance, SH (self healing)
U_N = AC 930 V	Rated voltage, overpressure disconnector
U_i = AC 850 V –25 … +85 °C	Insulation voltage, $T_{min} \dots T_{max}$
IEC 1071-1	IEC standard
Non PCB Germany	Note, country of origin
03.98	Month/year of manufacture

9 Delivery and packing

In the packing of products, EPCOS naturally supports the needs of protection of the environment. In other words:

- use of packaging made of environmentally compatible materials,
- reduction of packaging to the necessary minimum.

We have implemented the following measures to ensure compliance with regulations governing the handling and disposal of commercial waste:

- Use of Euro pallets.
- Securing of pallets by straps and edge guards of environment-friendly plastic (PE or PP). Stretch and shrink film (PE) are used.
- Shipping cartons are identified by the RESY symbol.
- Separating layers for pallets and cartons are primarily of paper or cardboard.
- Filler material consists of paper.
- Shipping cartons are sealed with recycled paper adhesive tape to ensure material of the same kind for disposal.
- We take our packaging back (especially product-specific packaging made of plastic). Nevertheless we request our customers to deliver cardboard products, corrugated board, paper, etc. to recycling or disposal operators in order to avoid unnecessary transport of empty packaging.

10 Mounting instructions

10.1 Overpressure disconnector

When mounting capacitors with overpressure disconnectors, make sure that the elastic elements of the fuse are not impeded.

This means:

- The connecting leads must be sufficiently elastic.
- There must be enough space left for expansion above the terminals of aluminum-cased capacitors (stated for the individual type).
- The folded crimps must not be held by retaining clamps.
- The elastic bottom of capacitors in round steel cases must be free to move.

10.2 Mounting position

Capacitors will usually be mounted upright, i.e. terminals on top. But the following exceptions to the rule are possible:

- Capacitors in aluminum cases with voltage ratings up to 1400 V and capacitors in rectangular steel cases may also be positioned horizontally.
- At higher voltages or for capacitors in round steel cases, horizontal positioning is also permissible. But consult the manufacturer first.
- Axial capacitors in fully insulated cases (type B25856) can be mounted in any position.

10.3 Mounting

The threaded bolt on the bottom of aluminum cases with a diameter of ≤ 60 mm and a height of ≤ 160 mm may be used for attachment if vibration stress does not exceed 5 *g*. For larger dimensions and vibration of > 5 *g*, the capacitors should be mounted by clamps, rings, etc.
The EPCOS selection of mounting accessories is shown in the chapter “Mounting parts”.

Mounting with threaded bolt:

Threaded bolt	Mounting hole	Maximum torque
M8	10 mm	4 Nm
M12	14 mm	10 Nm

10.4 Terminals

For terminal bolt and nut tightening torques, refer to the individual data sheets.

The terminal torque must not act upon the ceramic. So the lead should be locked between two nuts.

10.4.1 Minimum terminal connection cross-sections in accordance with VDE / DIN 0100 part 523 and 430, group 2.

For the electrical terminals on ceramic lead-throughs only flexible leads should be used so that these lead-throughs are guarded against mechanical stress.

The outer leads to the capacitor should be dimensioned so that no heat is conducted into the component. You are advised to scale these leads so that heat is conducted away from capacitor terminals.

Multicore leads (copper)

Rated current (A)	Nom. cross-section (mm^2)
12	0.75
15	1
18	1.5
26	2.5
34	4
44	6
61	10
82	16
108	25
135	35
168	50
207	70
250	95

10.5 Grounding

Either a threaded bolt or a strap serves for grounding to VDE 0100. Grounding is omitted for single-pole and fully insulated capacitors. The layer of varnish beneath the clamp should be removed when grounding with a metal clamp.

10.6 Safety precautions

Observe appropriate safety precautions in use (self-recharging phenomena and the high energy contained in capacitors).

10.7 Positioning

Within high-power inverter circuits the capacitors usually produce the smallest portion of the total losses, and the permissible operating temperatures are low compared to power semiconductors and resistors.

A GTO chopper drive for local rail traffic can be taken as an example to illustrate the loss components (clock frequency: 250 Hz, rms current: 600 A).

Capacitors (6 × 40 μF)	losses approx. 100 W
Snubber resistor	losses approx. 1000 W
Semiconductor	losses approx. 1200 W

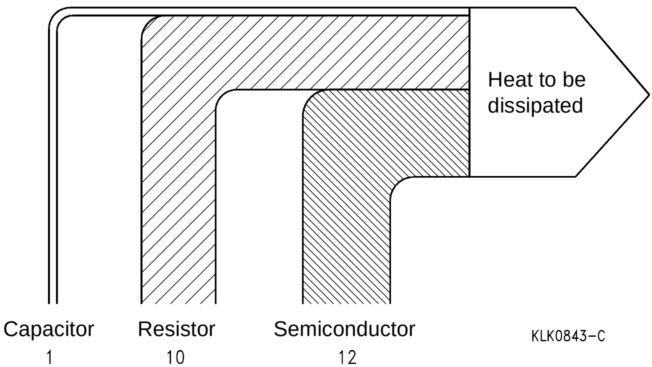

Bild 10

Portions of heat to be dissipated
of GTO chopper drive for local rail traffic

The example shows losses in a ratio of 1 : 10 : 12.

So, to make the best possible use of capacitors, technically and economically, it is advisable to supply cooling air to them first. This means that the capacitors can sustain a correspondingly higher load, and the following components will be located in an air flow that is only slightly warmed.

10.8 Soldering conditions

S+M capacitors satisfy the following test conditions to IEC 68, part 2-20:

Solderability: (275 ± 10) °C, (2 ± 0.5) s
Heat resistance: (350 ± 10) °C, 5 s

When soldering the terminals, make sure the capacitors are not damaged through excessive heat.

This means:

– Lead wires with a cross-section of > 1.5 mm^2 should not be soldered but clamped (soldering would require too much heat).
– Do not solder at spots where heat concentrates (see figure 11), otherwise there is a risk that the solder joint of the tags melts.

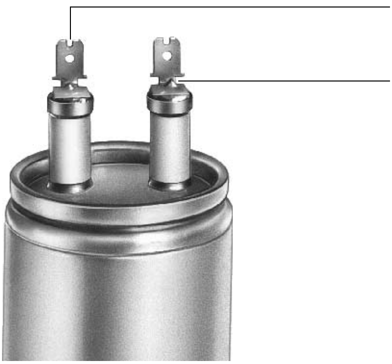

Bild 11

Where to solder

11 End of use and disposal

The materials used in capacitors for power electronics from EPCOS do not exceed the limits for chemical substances specified in the following national regulations:

– chemicals prohibition regulation,
– CFC halogen prohibition regulation.

Our capacitors for power electronics contain no means of impregnation with PCB. Refer to section 1.4 for further details of the means of impregnation used.

Capacitors without PCB for power electronics are not explicitly mentioned in the waste qualification regulations. From this it could be deduced that they do not have to be disposed of as “waste requiring special supervision”.

Because of our special commitment to and responsibility for the environment, we ask you to take every care when disposing of capacitors. We recommend that you drain the impregnation oil out of the capacitor and send it to an oil refuse depot. The emptied capacitor can then be disposed of as a grease and oil soiled item of apparatur. In any case it is advisable to consult a waste disposal facility and to find out abaout the applicable regulations in force.

12 Standards and specifications

Standards IEC 1071-1 and 2, which are identical to EN 61071-1 and 2 as well as to VDE 0560, parts 120 and 121, apply to capacitors for power electronics.

Standards IEC 831-1 and 2, which are identical to EN 60831-1 and 2 as well as to VDE 0560, parts 46 and 47, apply to capacitors for power factor correction.

Other specifications

VDE 0100	Installation of electrical power installations with rated voltages up to 1000 V	
DIN 40 011	Electrical engineering: ground, protective conductor, low-noise ground, frame, total insulation; identification on items of apparatus	
EN ISO 2899-1 resp. DIN 40 080	Sampling procedures and tables for inspection by attributes	
IEC 68	Basic environmental testing procedures	
	Part 1	General and guide
	Part 2-1	Test group A: cold
	Part 2-2	Test group B: dry heat
	Part 2-3	Test Ca: damp heat, steady state
	Part 2-6	Test Fc and guide: vibration , sinusoidal
	Part 2-13	Test group M: low air pressure
	Part 2-20	Test group T: soldering
	Part 2-21	Test group U: robustness of terminals
	Part 2-27	Test Ea and guide: shock

13 Literature

The following publications contain extra information:

- Power capacitors and their thermal ratings
- MKK – the dry power capacitor
- High-performance capacitors for low-inductance circuits
- Dry MKK capacitors for modern rail traction
- More power with PhaseCap

They can be obtained from

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