EPCOS Product Profile 2012

Film Capacitors
for Industrial Applications
Film Capacitors
for Industrial Applications

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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, EPCOS is 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 an EPCOS 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.epcos.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 the current version of the “General Terms of Delivery for Products and Services in the Electrical Industry” published by the German Electrical and Electronics Industry Association (ZVEI).

7. The trade names EPCOS, BAOKE, Alu-X, CeraDiode, CSMP, CSSP, CTVS, DeltaCap, DigiSiMic, DSSP, FormFit, MiniBlue, MiniCell, MKD, MKK, MLSC, MotorCap, PCC, PhaseCap, PhaseCube, PhaseMod, PhiCap, SIFERRIT, SIFi, SIKOREL, SilverCap, SIMDAD, SIMic, SIMID, SineFormer, SIOV, SIP5D, SIP5K, ThermoFuse, WindCap are trademarks registered or pending in Europe and in other countries. Further information will be found on the Internet at www.epcos.com/trademarks.
Introduction

Film capacitors as a reliable solution
The self-healing capability of film capacitors is one of their most important features. It protects them against cata-
strophic failures and makes them highly reliable compared
with other technologies. They also offer excellent thermal
stability. In addition, their key electrical parameters remain
constant when the voltage is changed thanks to the high
electrical stability of this technology. Low ESR values and
high \( I_{\text{rms}} \) handling capability are other important charac-
teristics of film capacitors, related to their self-heating in
operation. They are needed in applications operating with
high-frequency ripple currents.

RoHS
Directive 2002/95/EC (“RoHS”) from January 27th, 2003,
(OJ No. L 37/19 of February 13, 2003) defines the restric-
tions for hazardous substances used in electrical and elec-
tronic equipment. Article 4 (1), in force since July 1, 2006
prohibits electric light bulbs and luminaires containing lead,
mercury, cadmium, hexavalent chromium, polybrominated
biphenyls (PBB) and polybrominated diphenylethers (PBDE)
for domestic use and in electrical and electronic equip-
ment to be put on the market. This directive does not apply
to components. EPCOS nevertheless supplies products
– listed as RoHS-compatible – ready to use with electri-
cal and electronic equipment of the categories mentioned
above. As the banned substances cannot be replaced in all
applications, exemptions are granted in the RoHS Annex.
This has been amended by Directive 2005/717/EC of
25th, 2005. Due to natural impurities, a zero level of restricted sub-
stances cannot be achieved. Threshold levels had been

REACH
Regulation (EC) No 1907/2006 concerning Registration,
Evaluation, Authorization and Restriction of Chemicals
(REACH for short) has been in force since June 1, 2007.
Producers, importers and other suppliers of articles con-
taining Substances of Very High Concern (SVHC) included
in the candidate list according to article 59 (1, 10) of the
REACH Regulation in a concentration above 0.1% by
weight must provide the information that is available to
them. EPCOS is taking every effort to discontinue the use of
this SVHC as early as possible. The current status can be
found at www.epcos.com/reach.
As of today no FILM capacitor contains any substance
included in SVHC list in concentrations higher than allowed.

Halogens
Halogen free capacitors as defined according to
IEC 61249-2-21 Clause 3.1 (< 900 ppm for Cl, Br and
< 1500 ppm for Cl + Br per product weight), are available
under request.

Applicable standards
In terms of mechanical and electrical performance,
IEC 60384-2, IEC 60384-16 and IEC 60384-14 are the
sector standards for MKT, MKP and EMI suppression
 capacitors.
Capacitors designed to be used specifically in power
electronic equipment must also comply with the interna-
tional IEC 61071 standard. Its objective is to describe the
basic performance, testing, rating and safety rules of all
the capacitors used in semiconductor switching as well as
protection, filtering and energy-storage applications.
Film Capacitors for Drives

General
The function of an adjustable electrical drive is to control the speed, torque, acceleration, deceleration and direction of rotation of the motor driving a machine. Drives may be of direct current or adjustable frequency type (DC and AC drives, respectively). Because of their simplicity, ease of use, reliability and favorable cost, DC drives have been the preferred solution for industrial applications for many years. On the other hand, adjustable frequency AC motor drive controllers, frequently known as inverters, are typically more complex than DC controllers since they must perform two power-section functions: conversion from AC to DC and finally back from DC to AC. A number of different types of AC motor controllers are currently in widespread use as general purpose drives, i.e. pulse width modulated (PWM), current source input (CSI), and load commutated inverter (LCI) types. Each type offers specific benefits and characteristics, and the selection criterion is based on the final application requirements in terms of voltage and power.

Block diagram

Characteristics

<table>
<thead>
<tr>
<th>Function</th>
<th>Class</th>
<th>Type</th>
<th>Technical data</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC filtering Cx</td>
<td>MKT AC</td>
<td>B32932 ... B32936</td>
<td>305 V AC 47 nF ... 10 µF</td>
<td>+85 °C / 85% RH / 1000 h Connection in series with mains</td>
</tr>
<tr>
<td></td>
<td>X1</td>
<td>B32911 ... B32916</td>
<td>330 V AC 10 nF ... 6.8 µF</td>
<td>High pulse across the line UL/ENEC</td>
</tr>
<tr>
<td></td>
<td>X2</td>
<td>B32921 ... B32928</td>
<td>305 V AC 10 nF ... 45 µF</td>
<td>General purpose across the line UL/ENEC</td>
</tr>
<tr>
<td>EMC filtering Cy</td>
<td>Y1</td>
<td>B81123</td>
<td>250 V AC 1 nF ... 10 nF</td>
<td>Reinforced insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td></td>
<td>Y2</td>
<td>B32021 ... B32026</td>
<td>300 V AC 1 nF ... 1 µF</td>
<td>Basic insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td>DC link DC filtering Cbus</td>
<td>MKP</td>
<td>B32674 ... B32678</td>
<td>450 ... 1300 V DC 0.47 ... 200 µF</td>
<td>Very high ripple current Small size</td>
</tr>
<tr>
<td></td>
<td>MKT</td>
<td>B32520 ... B32529</td>
<td>63 ... 630 V DC 1 nF ... 220 µF</td>
<td>Up to +125 °C</td>
</tr>
<tr>
<td>DC/AC inverter: snubber, resonant Cs</td>
<td>MFP</td>
<td>B32632 ... B32634 B32686</td>
<td>250 ... 3000 V DC 1 nF ... 680 nF</td>
<td>Very high dV/dt</td>
</tr>
<tr>
<td></td>
<td>MKP</td>
<td>B32651 ... B32656 B32656S B32671L ... B32672L</td>
<td>250 ... 2000 V DC 1 nF ... 220 µF 1 nF ... 8.2 µF</td>
<td>General purpose, lead wires Strap terminals High V AC</td>
</tr>
<tr>
<td>Output filtering Cy</td>
<td>MKP</td>
<td>B32794 ... B32798</td>
<td>250 ... 400 V AC 820 nF ... 75 µF</td>
<td>Up to +105 °C Optimized AC voltage with small dimensions High ripple current</td>
</tr>
</tbody>
</table>
Film Capacitors for Uninterruptible Power Supplies

General
Uninterruptible power supplies (UPS) are designed to protect the load from any interruptions in the line, including spikes, over- and under-voltages and blackouts, by supplying the needed voltage to the output. In case of a blackout, the battery will feed the output from a few minutes to several hours depending on its size. A UPS can also be understood as a system designed to protect the load against instabilities in the power line, which is the best way of ensuring the reliability of the load over its operating life. Depending on their configuration, three major UPS topologies may be identified: off-line, line interactive and on-line.

Block diagram

Characteristics

<table>
<thead>
<tr>
<th>Function</th>
<th>Class</th>
<th>Type</th>
<th>Technical data</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC filtering $C_x$</td>
<td>X1</td>
<td>B32911 … B32916</td>
<td>330 V AC 10 nF … 6.8 µF</td>
<td>High pulse across the line UL/ENEC</td>
</tr>
<tr>
<td></td>
<td>X2</td>
<td>B32921 … B32928</td>
<td>305 V AC 10 nF … 45 µF</td>
<td>General purpose across the line UL/ENEC</td>
</tr>
<tr>
<td>EMC filtering $C_y$</td>
<td>Y1</td>
<td>B81123</td>
<td>250 V AC 1 nF … 10 nF</td>
<td>Reinforced insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td></td>
<td>Y2</td>
<td>B32021 … B32026</td>
<td>300 V AC 1 nF … 1 µF</td>
<td>Basic insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td>DC link DC filtering $C_{bus}$</td>
<td>MKP</td>
<td>B32674 … B32678</td>
<td>450 … 1300 V DC 0.47 … 200 µF</td>
<td>Very high ripple current Small size</td>
</tr>
<tr>
<td>DC/AC inverter: snubber $C_s$</td>
<td>MFP</td>
<td>B32632 … B32634</td>
<td>630 … 3000 V DC 1 … 680 nF</td>
<td>Very high dV/dt</td>
</tr>
<tr>
<td></td>
<td>MKP</td>
<td>B32651 … B32656</td>
<td>250 … 2000 V DC 1 nF … 8.2 µF</td>
<td>General purpose, lead wires Strap terminals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B32671L … B32672L</td>
<td></td>
<td>High V AC</td>
</tr>
<tr>
<td>Output filtering $C_r$</td>
<td>MKP</td>
<td>B32794 … B32798</td>
<td>250 … 400 V AC 0.82 … 75 µF</td>
<td>Up to 105 °C Optimal AC voltage with small dimensions High ripple current</td>
</tr>
</tbody>
</table>
General
Capacitors are widely used in photovoltaic systems as protecting elements for people and equipment. Film capacitors have also become a common solution in filters and more specifically in solar inverters. These are special devices that must fulfill several functions in the solar generator, assuring not only DC-AC conversion or energy storage, but also output power quality, various protection mechanisms and system checks. Additional requirements for these components, which are increasingly demanded by final customers and developers, are high efficiency and high reliability. These requirements have driven inverter development towards simpler topologies and structures, with fewer components and high modularity.

Block diagram

Characteristics

<table>
<thead>
<tr>
<th>Function</th>
<th>Class</th>
<th>Type</th>
<th>Technical data</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC filtering C_x</td>
<td>MKT AC</td>
<td>B32932 ... B32936</td>
<td>305 V AC</td>
<td>+85 °C / 85% RH / 1000 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>47 nF ... 10 µF</td>
<td>Connection in series with mains</td>
</tr>
<tr>
<td></td>
<td>X1</td>
<td>B32911 ... B32916</td>
<td>330 V AC</td>
<td>High pulse across the line UL/ENEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 nF ... 6.8 µF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X2</td>
<td>B32921 ... B32928</td>
<td>305 V AC</td>
<td>General purpose across the line UL/ENEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 nF ... 45 µF</td>
<td></td>
</tr>
<tr>
<td>EMC filtering C_y</td>
<td>Y1</td>
<td>B81123</td>
<td>250 V AC</td>
<td>Reinforced insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 ... 10 nF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y2</td>
<td>B32021 ... B32026</td>
<td>300 V AC</td>
<td>Basic insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 nF ... 1 µF</td>
<td></td>
</tr>
<tr>
<td>DC/DC converter, DC link</td>
<td>MKP</td>
<td>B32674 ... B32678</td>
<td>450 ... 1300 V DC</td>
<td>Very high ripple current</td>
</tr>
<tr>
<td>DC filtering C_{DC}, C_{BUS}</td>
<td></td>
<td>B32774 ... B32778</td>
<td>0.47 ... 200 µF</td>
<td>Small size</td>
</tr>
<tr>
<td></td>
<td>MKT</td>
<td>B32520 ... B32529</td>
<td>63 ... 630 V DC</td>
<td>Up to +125 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 nF ... 220 µF</td>
<td></td>
</tr>
<tr>
<td>DC/AC converter; snubber, resonant C_s</td>
<td>MFP</td>
<td>B32632 ... B32634</td>
<td>630 ... 3000 V DC</td>
<td>Very high dV/dt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B32686</td>
<td>1 nF ... 330 nF</td>
<td>General purpose, lead wires</td>
</tr>
<tr>
<td></td>
<td>MKP</td>
<td>B32651 ... B32656S</td>
<td>250 ... 2000 V DC</td>
<td>Strap terminals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B32656S</td>
<td>1 nF ... 8.2 µF</td>
<td>High V AC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B32671L ... B32672L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output filtering C_f</td>
<td>MKP</td>
<td>B32794 ... B32798</td>
<td>250 ... 400 V AC</td>
<td>Up to +105 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.82 ... 75 µF</td>
<td>Optimized AC voltage with small dimensions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High ripple current</td>
</tr>
</tbody>
</table>
Film Capacitors for Switch-Mode Power Supplies

**General**
A switch-mode power supply (SMPS) is a power electronic converter that basically converts the input voltage into a DC output voltage of a different magnitude. In general, most SMPS are connected to the power line, so the AC voltage coming from the line must be converted into the DC voltage needed at the input of the real DC/DC converter. That is why a rectifier is usually present at the input of any SMPS. SMPS offer higher efficiencies with more compact mechanical dimensions than other traditional DC/DC converters, which is an advantage for portable devices. However, they are more complex and may generate more electromagnetic noise – due to the switching operation of the semiconductors – which must be efficiently suppressed. Various topologies with different features (buck, boost, flyback, half-bridge, full-bridge etc.) are available depending on the required output power.

**Block diagram**

**Characteristics**

<table>
<thead>
<tr>
<th>Function</th>
<th>Class</th>
<th>Type</th>
<th>Technical data</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC filtering C&lt;sub&gt;x&lt;/sub&gt;</td>
<td>MKT</td>
<td>B32932 … B32936</td>
<td>305 V AC 47 nF ... 10 µF</td>
<td>85 °C / 85% RH / 1000 h Connection in series with mains UL/ENEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X1</td>
<td>330 V AC 10 nF ... 6.8 µF</td>
<td>High pulse across the line UL/ENEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X2</td>
<td>305 V AC 10 nF ... 45 µF</td>
<td>General purpose across the line UL/ENEC</td>
</tr>
<tr>
<td>EMC filtering C&lt;sub&gt;y&lt;/sub&gt;</td>
<td>Y1</td>
<td>B81123</td>
<td>250 V AC 1 ... 10 nF</td>
<td>Reinforced insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td></td>
<td>Y2</td>
<td>B32021 … B32026</td>
<td>300 V AC 1 nF ... 1 µF</td>
<td>Basic insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td>Power factor correction &amp; DC link DC filtering C&lt;sub&gt;dc&lt;/sub&gt;</td>
<td>MKP</td>
<td>B32671P … B32673P</td>
<td>450 ... 630 V DC 10 nF ... 2.2 µF</td>
<td>Small size High ripple current</td>
</tr>
<tr>
<td></td>
<td>MKT</td>
<td>B32520 … B32529</td>
<td>63 ... 630 V DC 1 nF ... 220 µF</td>
<td>Up to +125 °C Small size for 450 V DC</td>
</tr>
<tr>
<td>DC/DC converter: snubber, resonant C&lt;sub&gt;s&lt;/sub&gt;</td>
<td>MKP</td>
<td>B32651 … B32656</td>
<td>250 ... 2000 V DC 1 nF ... 8.2 µF</td>
<td>High AC voltage for B3267*L, miniaturized High RMS current</td>
</tr>
</tbody>
</table>

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Please read Important notes on page 4 and Cautions and warnings on page 29.
Film Capacitors for Electrical Welding Equipment

General
Electrical welding equipment uses electricity in order to generate the heat needed for joining metal parts. In the past, welding power supplies were based on large and heavy metal transformers that operated at 50 or 60 Hz and were relatively inefficient. Advanced power supplies based on inverter technology have become increasingly popular and have changed the design and capability of modern welding equipment. This new equipment, operating with high frequency signals, is much more efficient and can be even more compact and lightweight thanks to design optimization, where the use of film capacitors can play a key role.

Block diagram

| Characteristics |
|-----------------|-----------------|-----------------|-----------------|
| Function         | Class | Type | Technical data | Features |
| EMC filtering $C_x$ | X1    | B32911 ... B32916 | 330 V AC 10 nF ... 6.8 µF | High pulse across the line UL/ENEC |
|                  | X2    | B32921 ... B32928 | 305 V AC 10 nF ... 45 µF | General purpose across the line UL/ENEC |
| EMC filtering $C_y$ | Y1    | B81123 | 250 V AC 1 nF ... 10 nF | Reinforced insulation line to ground UL/ENEC |
|                  | Y2    | B32021 ... B32026 | 300 V AC 1 nF ... 1 µF | Basic insulation line to ground UL/ENEC |
| DC link          | MKP   | B32674 ... B32678 | 450 ... 1300 V DC 0.47 ... 200 µF | Very high ripple current Small size |
| DC filtering $C_{bus}$ | MFP | B32686 | 1 ... 330 nF 630 ... 3000 V DC | Very high dV/dt |
| DC/AC converter: snubber, resonant $C_s$ | MKP | B32651 ... B32656 | 250 ... 2000 V DC 1 nF ... 8.2 µF | General purpose, lead wires Strap terminals |
| Filtering in output rectifier $C_r$ | MKP | B32674 ... B32678 | 450 ... 1050 V DC 0.47 ... 60 µF | Up to +105 °C Optimized AC voltage with small dimensions |

Please read Important notes on page 4 and Cautions and warnings on page 29.
Film Capacitors for Lighting:
Electronic Ballast

General
New designs in lighting include advanced HID devices and intelligent ballast. The special features of these designs may be summarized as offering very high efficiency, operation with a wide range of input voltages (85-305 V AC) and long-term reliability. The demand for high reliability has led to the widespread use of film capacitors for these designs. Film capacitors are useful not only in PFC and DC/DC converters, but also in LC filters, as snubbers. They also protect the circuit board against overload and short circuits, open loops in any stage and input overvoltages. EMC filter capacitors are ideally suited for this purpose.

Block diagram

Characteristics

<table>
<thead>
<tr>
<th>Function</th>
<th>Class</th>
<th>Type</th>
<th>Technical data</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC filtering Cx</td>
<td>X2</td>
<td>B32921 ... B32928</td>
<td>305 V AC 10 nF ... 45 µF</td>
<td>General purpose across the line UL/ENEC</td>
</tr>
<tr>
<td>EMC filtering Cy</td>
<td>Y2</td>
<td>B32021 ... B32026</td>
<td>300 V AC 1 nF ... 1 µF</td>
<td>Basic insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td>Power factor correction &amp; DC link</td>
<td>MKP</td>
<td>B32671P ... B32673P</td>
<td>450 ... 630 V DC 10 nF ... 2.2 µF</td>
<td>Small size, High ripple current</td>
</tr>
<tr>
<td>DC filtering Cdc</td>
<td>MKT</td>
<td>B32520 ... B32529</td>
<td>63 ... 630 V DC 1 nF ... 220 µF</td>
<td>Up to +125 °C, Small size for 450 V DC</td>
</tr>
<tr>
<td>DC/AC inverter: snubber, blocking, resonant,</td>
<td>MFP</td>
<td>B32632 ... B32634</td>
<td>250 ... 3000 V DC 1 nF ... 8.2 µF</td>
<td>Very high dV/dt for HID</td>
</tr>
<tr>
<td>striking Cz</td>
<td>MKP</td>
<td>B32651 ... B32656</td>
<td>160 ... 1000 V AC 1 nF ... 8.2 µF</td>
<td>High RMS current, lead wires, Strap terminals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B32656S B32671L ... B32672L</td>
<td></td>
<td>High AC voltage, miniaturized</td>
</tr>
</tbody>
</table>
Film Capacitors for Lighting: LEDs

**General**
LEDs have become an important light source for vehicles, traffic signals, control lighting, street lighting and even in general lighting applications. In addition to their miniature size LED systems offer a long list of impressive features: exceptional lifetime of up to 100 000 hours, shock-resistance, and high efficiency, not to mention the fact that they emit zero UV radiation, are free of heavy metals, and offer quick start and dimming capabilities. Film capacitors offer the high reliability and operating life required in LED applications.

### Block diagram
![Block diagram of LED system](image)

### Characteristics

<table>
<thead>
<tr>
<th>Function</th>
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<tr>
<td>EMC filtering</td>
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<td>B32921 ... B32928</td>
<td>305 V AC 10 nF ... 45 µF</td>
<td>General purpose across the line UL/ENEC</td>
</tr>
<tr>
<td>EMC filtering</td>
<td>Y2</td>
<td>B32021 ... B32026</td>
<td>300 V AC 1 nF ... 1 µF</td>
<td>Basic insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td>Power factor correction &amp; DC link</td>
<td>MKP</td>
<td>B32671P ... B32673P</td>
<td>450 ... 630 V DC 10 nF ... 2.2 µF</td>
<td>Small size</td>
</tr>
<tr>
<td>DC filtering</td>
<td>MKT</td>
<td>B32520 ... B32529</td>
<td>63 ... 630 V DC 1 nF ... 220 µF</td>
<td>High ripple current</td>
</tr>
<tr>
<td>DC/DC converter: snubber resonant</td>
<td>MKP</td>
<td>B32651 ... B32656</td>
<td>250 ... 2000 V DC 1 nF ... 8.2 µF</td>
<td>High RMS current, lead wires, strap terminals</td>
</tr>
<tr>
<td>COUT</td>
<td>MKP</td>
<td>B32774 ... B32778</td>
<td>63 ... 1300 V DC 0.47 ... 200 µF</td>
<td>Small size</td>
</tr>
<tr>
<td></td>
<td>MKT</td>
<td>B32520 ... B32529</td>
<td>63 ... 630 V DC 1 nF ... 220 µF</td>
<td>Up to +125 ºC, uncoated capacitor</td>
</tr>
</tbody>
</table>

**Film Capacitors for Lighting: LEDs**

LEDs have become an important light source for vehicles, traffic signals, control lighting, street lighting and even in general lighting applications. In addition to their miniature size LED systems offer a long list of impressive features: exceptional lifetime of up to 100 000 hours, shock-resistance, and high efficiency, not to mention the fact that they emit zero UV radiation, are free of heavy metals, and offer quick start and dimming capabilities. Film capacitors offer the high reliability and operating life required in LED applications.

### Block diagram
![Block diagram of LED system](image)

### Characteristics

<table>
<thead>
<tr>
<th>Function</th>
<th>Class</th>
<th>Type</th>
<th>Technical data</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC filtering</td>
<td>X2</td>
<td>B32921 ... B32928</td>
<td>305 V AC 10 nF ... 45 µF</td>
<td>General purpose across the line UL/ENEC</td>
</tr>
<tr>
<td>EMC filtering</td>
<td>Y2</td>
<td>B32021 ... B32026</td>
<td>300 V AC 1 nF ... 1 µF</td>
<td>Basic insulation line to ground UL/ENEC</td>
</tr>
<tr>
<td>Power factor correction &amp; DC link</td>
<td>MKP</td>
<td>B32671P ... B32673P</td>
<td>450 ... 630 V DC 10 nF ... 2.2 µF</td>
<td>Small size</td>
</tr>
<tr>
<td>DC filtering</td>
<td>MKT</td>
<td>B32520 ... B32529</td>
<td>63 ... 630 V DC 1 nF ... 220 µF</td>
<td>High ripple current</td>
</tr>
<tr>
<td>DC/DC converter: snubber resonant</td>
<td>MKP</td>
<td>B32651 ... B32656</td>
<td>250 ... 2000 V DC 1 nF ... 8.2 µF</td>
<td>High RMS current, lead wires, strap terminals</td>
</tr>
<tr>
<td>COUT</td>
<td>MKP</td>
<td>B32774 ... B32778</td>
<td>63 ... 1300 V DC 0.47 ... 200 µF</td>
<td>Small size</td>
</tr>
<tr>
<td></td>
<td>MKT</td>
<td>B32520 ... B32529</td>
<td>63 ... 630 V DC 1 nF ... 220 µF</td>
<td>Up to +125 ºC, uncoated capacitor</td>
</tr>
</tbody>
</table>
Film Capacitors for Power Supplies in Smart Energy Meters

**General**
In recent years, the power meter market has experienced huge growth due to the increased awareness of the need to reduce energy consumption. Power meters are normally situated outdoors, therefore likely to be exposed to harsh climatic conditions (high humidity levels, elevated temperatures which may vary hour by hour). As a consequence, they require components that are highly reliable, stable and have a long lifetime, allowing zero maintenance throughout their operation. Key components used in a typical power meter include metallized film capacitors, which form part of a “capacitive power supply” mounted in series with the power network. When subjected to harsh climatic conditions, capacitance stability is essential for the long-term operation of the power meter.

**Block diagram**

![Block diagram](image)

**Characteristics**

<table>
<thead>
<tr>
<th>Function</th>
<th>Class</th>
<th>Type</th>
<th>Technical data</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage divider</td>
<td>MKP</td>
<td>B32651 ... B32656</td>
<td>200 ... 250 V AC 33 nF ... 4.7 µF</td>
<td>Connection in series with mains, see note High RMS vs. frequency High dV/dt</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Note: Overvoltage protection is recommended as it is not a UL / ENEC approved device</td>
</tr>
<tr>
<td></td>
<td>MKT AC</td>
<td>B32932 ... B32936</td>
<td>305 V AC 47 nF ... 10 µF</td>
<td>Connection in series with mains High capacitance stability under +85 °C / 85% RH / AC voltage. UL / ENEC approval for C ≤ 2.2 µF</td>
</tr>
</tbody>
</table>

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### Film Capacitors Overview

**Characteristics**

<table>
<thead>
<tr>
<th>Series</th>
<th>Technical data</th>
<th>Features</th>
<th>Ordering code/ Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film capacitors (medium power)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X2</td>
<td></td>
<td><strong>$V_{\text{rms}}$:</strong> 305 V AC</td>
<td>X2 (2 500 V) class for interference suppression and EMC &lt;br&gt;Approved acc. to international standards &lt;br&gt;Lead spacing 10 … 52.5 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>$C_r$:</strong> 10 nF … 45 µF</td>
<td></td>
</tr>
<tr>
<td>X1</td>
<td></td>
<td><strong>$V_{\text{rms}}$:</strong> 330 V AC</td>
<td>X1 (4 000 V) class for interference suppression and EMC &lt;br&gt;Approved acc. to international standards &lt;br&gt;Across the line connection &lt;br&gt;Lead spacing 10 … 37.5 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>$C_r$:</strong> 10 nF … 6.8 µF</td>
<td></td>
</tr>
<tr>
<td>Y2</td>
<td></td>
<td><strong>$V_{\text{rms}}$:</strong> 300 V AC</td>
<td>Y2 (5 000 V) class for interference suppression and EMC &lt;br&gt;Approved acc. to international standards &lt;br&gt;Line to ground connection &lt;br&gt;Lead spacing 10 … 37.5 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>$C_r$:</strong> 1 nF … 1 µF</td>
<td></td>
</tr>
<tr>
<td>Y1</td>
<td></td>
<td><strong>$V_{\text{rms}}$:</strong> 250 V AC</td>
<td>Y1 (8 000 V) class for interference suppression and EMC &lt;br&gt;Approved acc. to international standards &lt;br&gt;Line to ground connection &lt;br&gt;Lead spacing 15 … 22.5 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>$C_r$:</strong> 1 … 10 nF</td>
<td></td>
</tr>
<tr>
<td>MKT AC heavy duty</td>
<td></td>
<td><strong>$V_{\text{rms}}$:</strong> 305 V AC</td>
<td>+85 °C/85% RH/1 000 h/240 V AC &lt;br&gt;X2 safety class per UL/IEC (C ≤ 2.2 µF) &lt;br&gt;High stability on capacitance</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>$C_r$:</strong> 47 nF … 10 µF</td>
<td></td>
</tr>
<tr>
<td>MKP AC filtering</td>
<td></td>
<td><strong>$V_{\text{rms}}$:</strong> 250 … 400 V AC</td>
<td>Operating temperature up to +105 °C &lt;br&gt;Output AC filtering &lt;br&gt;Optimized AC voltage performance with small dimensions &lt;br&gt;High ripple current/frequency capability</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>$C_r$:</strong> 0.82 … 75 µF</td>
<td></td>
</tr>
</tbody>
</table>
### Characteristics

<table>
<thead>
<tr>
<th>Series</th>
<th>Technical data</th>
<th>Features</th>
<th>Ordering code/ Type</th>
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<tbody>
<tr>
<td><strong>Film capacitors (medium power)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MKP DC link &amp; DC filtering</strong></td>
<td>( V_r: 450 \ldots 1300 \text{ V DC} ) ( C_r: 1.5 \ldots 200 \mu F )</td>
<td>( V_r: 450 \ldots 1300 \text{ V DC} ) ( C_r: 1.5 \ldots 200 \mu F )</td>
<td>High-density series, compact Operating temperature up to (+105 \degree \text{ C}) Service life 100 000 h at (1.0 \cdot V_r, +70 \degree \text{ C}) High mechanical stability due to 4-pin terminals 2- and 4-pin versions Lead spacing 27.5 \ldots 52.5 \text{ mm}</td>
</tr>
<tr>
<td></td>
<td>( V_r: 300 \ldots 875 \text{ V DC} ) ( C_r: 0.47 \ldots 60 \mu F )</td>
<td>( V_r: 300 \ldots 875 \text{ V DC} ) ( C_r: 0.47 \ldots 60 \mu F )</td>
<td>High power: higher RMS current capability than B3277x Operating temperature up to (+105 \degree \text{ C}) Service life 100 000 h at (1.0 \cdot V_r, +70 \degree \text{ C}) High mechanical stability due to 4-pin terminals 2- and 4-pin versions Lead spacing 27.5 \ldots 52.5 \text{ mm}</td>
</tr>
<tr>
<td><strong>MKT DC link &amp; DC filtering</strong></td>
<td>( V_r: 63 \ldots 630 \text{ V DC} ) ( C_r: 1 \text{ nF} \ldots 220 \mu F )</td>
<td>( V_r: 63 \ldots 630 \text{ V DC} ) ( C_r: 1 \text{ nF} \ldots 220 \mu F )</td>
<td>Low voltage DC-link applications Operating temperature up to (+125 \degree \text{ C}) Service life 200 000 h at (1.0 \cdot V_r, +70 \degree \text{ C})</td>
</tr>
<tr>
<td><strong>MKP general purpose</strong></td>
<td>( V_r: 250 \ldots 2000 \text{ V DC} ) ( C_r: 1 \text{ nF} \ldots 8.2 \mu F )</td>
<td>( V_r: 250 \ldots 2000 \text{ V DC} ) ( C_r: 1 \text{ nF} \ldots 8.2 \mu F )</td>
<td>For snubbing, resonant and switching B3267xL for high frequency AC loads and pulses Operating temperature up to (+105 \degree \text{ C}) Possibility of AC and/or DC operation High dv/dt and RMS current capability Lead spacing 10 \ldots 37.5 \text{ mm}</td>
</tr>
<tr>
<td><strong>MKP PFC (power factor correction)</strong></td>
<td>( V_r: 450 \ldots 630 \text{ V DC} ) ( C_r: 0.010 \ldots 2.2 \mu F )</td>
<td>( V_r: 450 \ldots 630 \text{ V DC} ) ( C_r: 0.010 \ldots 2.2 \mu F )</td>
<td>Operating temperature up to (+125 \degree \text{ C}) Specially designed for PFC stage Lead spacing 10 \ldots 22.5 \text{ mm}</td>
</tr>
<tr>
<td></td>
<td>( V_r: 450 \ldots 630 \text{ V DC} ) ( C_r: 0.068 \ldots 2.2 \mu F )</td>
<td>( V_r: 450 \ldots 630 \text{ V DC} ) ( C_r: 0.068 \ldots 2.2 \mu F )</td>
<td>Operating temperature up to (+125 \degree \text{ C}) Specially designed for PFC stage @ 450 \ldots 630 \text{ VDC}</td>
</tr>
</tbody>
</table>
# Film Capacitors Overview

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Technical data</th>
<th>Features</th>
<th>Ordering code/ Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Film capacitors (medium power)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **MFP** | $V_r$: 330 ... 3000 V DC  
$C_r$: 1 ... 33 nF | For snubbering and resonant  
Very high $dV/dt$, frequency for MFP technology  
Operating temperature up to +110 °C  
Lead spacing 15 ... 37.5 mm | B32632 ... B32634 dipped  
B32686A boxed |
| **MKP snubber** | $V_r$: 850 ... 2000 V DC  
$C_r$: 0.047 ... 3.3 µF | For snubbering and resonant  
Strap terminals for direct IGBT mounting  
Operating temperature up to +110 °C  
Service life 200 000 h @ rated voltage | B32666S |
| **MFP snubber** | $V_r$: 1000 ... 2000 V DC  
$C_r$: 22 ... 680 nF | For snubbering and resonant  
Very high $dV/dt$ and frequency for MFP technology  
Strap terminals for direct IGBT mounting  
Operating temperature up to +105 °C  
Service life 200 000 h @ rated voltage | B32686S |
| **MKT uncoated**  
(Silvercap) | $V_r$: 63 ... 630 V DC  
$C_r$: 1 nF ... 33 µF | Operating temperature up to +125 °C  
High $dV/dt$  
Miniaturized versions  
Lead spacing 7.5 ... 27.5 mm | B32560 ... B32564  
B32572 ... B32573 |
Film Capacitors Functions

**EMC filtering**
As a rule, across-the-line and line-to ground capacitors are used in this filtering stage. In most cases these must be X2 and Y2 approved capacitors in accordance with international regulations.

The Y2 capacitor series B32021 … B32026 has capacitance values up to 1 μF at a lead spacing of 37.5 mm. The B32921 … B32928 series of compact high-performance capacitors is available for X2 capacitor requirements up to 45 μF.

In cases of higher voltage capability or reinforced insulation, X1 (B32911 … B32916) or Y1 (B81123) may be required.

The corresponding international approvals to the EMI suppression capacitor standards (IEC 60384-14, EN 132400, UL 1414, UL 1283, UL60384-14, CSA 22.2 No.1 and CSA 22.2 No.8) have been granted to all these series by the leading International Certification Institutes (VDE, UL).

**DC link**
Capacitors in the DC link module are used to boost the DC voltage after the AC/DC converter by supplying high current peaks to the load when required.

In many cases, plastic film dielectrics are used in parallel with aluminum electrolytic capacitors, as DC filters can filter/ supply current at higher frequencies thanks to their higher current capability and lower parasitic inductance. In other cases, film capacitors are used in a DC-link capacitor bank to satisfy higher reliability requirements.

A wide range of MKP capacitors is offered in various operating voltages (High Density B32774 … B32778 and High Power B32674 … B32678).

These series cover a range of capacitance values up to 200 μF (lead spacing 27.5 … 52.5 mm). They also feature very low ESR, high RMS current capability and continuous operating voltages from 450 to 1300 V DC. They can function at a maximum operating temperature of up to 105 °C.

MKT capacitors (B32529 … B32529) are offered either for a lower range of voltages (up to 630 V DC) or a high temperature range (up to +125 °C), also featuring a higher capacitance (up to 220 μF) compared to MKP capacitors.

**Power factor correction (PFC)**
PFC modules boost the DC voltage after the rectifier and compensate the lagging reactive power generated in the SMPS. Capacitors used in this part of the circuit must withstand a continuous DC voltage with a superimposed high-frequency ripple voltage. This must also be considered when designing the capacitor in order to avoid its overloading during operation.

In addition to the general-purpose MKT series, B32520 … B32529 or its powder-dipped version B32591 … B32594, the polypropylene B32671Z … B32673Z series is designed specifically to meet the requirements of this application. They ensure excellent performance while handling signals with high frequency components. Thanks to a maximum operating temperature of +110 °C, this series can withstand the toughest operating conditions of any SMPS.

The new MKP series B32671P … B32673P (450 … 630 V DC, up to 2.2 μF) specifically designed for switch-mode power supplies (SMPS) offers very small dimensions, a high ripple current and reduced acoustic noise emission.

In case of a higher capacitance or voltage range, the B32774 … B32778 (High Density) and B32674 … B32678 (High Power) series can be used for this application.

**DC-DC converters**
The capacitors used in DC-DC converters may have different current requirements depending on the topology used. Buck/ boost converters do not require such a high current/ frequency than capacitors in flyback or resonant converters.

If the current/ frequency requirement is not high, MKT capacitors (B32529 … B32526) with a voltage of up to 630 V DC, or MKP capacitors (B32774 … B32778) with a higher voltage and I_{RMS} current capability (up to 1300 V DC), both with high capacitance per volume, may be used.

Both high power series B32671Z … B32673Z (up to 2.2 μF) and B32674 … B32678 (up to 60 μF) offer a higher current for a given frequency.

For the highest current capability and pulse handling capability, snubber/ resonant capacitors should be used. They are described below.
Snubber/ resonant
Snubber capacitors are connected in parallel with semiconductor components in order to attenuate high voltage peaks produced by their high-frequency switching operations. So the snubber function can be integrated in various modules: DC-DC converters, PFC and inverters modules.

Resonant capacitors must withstand a continuous AC voltage at a high frequency, typically with a sinusoidal waveform and some capability to withstand overvoltages.

For both snubber and resonant functions, the thermal analysis and pulse handling capability of these capacitors are the key parameters to be considered. The best performance for these applications is offered by MKP capacitors from the B32651 … B32656 series: they feature a high IRMS current, a very good self-healing characteristic and a wide range of terminals (through-hole and strap terminals for screwing to IGBTs). B32671L … B32672L also offer excellent AC voltage capability.

For higher pulse handling capability, the B32632 … B32634 and B32686S series can withstand dv/dt values up to 20 000 V/μs, very high IRMS currents and frequencies exceeding 100 kHz.

AC output filtering
The basic purpose of output filters is to protect the load connected to the output by filtering the RF components coming from the inverter and to withstand the current peaks caused by pulses of rapidly changing voltages. The B32794 … B32798 series covers a capacitance range up to 75 μF, or rated voltages of up to 400 V AC.

If a higher pulse handling capability is required, the B32651 … B32656 series offers dv/dt values up to 8000 V/μs, with better self-heating behaviour at high frequencies.

Filtering in output rectifiers
An output rectifier is basically a half-wave rectifier. It converts the AC voltage (with the new frequency after the inverter) into a DC voltage. The positive semi-cycle is then used to carry out the welding process. The RF components are suppressed by the capacitor included in the output rectifier.

EPCOS offers the B32674 … B32678 high power series and the new B32794 … B32798 series with a wide range of voltages (250 Vrms … 400 Vrms, or 630 V DC to 1050 V DC) and capacitances up to 75 μF for this application.

Alternatively, the B32651 … B32656 series offers higher current capability per uF, with capacitance values of up to 8.2 μF at a lead spacing of 37.5 mm and rated voltages of up to 2000 V DC; it also has excellent characteristics for the requirements of this application, including very high dv/dt values (up to 8000 V/μs) and good thermal behavior (very low self-heating when high-frequency AC voltages are applied).

Capacitive power supplies (voltage dividers)
This application requires series connection of the capacitor to the line and extremely high demanding capacitance stability against temperature and humidity, conditions for which the typical miniaturised X2 film capacitors (like for example B3292”C/D series) are not suitable.

A new series of MKT film capacitors for AC applications (B32931 … B32936 Heavy Duty series) has been developed in order to fulfill the high demands required by power meters.

This series offers high durability and very low capacitance drift. Even after being subjected to 1000 hours of tests at +85 °C / 85% RH and 240 V AC, the maximum capacitance change of these components is less than 10%. The B32931 … B32936 series covers a capacitance range from 0.047 to 10 μF and is designed for a nominal voltage of 305 V AC. The maximum operating temperature of these capacitors is +105 °C. In addition, capacitance values up to and including 2.2 μF are certified as X2 capacitors.

This series fits perfectly with the new requirements of the market and, in summary, offers the following advantages:
- Suitable for high-humidity environments
- High capacitance stability under harsh conditions
- No need to over-dimension the components in the circuit
- Significantly reduced volume compared to other reliable solutions
- Approved according to the basic standard for capacitors IEC/UL 60384-14 (up to 2.2 μF)
## Overview

### Function

**Bypass/decoupling/smoothing**
The capacitor acts as a low-pass filter
- Preventing the transmission of AC voltages in both directions
- Suppressing fast transient changes

**DC link/energy storage**
The capacitor stores a charge and then releases it in a short high-energy pulse.

### Series

<table>
<thead>
<tr>
<th>Series</th>
<th>Use</th>
</tr>
</thead>
</table>
| B32520 … B32529 1 nF … 220 μF 63 ... 450 V DC Lead spacing 5 ... 37.5 mm | Dielectric: Polyester
Low voltage applications
Up to +125 °C
4 pin upon request |
| B32774 ... B32778 1.5 ... 200 μF 450 ... 1300 V DC Lead spacing 27.5 ... 52.5 mm | Dielectric: Polyester
High density of cap per volume
Up to +105 °C
2 and 4 pin versions |
| B32674 ... B32778 0.47 ... 60 μF 450 ... 1050 V DC Lead spacing 27.5 ... 52.5 mm | Dielectric: Polypropylene
High I_{RMS} vs. frequency
Up to +105 °C
2 and 4 pin versions |
| B32671Z ... B32673Z 0.01 ... 2.2 μF 450 ... 630 V DC Lead spacing 10 ... 22.5 mm | Dielectric: Polypropylene
High AC voltage capability
Up to +125 °C
For PFC modules |
| B32651 ... B32656 1 nF ... 8.2 μF 250 ... 2000 V DC Lead spacing 10 ... 37.5 mm | Dielectric: Polypropylene
High I_{RMS} vs. frequency
2 pin and strap terminals
4 pin upon request |
| B32671L ... B32672L 1 nF ... 1 μF 160 ... 900 V AC Lead spacing 10 ... 37.5 mm | Dielectric: Polypropylene
Miniaturized
Up to +125 °C
High AC voltage capability
High I_{RMS} vs. frequency
High dv/dt |
| B32632 ... B32634 0.47 ... 330 nF 630 ... 3000 V DC Lead spacing 15 ... 27.5 mm | Dielectric: Polypropylene
Metal foil technology (MFP)
Very high dv/dt
Powder-dipped |
| B32686 22 ... 680 nF 1000 ... 2000 V DC Lead spacing 37.5 mm | Dielectric: Polypropylene
Metal foil technology (MFP)
Very high dv/dt
2 pin and strap terminals |

### Diagrams

- Bypass/decoupling/smoothing
- DC link/energy storage
- Snubbering/resonant

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Please read Important notes on page 4 and Cautions and warnings on page 29.
# Film Capacitors Functions

## Overview

<table>
<thead>
<tr>
<th>Function</th>
<th>Series</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blocking/ coupling</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| The capacitor acts as a high-pass filter | B32520 … B32529 | Dielectric: Polyester  
|                            | 1 nF … 220 µF | General purpose AC or DC  
|                            | 63 … 630 V DC | High capacitance stability  
|                            | 40 … 200 V AC | Up to 125 °C                  |
|                            | Lead spacing 5 … 37.5 mm |                                          |
|                            |                      |                                          |
|                            | B32651 … B32656 | Dielectric: Polypropylene  
|                            | 1 nF … 8.2 µF | General purpose AC or DC  
|                            | 250 … 2000 V DC | High capacitance stability  
|                            | 160 … 700 V AC | High RMS vs. frequency  
|                            | Lead spacing 10 … 37.5 mm | High dv/dt  |
| **Voltage divider**       |                      |                                          |
| The capacitor C1 works as a voltage divider without thermal losses. | B32932 … B32936 | Dielectric: Polyester  
|                            | 47 nF … 10 µF | Internal serial connection  
|                            | 305 V AC | High capacitance stability under  
|                            | Lead spacing 15 … 37.5 mm | 85 °C / 85% RH / AC voltage.  
|                            |                      | X2 safety class (C ≤ 2.2 µF ) per  
|                            |                      | UL/IEC  |
|                            | B32652 … B32654 | Dielectric: Polypropylene  
|                            | 33 nF … 3.3 µF | High capacitance stability under  
|                            | 400 … 630 V DC | AC voltage.  
|                            | 200 … 250 V AC | High RMS vs. frequency  
|                            | Lead spacing 15 … 27.5 mm | High dv/dt  |
| **EMC filtering/ EMI suppression** | B32921 … B32928 | X2 (2500 V) class for interference  
| A capacitor/ resistor network on the input of a device supresses external noise pulses that could damage its components | 10 nF … 45 µF | suppression and EMC  
|                            | 305 V AC | Approved to international standards  
|                            | Lead spacing 10 … 52.5 mm | Across the line connection  |
|                            |                      | X1 (4000 V) class for interference  
|                            |                      | suppression and EMC.  
|                            |                      | Approved to international standards  
|                            |                      | Across the line connection  |
|                            | B32911 … B32916 | Y2 (5000 V) class for interference  
|                            | 10 nF … 6.8 µF | suppression and EMC  
|                            | 330 V AC | Approved to international standards  
|                            | Lead spacing 10 … 37.5 mm | Line to ground connection  |
|                            |                      | Y1 (8000 V) class for interference  
|                            |                      | suppression and EMC  
|                            |                      | Approved to international standards  
|                            |                      | Line to ground connection  |
|                            | B81123 | X1 (4000 V) class for interference  
|                            | 1 … 10 nF | suppression and EMC  
|                            | 250 V AC | Approved to international standards  
|                            | Lead spacing 15 … 22.5 mm | Line to ground connection  |
## Overview

<table>
<thead>
<tr>
<th>Function</th>
<th>Series</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output filtering at AC operation</strong></td>
<td>B32794 … B32798</td>
<td>Dielectric: Polypropylene</td>
</tr>
<tr>
<td>The capacitor under AC voltage operation acts as a low-pass filter, attenuating the higher frequency harmonics.</td>
<td>0.82 … 75 µF</td>
<td>Optimized AC voltage with small dimensions</td>
</tr>
<tr>
<td></td>
<td>250 … 400 V AC</td>
<td>High IRMS vs. frequency</td>
</tr>
<tr>
<td></td>
<td>Lead spacing 27.5 … 52.5 mm</td>
<td>Up to 105 ºC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 and 4 pin versions</td>
</tr>
<tr>
<td></td>
<td>B32651 … B32656</td>
<td>Dielectric: Polypropylene</td>
</tr>
<tr>
<td></td>
<td>1 nF … 8.2 µF</td>
<td>General purpose AC or DC</td>
</tr>
<tr>
<td></td>
<td>250 … 2000 V DC</td>
<td>High capacitance stability</td>
</tr>
<tr>
<td></td>
<td>160 … 700 V AC</td>
<td>High RMS vs. frequency</td>
</tr>
<tr>
<td></td>
<td>Lead spacing 10 … 37.5 mm</td>
<td>High dv/dt</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Flexibility as a broadliner: Not all the product range and encapsulation options are shown in the above table: Naked (B3256*), powder-dipped (B3261*, B3251*) and axial versions (B32669, B32231, B32232) of these products can be found on www.epcos.com as well as the Film Capacitors Data Book.
General Technical Information

**Self healing**
The most important reliability feature of film capacitors is their self-healing capability, i.e. their ability to clear faults (such as pores or impurities in the film) under the influence of a high voltage.

The metal coatings, vacuum-deposited directly onto the plastic film, are only 20 ... 50 nm thick. If the dielectric breakdown field strength is exceeded locally at a weak point, a dielectric breakdown occurs. The high temperatures reached in the breakdown channel (up to 6000 K) transform the dielectric into a highly compressed plasma that forces its way out. The thin metal coating in the vicinity of the channel is totally evaporated by interaction with the plasma so that it escapes from the breakdown channel. The rapid expansion of the plasma causes it to cool after a few microseconds, thus quenching the discharge before a greater voltage drop takes place. The insulated region resulting around the former faulty area will cause the capacitor to regain its full operational ability.

It should be noted that the voltage levels needed to activate the self-healing mechanism are far above nominal voltages: this is a safety feature designed to act when the capacitors are operated out of their rated conditions.

**Thermal analysis**
The ability of a capacitor to withstand a continuous (sinusoidal) alternating voltage $V_{\text{RMS}}$ or alternating current $I_{\text{RMS}}$ is a function of the frequency and is limited by different factors. Across the whole frequency range, three regions can be identified in terms of the limiting factor for the $V_{\text{RMS}}$ voltage level admissible for the capacitor: they go from a regime where the voltage is limited by the corona discharge (A) to a range where it is limited by the peak current admissible for the contacting part of the capacitor (C). In between, there is a wide range of frequencies in which the maximum permissible voltage (i.e. current) is limited by the maximum admissible self-heating of the capacitor (B).

Our area of interest is therefore region B, which is limited by thermal dissipation. This means that at any operating point ($f$, $I_{\text{RMS}}$, sine wave) of the curve, the self-heating will be around 15 °C. The sum of this self-heating ($\Delta T$) in the capacitor and the ambient temperature ($T_a$) around the capacitor induced by other components will give the total temperature of the capacitor: capacitor temperature $T = T_a + \Delta T$. This temperature should be used in further calculations of the maximum operating voltage and operating life.
How to estimate self-heating in region A

In region A, the AC voltage is limited by corona discharge, so the self-heating is negligible, especially in MKP products. To estimate the $I_{\text{rms}}$ in region (A) that would cause a self-heating of 15 °C, we could extend the curve of region (B) towards region A (red line). So the values in the figure ($f_1$, $I_{\text{ref}1}$, sinusoidal) would cause a self-heating of 15 °C. Then under $I_1$ (sinusoidal), the expected self-heating could be estimated from:

$$\Delta T = \left( \frac{I_1}{I_{\text{ref}1}} \right)^2 \cdot 15$$

What to do in case of a non-sinusoidal waveform:

First, it is necessary to estimate the contribution from the main harmonics by performing a Fourier decomposition. Assuming for example that three main harmonics are obtained:

- $x_1$: ($f_1$, $I_1$) operating point, then $I_{\text{ref}1}$ can be obtained from the curve
- $x_2$: ($f_2$, $I_2$): operating point, then $I_{\text{ref}2}$ can be obtained from the curve
- $x_3$: ($f_3$, $I_3$): operating point, then $I_{\text{ref}3}$ can be obtained from the curve

We know that the curve was calculated for 15 °C. The maximum self-heating of the capacitor over the ambient temperature ($T_A$) induced by other components would be:

$$\Delta T = \left( \frac{I_{\text{ref}1}}{I_1} \right)^2 \cdot 15 + \left( \frac{I_{\text{ref}2}}{I_2} \right)^2 \cdot 15 + \left( \frac{I_{\text{ref}3}}{I_3} \right)^2 \cdot 15$$

The total self-heating ($\Delta T$) plus the ambient temperature ($T_A$) result in the capacitor temperature, which must be lower than the maximum operating temperature stated in the corresponding data sheet.

In any case, a real test using thermocouples on the surface of the capacitor is strongly recommended. The thermocouples should be placed on the center of the case surface, as shown in the following figure (an unconnected dummy capacitor is used to estimate $T_A$):

Example of the maximum permissible $V_{\text{rms}}$ vs. frequency $f$ for a sinusoidal waveform.

Figure below shows that a 220 nF capacitor has a maximum $V_{\text{rms}}$ of 100 V at 20 kHz. So under these conditions ($100 V_{\text{rms}}$, 20 kHz) the self-heating ($\Delta T$) will be 15 °C. Let us now calculate the maximum $I_{\text{rms}}$ at this frequency:

$$I_{\text{rms}} = V_{\text{rms}} \cdot 2\pi f \cdot C = 100 \cdot 2\pi \cdot 20000 \cdot 220 \cdot 10^{-9} = 2.765 \text{ A}$$
For intermediate values of capacitance not included in the graphs, for example C' = 200 nF, the permissible RMS voltage or current can be approximately calculated from the closest existing curves according to:

\[ V'_{RMS} = V_{RMS} \cdot \sqrt{\frac{C'}{C}} = 100 \cdot \sqrt{\frac{220}{200}} = 104.8 \text{ V} \]

\[ I'_{RMS} = I_{RMS} \cdot \sqrt{\frac{C'}{C}} = 2.765 \cdot \sqrt{\frac{200}{220}} = 2.636 \text{ A} \]

Sometimes it is necessary to estimate the self-heating \( \Delta T' \) for a given \( V_{RMS} \) (i.e. 75 V) and frequency (i.e. 20 kHz). From each curve in the corresponding data sheet we can obtain the maximum permissible \( V_{RMS,\text{max}} \) at the required frequency. In this example, it is 100 V at 20 kHz. The following equation is applied:

\[ \Delta T'_{V,T} = \left( \frac{V'_{RMS}}{V_{RMS,\text{max}}} \right)^2 \cdot \Delta T_{V,T} = \left( \frac{75}{100} \right)^2 \cdot 15 = 8.4 \text{ °C} \]

**Reliability and life expectancy**

The reliability of our capacitors is given by their probability to perform satisfactorily for a given period of time while operating under specified conditions. Two significant statistical parameters are specified for the reliability of our products: Failure rate (\( \lambda \)) and service life (\( t_s \)).

Our product series are characterized in terms both reliability parameters, with data obtained from life and endurance tests. We usually provide the failure rate referenced to the standard conditions, and the service life referred to nominal conditions. These values can be found in the data sheet for the specific product.

Both service life and failure rate can be extrapolated to different conditions, taking into account the appropriate correction factors:

\[ \lambda = \lambda_{\text{ref}} \cdot \pi_V \cdot \pi_T \]

\[ t_s = t_{s,\text{ref}} \cdot \frac{1}{\pi_V} \cdot \frac{1}{\pi_T} \]

For this calculation, the standard factors of the IEC 1709 should be applied:

<table>
<thead>
<tr>
<th>( T ) (ºC)</th>
<th>( \pi_T )</th>
<th>( T ) (ºC)</th>
<th>( \pi_T )</th>
<th>( V / V_{R} )</th>
<th>( \pi_V )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \leq 40 )</td>
<td>1</td>
<td>110</td>
<td>77</td>
<td>10%</td>
<td>0.26</td>
</tr>
<tr>
<td>50</td>
<td>1.8</td>
<td>120</td>
<td>206</td>
<td>25%</td>
<td>0.42</td>
</tr>
<tr>
<td>55</td>
<td>2.3</td>
<td>125</td>
<td>346</td>
<td>50%</td>
<td>1.00</td>
</tr>
<tr>
<td>60</td>
<td>3.1</td>
<td></td>
<td></td>
<td>60%</td>
<td>1.42</td>
</tr>
<tr>
<td>70</td>
<td>5.2</td>
<td></td>
<td></td>
<td>70%</td>
<td>2.04</td>
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<tr>
<td>80</td>
<td>9</td>
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<td>80%</td>
<td>2.93</td>
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<tr>
<td>85</td>
<td>12</td>
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<td></td>
<td>90%</td>
<td>4.22</td>
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<tr>
<td>90</td>
<td>16</td>
<td></td>
<td></td>
<td>100%</td>
<td>6.09</td>
</tr>
<tr>
<td>100</td>
<td>33</td>
<td></td>
<td></td>
<td>110%</td>
<td>9.00</td>
</tr>
<tr>
<td>105</td>
<td>50</td>
<td></td>
<td></td>
<td>120%</td>
<td>13.00</td>
</tr>
</tbody>
</table>

Where \( T \) is the temperature of the capacitor, \( V \) is its voltage, and \( V_{R} \) its rated voltage.

**Example:**

Suppose that we need to know the service life of a product when it operates at +85 ºC and rated voltage. According to the product data sheet, its service life is 200,000 h at +40 ºC and rated voltage:

\[ t_{40°C,V,R} = 200,000 \text{ h} \]

We therefore need the conversion factor from the reference temperature of +40 ºC to +85 ºC. We get this from the previous table:

\[ \pi_{85°C} = 12 \]

With this, and using the formula above, we can estimate the service life of the capacitor at +85 ºC and nominal voltage as follows:

\[ t_{\text{85°C},V,R} = t_{\text{85°C},V,R} \cdot \frac{1}{\pi_{85°C}} = 200,000 \cdot \frac{1}{12} = 16,666.67 \text{ h} \]

If we wanted to estimate its service life at a continuous voltage and temperature differing from the reference values, we would need an additional factor for the voltage. Suppose we now want to estimate the service life of the same capacitor for continuous operation at +85 ºC and 90% of the rated voltage. Then we should use two factors:

For temperature: \( \pi_{85°C} = 12 \)

For voltage: \( \pi_{V_n} = \frac{\pi_{90%V_n}}{\pi_V} = \frac{4.22}{6.09} = 0.693 \)
And with this, again applying the above formula:

\[
\frac{t_{95°C,V_R}}{t_{85°C,V_R}} = \frac{1}{200,000} \cdot 1 \cdot 0.693 = 24,052.13 \text{ h}
\]

And here we see that reducing the continuous applied voltage to this capacitor in this case increases its service life by more than 44%.

Additional details on reliability can be found in chapter Reliability of our Film Capacitors Data Book.

**Thermal stability and reliability**

Thermal stability, efficiency and reliability are key requirements for modern industrial designs that are now perfectly fulfilled by film capacitors. The stability of their electrical properties is decisive when deciding on the capacitance to be used in the final design. In many cases and industrial applications, stability is the reason for over-dimensioning the capacitor bank.

For MKP film capacitors, the capacitance change remains within ±5% across a wide range of temperatures from -50 °C to +105 °C, four times lower than the typical drift allowed to alternative capacitor technologies, whose temperature operating window is even narrower. There is also no voltage influence on the capacitance value.

Product reliability is a major concern for designers of state-of-the-art industrial applications. EPCOS offers a wide range of highly reliable series of film capacitors with service lives well above that offered by other technologies. This superior performance of EPCOS film technology is consistent across a wide range of application temperatures.
Quick Guide to Operating Conditions vs. Technical Parameters

The example shown below serves as a guide for selecting the appropriate capacitor on the basis of the operational parameters:

**Inputs required**
- Capacitance
- V, I waveforms
- Ambient temperature around the capacitor T_A or in case of real testing, capacitor temperature T measured on case (see chapter Thermal Analysis).

### Basic selection criteria
Selection of capacitor to comply with data sheet parameters:
- \( V_{op,max} \leq V_{DC} \)
- \( V_{pp,max} \leq 2 \cdot 1,41 \cdot V_{RMS} \)
- \( T_A \leq T_{max} \)

**Thermal analysis**
Thermal analysis or estimation of capacitor temperature: Calculation of main harmonics \( V_{RMS} \) or \( I_{RMS} \) at every frequency. Estimate the self-heating \( \Delta T \) (following the indications given in chapter Thermal Analysis). The temperature measured on the capacitor will be: \( T = T_A + \Delta T \)

### Derating
The operating voltage may need to be derated as a function of the capacitor temperature T by applying the derating factor given in the specific data sheet. Alternatively, a new capacitor with higher \( V_{R} \) may be chosen, thus allowing a higher operating voltage.

For example, for a MKP capacitor \( V_{R} = 800 \) V DC whose derating starts at 85 °C as shown in figure below:

- If the temperature of the capacitor T is +70 °C and the maximum expected operating voltage \( V_{op} = 800 \) V, the capacitor selection is correct.
- If the capacitor temperature is +100 °C and maximum \( V_{op} = 800 \) V, then the maximum voltage of the application shall be limited to \( 0.8 \cdot 800 \) V = 640 V

A capacitor with \( V_{R} = 1000 \) V DC should be selected to allow \( 800 \) V at 100 °C.

**Peak current**
Maximum peak current \( (A) = C \ (\mu F) \cdot dV/dt \ (V/\mu s) \).
\( dV/dt \) values and the pulse characteristic \( K_0 \) are given in every product data sheet. \( K_0 \) provides the reference to evaluate the heat energy generated by a pulse. These \( dV/dt \) and \( K_0 \) parameters are valid for isolated pulses, i.e. the heat energy (Q) of one pulse is dissipated completely before a second pulse is received.

If a train of pulses is applied, this criterion alone is not applicable and a thermal analysis should be performed as described in section “Thermal Analysis”.

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Please read **Important notes** on page 4 and **Cautions and warnings** on page 29.
Technical Parameters

Rated capacitance $C_R$
The capacitance measured at 1 V AC and 1 kHz under standard ambient conditions (in accordance with IEC 60068-1, sub-clause 5.2). This value is normally marked on the product.

Capacitance tolerance
Defined as the permissible relative deviation of the capacitance from the rated value: it is expressed as a percentage of the nominal value. The capacitance should be measured at a temperature of +20 °C, 1 V AC and 1 kHz.

Capacitance drift
Capacitance is subject to both irreversible and reversible changes. The capacitance drift is the sum of all time-dependent irreversible changes of capacitance during its service life. This variation is stated as a percentage of the capacitance value at delivery. The typical figure is ± 5%.

Dissipation factor $\tan \delta$
Also referred to as the loss factor or $\tan \delta$. It is the ratio between the effective power (power dissipation) and the reactive power for a sinusoidal load of specified frequency, expressed in per cent.

Equivalent Series Resistance ESR
The ESR represents the global ohmic resistance associated with a capacitor. It comprises not only the resistance of the contacts ($R_s$), but any other phenomena which contribute their resistance, such as the dielectric polarization and leakage (parallel resistance $R_p$), already described for the dissipation factor.

From the definition of $\tan \delta$, the ESR can be expressed as:

$$E_{SR} = \frac{\tan \delta}{2\pi fC}$$

The ESR depends not only on the dielectric characteristics but also on design parameters, and varies considerably depending on the series.

The ESR is important because it determines the power dissipation of the capacitor and thus its self-heating. For frequencies well below the natural resonance frequency, the equivalent circuit diagram of the capacitor can be simplified to a series connection of the capacitance $C$ and the equivalent series resistance (ESR).

Here the power dissipation is a function of the voltage $V_{ESR}$ across the equivalent series resistance (ESR), or the current $I$ through it, and is expressed by:

$$P = \frac{V_{ESR}^2}{E_{SR}} = E_{SR} \cdot I^2$$

Since

$$V_{ESR}^2 = \frac{ESR^2 \cdot V^2}{ESR^2 + \frac{1}{(2\pi fC)^2}}$$

And since for film capacitors $\tan \delta = 2\pi fC \cdot E_{SR} << 0.1$

$$V_{ESR}^2 = ES R^2 \cdot (2\pi fC)^2 \cdot V^2$$

The power can be expressed as

$$P = 2\pi fC \cdot \tan \delta \cdot V^2$$

**Rate of capacitance $C_R$**

The capacitance measured at 1 V AC and 1 kHz under standard ambient conditions (in accordance with IEC 60068-1, sub-clause 5.2). This value is normally marked on the product.

**Capacitance tolerance**

Defined as the permissible relative deviation of the capacitance from the rated value: it is expressed as a percentage of the nominal value. The capacitance should be measured at a temperature of +20 °C, 1 V AC and 1 kHz.

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$$V_{ESR}^2 = ES R^2 \cdot (2\pi fC)^2 \cdot V^2$$

The power can be expressed as

$$P = 2\pi fC \cdot \tan \delta \cdot V^2$$
Technical Parameters

**Insulation resistance \( R_{\text{ins}} \)**

The insulation resistance \( R_{\text{ins}} \) of a capacitor is a measure of its resistance in DC operation. Under a stationary DC voltage, a leakage current flows through the dielectric and over the capacitor surfaces.

\( R_{\text{ins}} \) is measured by determining the ratio of the applied DC voltage to the resulting leakage current flowing through the capacitor, once the initial charging current has ceased (typically, after a period of 1 min ± 5 s).

The measuring voltage depends on the rated voltage and is specified in Section 4.5.2. of IEC 60384-1:

<table>
<thead>
<tr>
<th>Rated voltage ( V_R ) of capacitor</th>
<th>Measuring voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 V ≤ ( V_R ) &lt; 100 V</td>
<td>(10 ± 1) V</td>
</tr>
<tr>
<td>100 V ≤ ( V_R ) &lt; 500 V</td>
<td>(100 ± 15) V</td>
</tr>
<tr>
<td>500 V ≤ ( V_R )</td>
<td>(500 ± 50) V</td>
</tr>
</tbody>
</table>

**Pulse handling capability \( \text{dV/dt, } K_0 \)**

The pulse handling capability of our capacitors is characterized by their maximum \( \text{dV/dt} \) and the parameter \( K_0 \). The maximum permissible \( \text{dV/dt} \) defines the ability of a capacitor to withstand high current peaks due to fast voltage changes. The peak current is the product of the capacitance (in \( \mu \text{F} \)) and the \( \text{dV/dt} \) (in V/\( \mu \text{s} \)). The characteristic factor of a pulse waveform, \( K_0 \), provides its energy content. The maximum permissible \( K_0 \) defines the ability of a capacitor to withstand pulses involving several current peaks.

These \( \text{dV/dt} \) and \( K_0 \) parameters are valid for isolated pulses, i.e. the heat energy (\( Q \)) of one pulse is dissipated completely before a second pulse is received.

If a train of pulses is applied, this parameter is not sufficient and a thermal analysis should be performed.

**Rated voltage \( V_R \)**

This is the maximum voltage which may be continuously applied to a capacitor at any ambient temperature below the rated temperature.
Cautions and Warnings

General
See "Important notes" on page 4.

Storage
- Store capacitors in original packaging only. Do not open the package prior to storage.
- Storage conditions in original packaging: storage temperature –25 °C ... +40 °C, relative humidity 75% annual mean, maximum 80%, dew precipitation is inadmissible.
- Do not store capacitors where they are exposed to heat or direct sunlight. Otherwise, the packing material may be deformed or components may stick together, causing problems during mounting.
- Avoid contamination of capacitor surface during storage, handling and processing.
- Avoid storage of capacitors in harmful environments like corrosive gases (SOx, Cl etc.).
- Use the components as soon as possible after opening the factory seals, i.e. the polyvinyl-sealed packages.
- Solder capacitors within the time specified after shipment from EPCOS. For leaded components this is 24 months.

Handling
- Capacitors must not be dropped. Chip-offs or any other damage must not be caused during handling of capacitors.
- Do not touch components with bare hands. Gloves are recommended.
- Avoid contamination of capacitor surface during handling.

Soldering
- Use resin-type flux or non-activated flux.
- Insufficient preheating may cause ceramic cracks.
- Rapid cooling by dipping in solvent is not recommended.
- Complete removal of flux is recommended.

Mounting
- Ensure that no thermo-mechanical stress occurs due to production processes (curing or overmolding processes) when capacitors are sealed, potted or overmolded or during their subsequent operation. The maximum temperature of the capacitor must not be exceeded. Ensure that the materials used (sealing/ potting compound and plastic material) are chemically neutral.
- Electrodes/ contacts must not be scratched or damaged before/ during/ after the mounting process.
- Contacts and housing used for assembly with the capacitor must be clean before mounting.
- Ensure that adjacent materials are designed for operation at temperatures comparable to the surface temperature of the capacitor. Be sure that surrounding parts and materials can withstand the temperature.
- Avoid contamination of the capacitor surface during processing.
- The connections of sensors (e.g. cable end, wire end, plug terminal) may only be exposed to an environment with normal atmospheric conditions.
- Tensile forces on cables or leads must be avoided during mounting and operation.
- Bending or twisting of cables or leads directly on the capacitor body is not permissible.
- Avoid using chemical substances as mounting aids. It must be ensured that no water or other liquids enter the capacitors (e.g. through plug terminals). In particular, water based substances (e.g. soap suds) must not be used as mounting aids for sensors.

Operation
- Use capacitors only within the specified operating temperature range.
- Use capacitors only within the specified power range.
- Environmental conditions must not harm the capacitors. Only use the capacitors under normal atmospheric conditions or within the specified conditions.
- Contact of capacitors with any liquids and solvents should be prevented. It must be ensured that no water enters the capacitors (e.g. through plug terminals). For measurement purposes (checking the specified resistance vs. temperature), the component must not be immersed in water but in suitable liquids (e.g. Galden).
- Avoid dewing and condensation unless capacitor is specified for these conditions.
- Bending or twisting of lead wires is not permissible during operation of the capacitor in the application.
- Be sure to provide an appropriate fail-safe function to prevent secondary product damage caused by malfunction.

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. Additional potting or/ and metal enclosures can help to withstand severe ambient conditions.
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