



# Power Electronics Film Capacitors

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For further information please refer to KEMET's Internet web site:

<http://www.kemet.com>

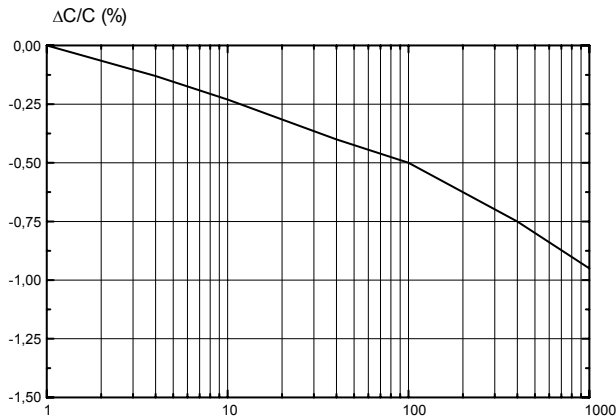
# PRODUCT SELECTION GUIDE

Axials capacitors	Snubber	<b>C4C / C4H</b>
Axials capacitors	Switching	<b>C4G / C4M</b>
Alluminium Case	General Purpose	<b>C44A</b>
Alluminium Case	AC Filtering	<b>C44E</b>
Single and Three Phase		<b>C44P</b>
		<b>C20A</b>
		<b>C44H</b>
		<b>C9T</b>
Alluminium Case	DC Link	<b>C44U</b>
Alluminium Case	Snubber	<b>C44B / C20B</b>
Plastic Box	Wire Terminals DC Link	<b>C4AE</b>
Plastic Box	Wire Terminals Snubber	<b>C4AS</b>
Plastic Box	Wire Terminals Switching	<b>C4AT</b>
Plastic Box	Lug Terminals Snubber	<b>C4BS</b>
Plastic Box	Lug Terminals Switching	<b>C4BT</b>
FLAT Execution	GTO Snubber	<b>C4DC</b>
FLAT Execution	DC Link	<b>C4DE</b>
FLAT Execution	GTO Clamper	<b>C4DR</b>
	<b>Applications</b>	
	Snubber	• • • • • • • • • • •
	Clamper	• • • • • • • • • • •
	Commutation	• • • • • • • • • • •
	DC Ripple Filter / Energy Storage	• • • • • • • • • • •
	Resonance	• • • • • • • • • • •
	Pulse	• • • • • • • • • • •
	Harmonic Filters	• • • • • • • • • • •
	Power Factor Correction	• • • • • • • • • • •
	Blocking	• • • • • • • • • • •
	Coupling / Decoupling	• • • • • • • • • • •

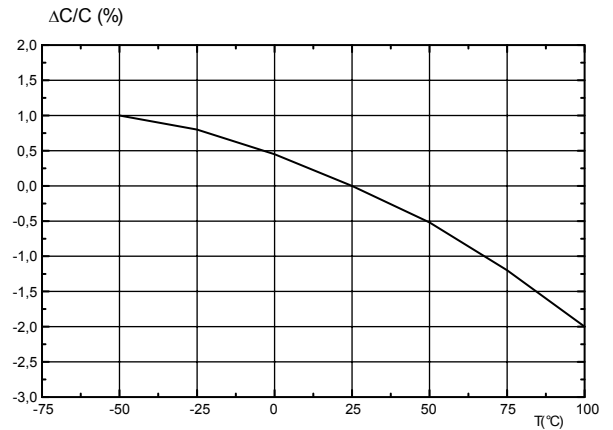
## Polypropylene Typical Dielectric Features

The selection of Polypropylene as a dielectric is due to the following inherent properties:

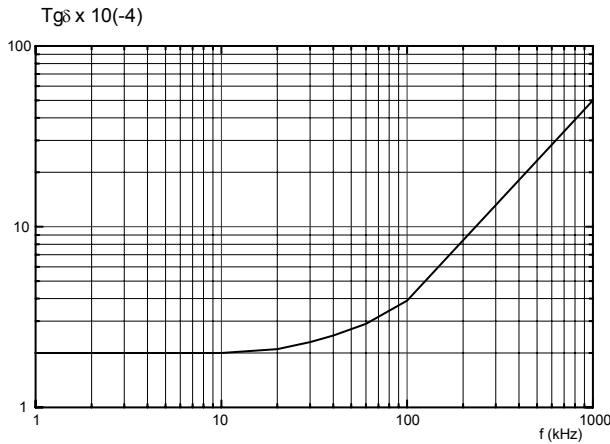
- Very low dissipation factor
- High insulation resistance
- High thermal stability
- Good self-healing features



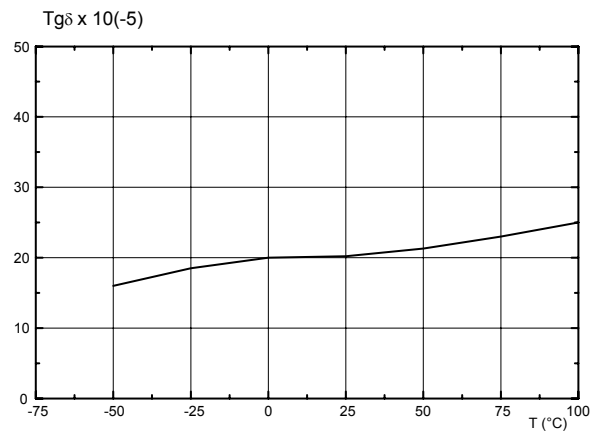
Capacitance change vs. frequency (room temperature)



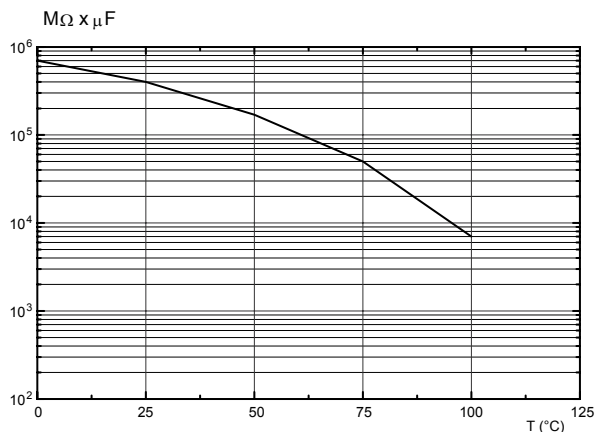
Capacitance change vs. temperature at 1kHz



Dissipation factor vs. frequency (Room temperature)



Dissipation factor vs. temperature at 1kHz



Time constant vs. temperature

## Introduction

The technological development of Power semiconductors led to an ever-increasing widespread use of power electronics.

Many of these applications are based on the usage of capacitors specially designed to withstand the electric and thermal stresses required.

KEMET developed a wide range of capacitors for power electronics that are shown in this catalogue and suitable to be used in applications like forced commutation, damping, clamping, snubbing, A.C. and D.C. filtering.

These capacitors are wound in such a way to provide low values of stray inductance (ESL), series resistance (ESR) in order to minimize the power dissipation ( $Tg\delta$ ).

With these characteristics the capacitors for power electronics made by KEMET allow to operate with high values of RMS and Peak currents producing a negligible temperature rise of the case.

These performances are obtained using low loss dielectrics, which assure high stability of capacitance versus temperature and time.

The metallized electrodes under vacuum assure the self-healing characteristic, this means that voltage transients exceeding the rated voltage can be applied without causing short circuits.

The tight production of the case guarantees a complete protection against humidity and external pollutants.

The capacitors for power electronics shown in this catalogue are the most common models, but many others are normally in production or in development stage.

For particular requirements or custom designed products please contact directly the Arcotronics local office.

### QUALITY

KEMET capacitors are manufactured with maximum attention to product quality and customer service is our first task. In order to assure high quality and reliability to its products, Arcotronics adopts the most modern worldwide standards and procedures of continuous improvement. KEMET quality system is certified by **ISO9001 EN 29001-BS5750** part 2 and **CECC 00114** part 1. The target of KEMET quality control is the achievement of zero defects.

### TERMINATIONS

The standard terminations of capacitors with aluminum case are made by two M6 tinned brass screws allowing a maximum driving torque of 6 Nm. Upon request it is possible to supply single or double tinned brass 6.35x0.8 mm faston or 2.8x0.5 mm mini faston. The solderability of fastons is guaranteed for a period of 4 months starting from the manufacturing date marked on the case. Axial and Box executions are provided with tinned copper wire terminations.

### MARKING

The marking is made in black color. Every product is marked with most of the information that can be fitted on the case depending on its dimensions. The standard marking is the following: KEMET trade-Mark, Series number, Capacitance in microfarad, tolerance in %, Rated DC and AC voltages, operating temperature range in degree Centigrade, coded climatic class and reliability data according to DIN 40040, Self-healing property SH, Batch number, year and month of production coded in accordance with DIN 42314 standard shown in the following table:

Year	Letter	Month	Letter
1995	F	January	1
1996	H	February	2
1997	J	March	3
1998	K	April	4
1999	L	May	5
2000	M	June	6
2001	N	July	7
2002	P	August	8
2003	R	September	9
2004	S	October	O
2005	T	November	N
2006	U	December	D
2007	V		
2008	X		

### GENERAL TECHNICAL DATA

The capacitive cartridge is wound on high-speed automated machines, in cylindrical shape, non-inductive, self-healing, surge proof and low loss metallized plastic dielectric films.

The terminations are connected to the electrodes through metal-sprayed front ends (Shoopage), assuring a high contact reliability and low values of ESR.

### VIBRATION STRENGTH

The vibration strength of Aluminum can capacitors having a diameter  $\leq 60$ mm and height  $\leq 160$ mm, corresponds to the test loading according to the standard DIN 40046 page 8, test FC – B1 or IEC Publication 68-2-6 at the following conditions:

Case diameter .....  $\leq 60$ mm ..... 65mm

Test duration ..... 6 hours ..... 6 hours

Frequency range..... 10 to 55 Hz ..... 10 to 55 Hz

Amplitude ..... 0.75mm ..... 0.75 mm

Acceleration max ..... 10 g ..... 2 g

Fixing method is very important in order to minimize the Detrimental effects of vibrations.

## Specifications and Test Methods

- **Capacitance: C (μF)**  
The rated capacitance measured at 20°C±5°C at 1 kHz.
- **Tolerance**  
The maximum admitted deviation from the rated value of Capacitance measured at 20°C, ±5% code J, 610% Code K.
- **Capacitance change versus temperature**  
The capacitance changes from nominal value at 20°C ± 5°C in the specified temperature range. The typical capacitance change versus temperature is shown in the diagrams on Page 4.
- **Rated D.C. Voltage: U<sub>n</sub>**  
The U<sub>n</sub> voltage refers to the maximum operating peak recurring voltage of either polarity but of the non-reversing type waveform.
- **Rated A.C. Voltage: U<sub>RMS</sub>**  
The maximum RMS value of the sinusoidal alternating voltage marked on the capacitor.
- **Non recurrent surge voltage: U<sub>PK</sub>**  
The maximum non-recurrent peak D.C. voltage that can be applied in either polarity for a limited number of times. The application of higher than rated peak voltage U<sub>PK</sub> may result in premature failure of the dielectric.
- **U<sub>RMS</sub> trapezoidal**  
The RMS value of trapezoidal A.C. voltage at which the capacitor will provide full rated life.
- **Ū<sub>MAX</sub>** - The maximum repetitive peak DC voltage that can be applied in either polarity.
- **Voltage test between terminal: U<sub>t</sub>**  
All capacitors are tested at 20 °C ± 5 °C for 10 s at one or both the following voltages:  
D.C. Test Voltage: 2.5 U<sub>n</sub> / Ø2  
A.C. Test Voltage: 1.5 U<sub>RMS</sub>
- **Voltage test between terminals and case U<sub>tc</sub>**  
The standard test conditions are 3 kVRMS sinus at 50 Hz, 20°C ± 5°C for 1 minute, no breakdown discharges are admitted. The maximum operating voltage applied continuously between each terminal and case is:  
- 1.25 U<sub>RMS</sub> for A.C. Applications  
- 1.25 U<sub>PK</sub> for D.C. Applications
- **Self-healing: SH**  
The capacitors for Power Electronics are wound with vacuum metallized films with the self-healing characteristics. Electrical discharges between electrodes may thus occur during operation without damaging dielectric, producing only a negligible capacitance reduction.
- **Dissipation Factor DF (tgδ)**  
Two values may be specified:  
1) tgδ max, that represents the max guaranteed value.  
2) tgδ typ, that is the typical value of the capacitors.  
The tgδ value is measured at 20°C ± 5°C at 1 kHz.  
The max error of tgδ measurement is less than ±1x10<sup>-4</sup>+ 10% of the measured value.  
Note: the measurements of capacitance and tgδ of capacitors MKP C.44/3 series are carried out at 50 Hz.
- **Equivalent Series-Inductance: ESL**  
The capacitor has a certain inductance due to the length of connections and capacitive element; the sum of these stray inductances represents the Equivalent Series Inductance (ESL).The value indicated is typical and is measured at 20°C ± 5°C at the self-resonance frequency; it is expressed in nano-Henry (nH).
- **Equivalent Series Resistance: ESR**  
The ESR is the equivalent series resistance due to resistivity of electrodes, internal connections and dielectric losses. The ESR is measured in milliohm (mΩ) at 20 °C ± 5 °C and a frequency of 10 kHz.
- **Insulation Resistance: I.R.**  
The insulation resistance between terminals is expressed by means of the discharge time constant R.C. according to DIN 41180. The standard guaranteed value is of RC≥3000 s Measured for 1 minute at 100 Vdc and at 20°C ± 5°C. Climatic category: 40/85/21 according to IEC 68-1.
- **I.R. between terminals and case.**  
Applying a D.C. voltage of 500 V, the capacitor should display a Resistance value higher than 3 x 10<sup>-4</sup> MW.
- **Rated insulation Voltage: U<sub>i</sub>**  
The rated insulation voltage is the RMS value of the A.C. Voltage for which the capacitor insulation between terminals and case is designed.
- **Operating temperature - Climatic category - Reliability Data**  
All capacitors for Power Electronics are made in accordance with standard DIN 40040. Metal case execution: DIN 40040 GPD/LS.  
G = -40 °C, P = + 85 °C,  
D = average humidity ≤ 80 %,  
L = Failure quota 300/109 components hours,  
S = load duration 30,000 hours.  
E = average humidity ≤ 75%. Polyester film coated execution: DIN 40040 GPE/LS.
- **Storage temperature**  
The range over which the capacitor may be stored unenergized, with no degradation is - 55... + 105°C.

## Specifications and Test Methods

### - Altitude

The maximum allowable altitude is 2200 meters. As the barometric pressure decreases, the terminal arc-over susceptibility increases. Heat generated cannot be properly dissipated operating at high altitude and can result in high  $RI^2$  losses and eventual failure.

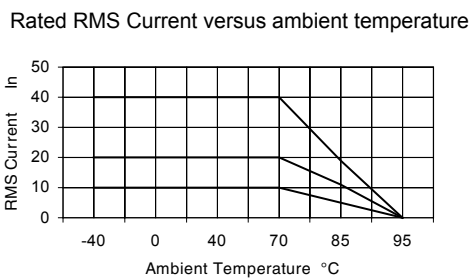
### - Thermal Dissipation Coefficient: K

The thermal dissipation coefficient K is the typical value that allows to calculate the temperature rise of capacitor case compared to the ambient temperature in operating conditions.

$$\Delta T = K ESR I_{RMS}^2 \text{ (}^\circ\text{C)}$$

### - Rated RMS current: $I_{RMS}$

The rated RMS current is the highest permissible RMS value of the continuous current flowing through the capacitor at the max temperature of 70 °C. Operating at the rated RMS current, the capacitor produces a case temperature rise of about 15 °C over the ambient due to the resistive losses of dielectrics, plates and conductors. The rated RMS current  $I_{RMS}$  must be derated taking into account the ambient temperature and the skin effect due to the duration of peak current time according to the following diagram:



### - Materials and environment

The selection of materials, used by Arcotronics for the production of capacitors, is the result of a long experience and constant attention to the environment protection. KEMET selects its suppliers according to ISO9001 standards and carries out statistical analysis on the materials purchased before acceptance. All materials are, to its present knowledge, non-toxic and free from: Cadmium, Mercury, Chrome and compounds, PCB (Polychlorine Triphenyl), Bromide and Chlorine Dioxins Bromurate Chlorurate, CFC and HCFC, Asbestons.

### - Disposal

The capacitors should be disposed of in compliance with the local laws and active regulations according to the following European classifications:

91/156/CEE

91/ 689 / CEE

### - Voltage rise time: $dv/dt$

This value shows the maximum voltage rise/fall time, it is expressed in volts per microsecond, and cannot be overcome.

### - Peak Repetitive Current: $I_{PKR}$

The peak repetitive current is the maximum value that the peak current can assume.

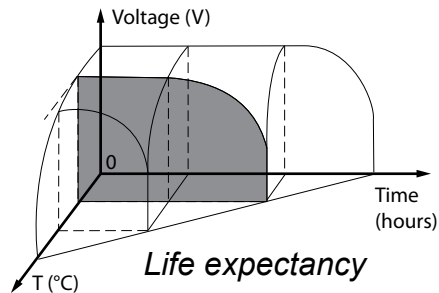
### - Peak Non Repetitive Current: $I_{PKN}$

The peak non-repetitive current is the maximum admissible non-periodic current peak.

### - Expected life

Any material or element has a longer or shorter life according to the working conditions to which it is submitted due to its intrinsic properties. The capacitor is subjected to several types of stresses: overvoltage, overheating, pollution, humidity, radiation, and vibrations. The ageing causes an irreversible change of its properties as a result of the application of an external stress. The expected life is the time required by the capacitor to reach the specified limit of reduced value of the electrical parameters. The main stresses are both electric and thermal in origin. It is possible to demonstrate a model of life for each series of capacitors and type of stress in order to estimate the life of the component according to the temperature and voltage applied.

$$L \text{ (hours)} = F (V, T)$$



### - Life expectancy versus voltage

The life expectancy of a capacitor subjected to a voltage different from the nominal one, can be approximately calculated with the following simplified formula:

$$L_E = L_N \times (V_N / V)^8$$

$L_E$  = Life expectancy at operating voltage (hours)

$L_N$  = Life expectancy at nominal voltage (hours)

$V_N$  = Nominal voltage  $U_n$  (V)

$V$  = Operating voltage (V)

The above formula is valid within  $\pm 20\%$  of the nominal Voltage.

### - Life expectancy versus temperature

The life expectancy of a capacitor subject to a temperature different from the rated one of 70 °C can be calculated with:

$$L_E = L_{T_0} \times 2^{(T_0 - T_{hs}) / 7}$$

$L_E$  = Life expectancy at operating temperature (hours)

$L_{T_0}$  = Life expectancy at 70°C (hours)

$T_0$  = Reference temperature (70°C)

$T_{hs}$  = Hot spot case temperature ( $\leq 70^\circ\text{C}$ )

7 = Arrhenius coefficient



## Capacitors Failure Modes

Plastic dielectric film capacitors can undergo two classic failure modes: opens or shorts. Included in these categories are intermittent opens, shorts or high resistance shorts. In addition to these failures, capacitors may fail due to capacitance drift, instability with temperature, high dissipation factor or low insulation resistance. Failures can be the result of electrical, mechanical or environmental overstress, due to dielectric degradation during operation.

### - Dielectric breakdown (Shorts)

The classic capacitor failure mechanism is dielectric breakdown. The dielectric in the capacitor is subjected to the full potential to which the device is charged and, high electrical stresses are common. Dielectric breakdowns may develop after many hours of satisfactory operation. There are several causes that could be associated with operational failures. If the device is operating at or below its maximum rated conditions, most dielectric materials gradually deteriorate with time and temperature to the point of eventual failure. Most of the common dielectric materials undergo a slow ageing process by which they become brittle and are more susceptible to cracking. The higher the temperature is, the more the process is accelerated. Chemical or aqueous cleaning may also have an adverse effect on capacitors. Dielectric breakdown may occur as a result of misapplication of high transients (surges). The capacitor may survive many repeated applications of high voltage transients, however, this may cause a premature failure.

### - Open capacitors

Open capacitors usually occur as a result of overstress in application. For instance operation of DC rated capacitors at high AC current levels can cause a localized heating at the end terminations. The localized heating is caused by high  $RI^2$  losses. Continued operation of the capacitor can result in increased end termination resistance, additional heating, and possible failure. The open condition is caused by a separation of the end-connection of the capacitor. Both RMS and Peak currents may cause the open condition when overcome. Mounting capacitors by the leads in high vibration environment may also cause an open condition. The lead wire may fatigue and break at the egress area if a severe resonance is reached. The capacitor body must be fastened into place by use of a clamp or a structural adhesive.

### - Environmental considerations

The following list is a summary of most common environmentally critical factors affecting the life of capacitors. The design engineer must take into consideration his own applications and the effects caused by combinations of various environmental factors.

- Service life of a capacitor must be taken into consideration. The service life decreases when the temperature increases (see page 8).

- Capacitance will change up and down with temperature  
Due to the dielectric constant and an expansion or Shrinking of the dielectric material (see diagram  $\Delta C/T$  on page 5). Capacitance changes can be the result of excessive clamping pressure on non-rigid cases.

### - Insulation resistance

When the capacitor temperature increases the insulation resistance decreases. This is due to increased electron activity. Low insulation resistance can also be the result of moisture trapped in the windings, caused by a prolonged exposure to excessive humidity.

### - Dissipation factor $tg\delta$

The dissipation factor is a complex function involved with the inefficiency of the capacitor. The  $tg\delta$  may change up and down with increased temperature (see diagram  $tg\delta/T$  on page 5).

### - Dielectric strength

The dielectric strength (dielectric withstanding voltage or "stress" voltage) level decreases as the temperature increases. This is due to chemical activity of the dielectric material that causes a change in the physical or electrical properties of the capacitor.

### - Sealing

Hermetically Sealed Capacitors When the temperature increases, the pressure inside the Capacitor increases. If the internal pressure is high enough, it can cause a breach in the capacitor, which can then cause leakage of impregnation or filling fluid or moisture susceptibility.

### - Epoxy encased / Wrap and fill capacitors

The epoxy seals on both epoxy encased and wrap and fill Capacitors will withstand short-term exposure to high humidity environments without degradation. Epoxies and plastic tapes will form a pseudo-impervious barrier to humidity and chemicals. These case materials are somewhat porous and through osmosis can cause contaminants to enter the capacitor. The second area of contaminated absorption is the lead-wire / epoxy interface. Since epoxies cannot 100% bond to tinned wires, there can be a path formed, up to the lead wire, into the capacitor section. Aqueous cleaning of circuit boards can aggravate this.

### - Vibration, Acceleration and shock

A capacitor can be mechanically destroyed or may malfunction if it is not designed, manufactured, or installed to meet the vibrations, shock or acceleration requirement within a particular application. Movement of the capacitor within the case can cause low insulation resistance, shorts or opens. Fatigue in the leads or mounting brackets can also cause a catastrophic failure.

### - Barometric Pressure

The altitude at which hermetically sealed capacitors have to be operated controls the voltage rating of the capacitor. As the barometric pressure decreases so does the terminal arc over susceptibility increase. Non-hermetic capacitors can be affected by internal stresses due to pressure changes. This can be in the form of capacitance changes or dielectric arc-over as well as low insulation resistance. Heat transfer can also be affected by altitude operation. Heat generated in operation cannot be dissipated properly and can result in high  $RI^2$  losses and eventual failure.

### - Radiation

Radiation capabilities of capacitors must be taken into consideration. Electrical degradation in the form of dielectric embitterment can take place causing shorts or opens.