General technical information

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General technical information

IMPORTANT: information and data contained in the chapter “General technical information”, must be considered as a completing part of the single series specifications.

The series specifications must be completed with the data given in the “General Technical Information” chapter.

Data and characteristics shown in this catalogue are subjected to modifications without notice.

Always refer to ICEL web site, www.icel.it, for products updated characteristics, last revision specifications, general data and information, products certifications and news.

General technical information

A-Capacitor design and construction

Plastic film capacitors can be subdivided into two main groups on the base of their construction: film-foil capacitors and metallized film capacitors.
The combination of these two technologies brings to a third main group of capacitors, which gets the advantages of both the other groups.

A1- Film-foil capacitors

Typical film-foil capacitor consists of two metal foil electrodes with a plastic film between them, used as dielectric.
Metal foils thickness is typically 5 to 9µm and the plastic film must be thick enough to guarantee the necessary capacitor reliability in terms of voltage withstanding and long term behaviour.
Film-foil capacitors, being not able to self-heal (refer to related paragraph) usually need a dielectric thickness higher than the equivalent metallized film capacitors one, having the same voltage ratings.
It means that, considering the same dielectric type, capacitance and voltage rating, the typical dimensions of the film-foil capacitors are larger than metallized film capacitors ones.
The presence of metal foil electrodes ensures high insulation resistance, very good capacitance stability, low losses even at high frequency and excellent pulse handling capability.
Film-foil capacitors don’t have self healing properties.

A2- Metallized film capacitors

In metallized film capacitors, the metal electrodes are vacuum deposited directly onto the dielectric film surface.
The different metal alloys, shape and thickness of the metal layer influence in a relevant way the characteristics, behaviour and typical usage destination of the capacitors.
The outstanding advantage of metallized film capacitor technology is the self-healing property.
The extremely thin metal layer obtained (typical thickness 0.02 to 0.05µm for “flat” metallization) and the availability of low thickness dielectric films allow the production of capacitors with smaller dimensions than film-foil ones, having the same voltage rating.
The contacting of metallized film capacitors is made by spraying metal alloys onto the windings face ends and then welding the leads on these metal sprayed areas.
This ensures a low inductance and low loss characteristics.
Metallized film capacitors do not typically guarantee high pulse withstanding capability.
Nevertheless, a medium-high pulse handling capability can be reached with metallized film technology, using special films having metallization with reinforced contact edges and particular metal alloys, or adopting inner series connection design.
Special metallization design, like slope profile (variable R, metallization thickness and metal alloy combination along the film width) can be used to obtain high performances and special characteristics, focused on particular application needs.

A3- Self-healing

Self-healing (or clearing) process consists in the removal of imperfections, pin holes and dielectric film flaws which can cause permanent voltage breakdowns when voltage is applied to the capacitor.
The electric arc which takes place with breakdown, evaporates and changes the characteristics of the metallized area around the fault, insulating the defect: the capacitor instantaneously regains its full operation ability.
The time necessary for self-healing process is usually less than 10µs and the electric arc occurs only if the necessary energy is available either as charge energy or as external energy.
Self-healing occurs only occasionally, thanks to the capacitor design (film metallization characteristics, dielectric film thickness and films disposal and combination in the winding) even when the maximum voltage allowed is continuously applied to the capacitor up to the higher temperature limit.
Moreover, only fractions of the total energy stored in the capacitor are dissipated during the self-healing process, therefore the related voltage drop remains low.
When prescribed by approval normative, capacitors having self-healing characteristic are printed with “SH” or “#” symbol.

A4- Mixed film-foil and metallized film capacitor technology

The combination of film-foil and metallized film technology typically offers the advantages of the two above described types, obtaining self-healing property, high current and pulse capability and low losses with extended frequency ranges.
On the base of the foreseen application and needed capacitors characteristics, metal foils electrodes can be replaced by double side metallized films and some types also cover high voltage ranges thanks to a particular inner structure design.
Since these kind of capacitors maintain the self healing capability, they are conventionally classified among metallized film capacitors.

A5- Dielectrics

Many different materials and plastic films may be used as a dielectric.
The main dielectrics used in ICEL products are:

Polyester
Polypropylene
(Polycarbonate is no more available / in use: EXPIRED SERIES - NOT FOR NEW DESIGN)

The use of different dielectrics gives different characteristics and behaviour to the capacitors: different dielectric types are adopted as a function of the design needs and foreseen application characteristics.
A comparison of the main characteristics of the above mentioned plastic films is shown in the following table:

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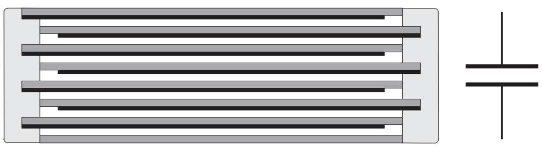
Comparative table of plastic film dielectric main characteristics (typical values)				
Characteristic	Polyester	Polycarbonate	Polypropylene	Polystyrene
Relative dielectric costant (25°C, 1kHz)	3.3	2.8	2.2	2.5
Max. working temperature (°C)	125	125	105 (+115)*	70
Loss factor ($x10^{-4}$, 1kHz/100kHz)	50/180	10/100	2/3	2/3
Insulation resistance (MΩ x µF, +20°C)	30	50	300	300
Temperature coefficient (ppm/°C)	-	+150	-200	-150
Dielectric strenght (V/µm)	250	180	350÷400	150
Water absorption (% in weight)	0.2	0.3	<0.01	0.1
Density (g/cm^3)	1.39	1.21	0.91	1.05

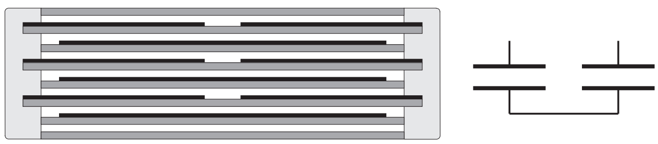
*Special base film for high temperature applications

A6- Capacitors winding

Capacitive elements are obtained rolling together a stated number of different types of films and films and metal foils, having characteristics, arrangement and sequence function of design targets, obtaining cylindrical rolls called windings (in the following examples, 2 sections inner series connection is shown but depending on design, sections can be many more)

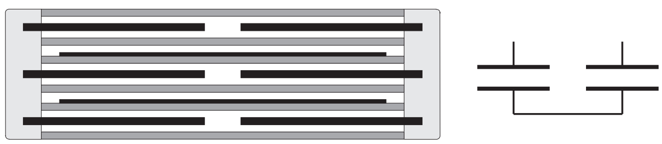


Extended metallized film design

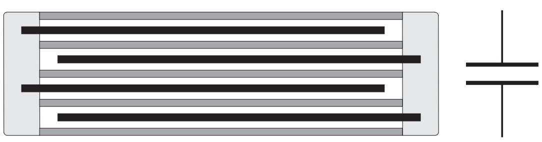


Extended metallized film design
with internal series connection
(series connection of 2 elements)

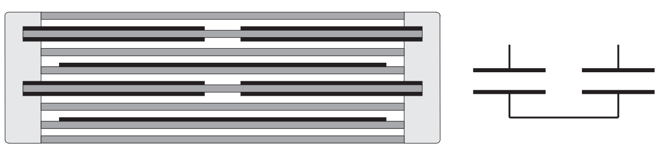
Extended double side metallized
carrier film design



Extended foil design with internal series
connection and metallized film
(series connection of 2 elements)



Extended foil design



Extended double side metallized carrier
film design with internal series
connection and metallized film
(series connection of 2 elements)

Plain film (dielectric / protection)

Metal foil (electrodes)

Single side metallized film
(dielectric+electrodes)

Double side metallized film
(electrodes)

Sprayed metal head contact

A7- Capacitors assembly and testing

The capacitive windings are submitted to thermal treatments, heads contact spraying and then are submitted to 100% clearing and electrical parameters pre-testing.
The windings can be flattened (oval transverse section), in order to obtain axial or dipped units having specified dimensions or to be sealed in box. After the leads welding, the units are finished in accordance with specifications (wrap and fill, dipped, sealed in box style and so on). Additional 100% or statistical checks are executed at different points of the production cycle in order to guarantee the materials and capacitors conformity with specifications.
At the end of the production cycle, capacitors are submitted to final tests (typicallly 100% of the production) and printing, in accordance with reference standards and applicable approval normatives and packed for shipment or storage.
ICEL s.r.l. Quality Assurance system is in conformity with ISO9001:2008 normative (please refer to ICEL web site www.icel.it for details and current approval state).

B-Technical terms (reference standards: EN, IEC, and DIN normatives; for other applicable refereces please refer to the single type specification) and general technical data

B1- Rated Capacitance (Cr)

It is the capacitance value for which the capacitor has been designed.
If not differently specified, it is typically measured at 1kHz ±20% at a max. testing voltage 3% of the rated voltage or 5V (whichever is the lowest), at 20°±5°C.
Capacitance rated values are typically graded in accordance with E series (refer to E series table; paragraph B28).

B2- Capacitance Tolerance

It is the maximum admitted deviation from rated capacitance value, measured at 20±5°C.
It is expressed in %. It can be also indicated with correspondent letter codes.
Preferred tolerance values and correpondent letter codes are:

±1%= F; ±1.25%= A; ±2%= G; ±2.5%= H; ±3%= I; ±5%= J; ±10%= K; ±20%= M
M letter code may not appear in units printing. In this case the capacitance tolerance is assumed as ±20%.

B3- Temperature Coefficient (α)

Applies to capacitors of which the reversible variation of capacitance as function of temperature is linear or approximately linear and can be expressed with a certain precision.
It is the rate of change with temperature measured over a specified temperature range within the category temperature range.
It is normally expressed in parts per million per degree celsius (10^{-6}/°C) and shall be calculated as follows:

$$\alpha_i = \frac{C_i - C_o}{C_o(\theta_i - \theta_o)}$$

C_0 = capacitance measured at 20±2°C
θ_0 = 20±2°C
C_i = capacitance measured at θ_i
θ_i = temperature measured on test

B4- Long Term Stability

It is the maximum irreversible capacitance change after a period of 2 years at standard environmental conditions (refer to “Storage conditions / Standard environmental conditions” paragraph).

B5- Rated Voltage (Ur)

The rated voltage is the voltage for which the capacitor has been designed.
It is the maximum direct voltage or the maximum r.m.s. alternating voltage or peak value of pulse voltage which may be continuously applied to a capacitor at any temperature between the lower category temperature and the rated temperature (unless other declared limitations or otherwise stated in reference specifications).

B6- Category Voltage (Uc)

It is the maximum voltage which may be applied continuously to a capacitor at its upper category temperature.

B7- Temperature Derated Voltage

For any temperature between the rated temperature and the upper category temperature, the temperature derated voltage is the maximum voltage that may be applied to a capacitor.

B8- Superimposed AC Voltage

When alternating voltage is present, the working voltage of the capacitor is the sum of the direct voltage and the peak alternating voltage. This sum shall not exceed the rated voltage value, unless differently specified.

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B9- Permissible AC Voltage up to 60Hz

It is the pure sine wave voltage that may be applied to the capacitor at a frequency up to 60Hz.
The dissipated power and currents must be considered in case of operation at higher frequency.
The AC rated voltages stated for each series refer to an operating frequency of 50÷60Hz and sinusoidal waveforms (no transient voltages).
The permissible AC voltage at frequency over 60Hz, under sinusoidal waveforms, can be obtained from the AC voltage versus frequency graphs of each capacitor series. If not differently specified, the graphs are referred to an estimated capacitor temperature rise from the ambient temperature of +10°C.

Warning: even if the permissible AC voltage covers the lines voltage range, standard film capacitors are basically not suitable for operation in direct connection to public power networks. Unless not specified and if not omologated in accordance with related normatives, capacitors cannot be used as class X or class Y units.

B10- Test Voltage between leads (Ut)

It is the specified voltage value that may be applied for a specified time to the capacitor in order to test its dielectric strength.
The occurrence of self-healing during the application of test voltage is permitted for metallized film capacitors.

Warning: unless differently specified, many capacitors connected in parallel or self-healing capacitor connected in parallel with other capacitors should not be tested without using adequate limiting discharging devices.
Discharging or protecting devices are necessary to prevent the rapid dissipation of the complete energy of the capacitors bank at the breakdown/ clearing point, in case of self-healing, which would probably cause the damage or destruction of the self-healing capacitor.
This must be taken in consideration when making voltage proofs and high voltage tests prescribed by relevant normative on equipments where several connected together capacitors are used.

B11- Test Voltage between leads and case (Utc)

It is the specified voltage value (insulation voltage) that may be applied for a specified time to the capacitor between its leads and case in order to test insulation characteristics of its external protection.
The occurrence of breakdown or discharge during the application of test voltage is not admitted.

B12- Non Recurrent Surge Voltage (Upk) and Recurrent Peak Voltage (Upkr)

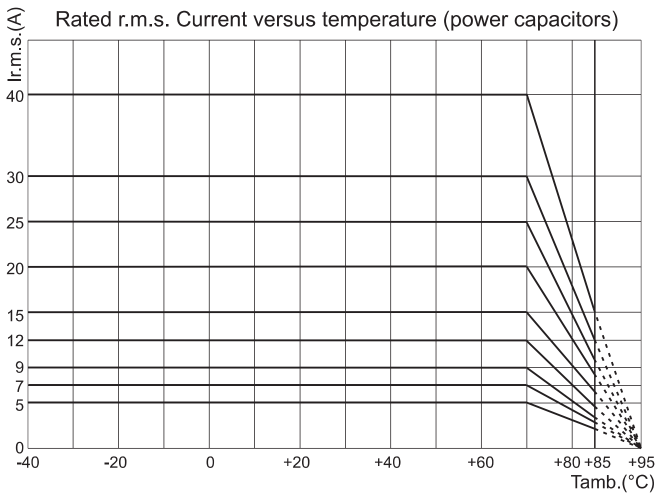
Upk is the maximum non recurrent peak DC voltage that may be applied to the capacitor for a limited number of times and for a short period. The application of voltage higher than Upk may result in premature dielectric failure. Upkr is the maximum recurrent peak DC voltage that may be applied, under specified conditions, during the life of the capacitor.

B13- Rated Ripple Current (Ir)

It is the r.m.s. current value of the maximum allowable alternating current of a specified frequency at which the capacitor may operate continuously at a specified temperature.

B14- Rated r.m.s. Current (Irms)

It is the highest permissible r.m.s. value of the continuous current flowing through the capacitor at the specified max. case temperature (unless differently specified, the typical reference temperature is +70°C for power capacitors).
If not differently indicated in the reference specifications, the Irms of the power series must be derated in relation to the ambient temperature according to the following graph (for the derating due to skin effect in case of short duration of peak current refer to correspondent graph; paragraph C2):



B15- Max. Repetitive Peak Current (Ipeak)

It is the maximum value of the repetitive peak current that may be applied to the capacitor.
Refer to “Pulse Rise Time (du/dt) and Waveform Energy Content (Ko)”; paragraph B21.

B16- Max. Non Repetitive Peak Current (Ipk)

It is the maximum non recurrent peak current that may be applied to the capacitor for a limited number of times and for a short period. The application of higher peak currents than Ipk may damage the capacitor permanently.

B17- Category Temperature Range

It is the range of temperature for which the capacitor has been designed to operate continuously.
It is defined by the temperature limits of the appropriate category.

B18- Lower / Upper Category Temperature

It is the minimum / maximum ambient temperature for which the capacitor has been designed to operate continuously.

B19- Rated Temperature

It is the maximum ambient temperature at which the rated voltage may be continuously applied.

B20- Ambient Temperature (θamb)

It is the temperature in the immediate surrounding of the capacitor and it is identical with the body surface (case) temperature of the unloaded capacitor.

B21- Pulse Rise Time (du/dt) and Waveform Energy Content (Ko)

The pulse rise time is the slope of voltage wave shape during charging or discharging of the capacitor and it is expressed in V/µs.
The maximum pulse rise time value is typically referred to the rated voltage of the capacitor.

The current loading correspondent to the pulse rise time value is:

$$I_{peak} = C_r \times du/dt$$

Ipeak in A, *Cr* in µF, *du/dt* in V/µs.

The peak current flowing through the capacitor, causes a localized heating of the contact area in the capacitor, due to contact resistance between leads - metal sprays on the winding heads - electrodes of the winding (winding film contact edges or metal foils).
Note: the contacts localized heating extend to the entire capacitor body, when the pulse stress is repetitive and constantly applied.

The energy W involved in the heating can be obtained by the formula

$$W = \int I_{peak}^2 \cdot R_i \cdot dt$$

Ri = inner resistance

The energy content of the waveform applied to the capacitor is defined as follows

$$K_o = 2 \cdot \int_0^t (du/dt)^2 \cdot dt$$

t = pulse width
Ko is expressed in V²/µs

At low voltage / medium-low pulse levels, when working at lower voltage Ua than the rated voltage Ur, capacitors may be operated at a pulse rise time= du/dt at specification x Ur / Ua.
In any case, correspondent Ipeak must be ≤ Ipk (max. non repetitive peak current admitted) and maximum Ko values stated in specifications must not be exceeded in order to avoid a dangerous overheating of the capacitors.
Note: in any case, for safety reasons, in the above conditions do not overcome 1,5 x the rated dv/dt value

B22- Power Dissipation

The heat to be dissipated by the capacitor can be calculated as follows

$$P = \sum_{i=1}^{n} Vrms_i^2 \cdot 2\pi f_i \cdot C \cdot tg\,\delta(f_i)$$

P = dissipation in Watt
$Vrms_i$ = r.m.s. voltage of the i[th] harmonic in Volt
f_i= frequency of the i[th] harmonic in Hz
C = capacitance in Farad
$tg\delta(f_i)$ = dissipation factor at the frequency of the i[th] harmonic
n = number of significant harmonics

In case of sinusoidal waveforms (n=1), the formula is

$$P = Vrms^2 \cdot 2\pi f \cdot C \cdot tg\,\delta(f)$$

This formula may be also used to approximate the capacitor dissipation when submitted to non sinusoidal or pulse conditions, where

P = dissipation in Watt
Vrms = r.m.s. value of the AC voltage
f = repetition frequency of the pulse waveform
C = capacitance in Farad
$tg\delta$ = dissipation factor at the frequency of the steepest pulse part (pulse frequency=1/ pulse width)

The maximum power dissipation admitted for a capacitor under normal conditions, depends on many different factors like the execution, design, shape, dimensions, materials and so on.
An estimated value of the power dissipation capability may be calculated with the following formula

$$Pd = K \times S \times \Delta T$$

K (mW/°C x cm^2) may assume different values in function of different types, design and executions of the capacitors; typical values are in the range 0,7÷2,0.

Lower K values should be considered for general purpose metallized film capacitors and capacitors having construction and shape not favourable for heat dissipation (long length or wide pitch compared to the other sizes, small surface heads); higher K values could be considered for film-foil capacitors and capacitors having double side metallized film electrodes or units having design, construction and shape favourable for heat dissipation (wide surface heads, short length compared to the other sizes or thin shape) like power capacitors.
The heat transmission from the inside to the surface of the capacitor is typically much more efficient and quick along the metallized or metal layers of the winding than through the dielectric: high K values are typically related to capacitors having wide heads surfaces compared with the total dissipating body surface and/ or capacitors with low transversal section.
Separated double side metallized current carriers (the metal ones even more effectively) or special design metallization films do typically allow a better heat dissipation, helping the heat extraction from the inside of the capacitors body, as also supported by wide section and oversized terminals like lugs or multiple pins.
The choice of lower K values will ensure high safety margin in Pd extimation.

S= case surface (cm^2)

Parts of the capacitors surface not able to adequately dissipate the heat because of capacitor position or other limitations, like the radial–box capacitors face laying on PCB surface, should not be taken in consideration.

ΔT (°C)= difference between the hot spot case temperature of the capacitor in stationary working conditions and the ambient temperature (example: assuming an ambient temperature = +50°C, if the hot spot case temperature of the working capacitor has to be mantained ≤+70°C, the maximum ΔT must be 20°C).

Max. assumed ΔT must be:
≤ 40°C whichever is the type of capacitor considered
≤ 20°C for general purpose metallized polypropylene film capacitors, capacitors not having metal foil or double side metallized electrodes and not designed for power applications.
Moreover, as a general safety consideration and unless differently specified, following suggested max. ΔT should be considered when capacitors operate at high temperatures, near the rated maximum operating temperatures:
≤ 10°C at +85°C ambient temperature whichever is the type of capacitor considered
≤ 5°C at +85°C ambient temperature for general purpose metallized polypropylene film capacitors (capacitors not having metal foil or double side metallized electrodes and not designed for power applications).

If not differently indicated and permitted in accordance with reference specifications, avoid operation conditions which cause relevant power dissipation at ambient temperatures over +95°C, even in case of capacitors having higher rated upper category temperature.
During stationary operation, the capacitor temperature must be always ≤ max. operating temperature stated for the capacitor.
Mantaining a safe temperature margin, avoiding the reaching of the max. temperature limit, encreases the capacitors reliability and expected life.

Therefore **P must be ≤ Pd**.

If the above condition is not respected, possible actions are:
- reduction of the ambient temperature
- forced air cooling (in any case taking in consideration the heating level inside the capacitor)
- parallel connection of many capacitors
- use of different type of capacitors or capacitors having better dissipation characteristics

NOTE: in the specifications about capacitors series for power applications, Irms ratings are typically referred to a max. ΔT of +15°C from ambient temperature (operation at rated power, current, voltage, at natural cooling, +70°C or +85°C observing voltage and current derating; unless differently specified).

As a general indication, with all the other conditions unchanged,
- a ΔT limited to about +10°C can be obtained applying a Irms reduced to about 0.82x Irms max.
- a ΔT limited to about +5°C can be obtained applying a Irms reduced to about 0.58 x Irms max.

IMPORTANT: nevertheless the estimated Pd, always consider the max. voltage and the max. current (and their de-rating, if applicable) withstandable by the capacitor and particularly the current capability allowed by the leads type.
Infact, a theoretical obtained Pd value may correspond to higher voltage values than permissible Urms voltage (over ionization level at medium-low frequencies) or may correspond to current values not tolerable by the capacitor and its terminals (at medium-high frequencies).

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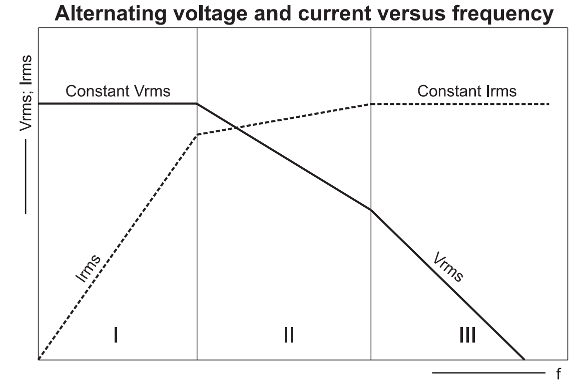
The typical capacitor Urms and Irms (sinusoidal waveform) withstanding capability versus frequency is as follows:

Alternating voltage and current versus frequency



I: voltage limited by ionization
II: voltage and current limited by power dissipation and tgδ
III: current limited by leads

The following indicative max. current values, as a function of the terminals type, shape and section (referred to a single terminal) could be taken in consideration for power capacitor series (referred to +70°C):

Tinned copper wire leads or cables, 0.6mm diameter / approx. 0.385mm² section= up to about 5A
Tinned copper wire leads or cables, 0.7mm diameter / approx. 0.385mm² section= up to about 7A
Tinned copper wire leads or cables, 0.8mm diameter / approx. 0.50mm² section= up to about 8A
Tinned copper wire leads or cables, 1.0mm diameter / approx. 0.785mm² section= up to about 10,5A
Tinned copper wire leads or cables, 1.2mm diameter / approx 1.13mm² section= up to about 14A
Lugs used for axial units (MPHL type)= up to about 25A
Other lugs types= up to about 35÷40A (depending on type and shape)

Important factors when estimating the capacitors terminals-contacts current capability, are the terminals welding mode, the contacts welded surface, the winding heads spraying type and thickness and the capacitor working temperature.
For this reason the above listed currents must be considered as approximative and indicative values.
Always refer to the capacitors specifications in order to obtain max. currents withstandable.

If needed data are not present in the capacitors specification, not corresponding or referred to the coperating conditions (particularly in case of severe application with complex voltage and current waveforms which may cause relevant power dissipation and capacitor heating), ICEL Technical Office shall be contacted in order to ensure the use of the correct kind of capacitor for the application.

Moreover, since above data are based on very generalized assumptions, they do not allow absolute correct deductions in case of critical cases: **a practical test at the real working conditions should always be made in order to verify the correctness of the theoretical assumptions.**

B23- Equivalent Series Resistance (E.S.R.)

It is the resistive part of the equivalent series circuit.
It is due to the resistivity of electrodes, internal connections and dielectric losses and depends on frequency and temperature.
The E.S.R. is related to the capacitive reactance and dissipation factor of the capacitor by the formula:

$$ESR = \frac{tg\,\delta}{\omega \cdot C}$$

C = capacitance in Farad
ω = 2πf (f = frequency in Hz)

B24- Dissipation Factor (tgδ)

It is the power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage of a specified frequency.
The reciprocal value of the dissipation factor is known as the Q factor.

$$tg\,\delta = \frac{1}{Q}$$

B25- Impedance (Z)

It is the magnitude of the vectorial sum of the E.S.R. and the capacitive reactance in an equivalent series circuit, under consideration of series inductance

$$|Z| = \sqrt{ESR^2 + \frac{1}{(\omega \cdot C)^2}}$$

B26- Self Inductance (Ls) and Resonant Frequency (fo)
Self inductance depends on the inductance of the connecting leads and of the winding.
Thanks to metal spraying by which all winding turns are connected, the self inductance is typically extremely low.
Since the inductance can be reduced but never completely eliminated, at a certain frequency (fo) the capacitive and inductive reactances are equal.

$$\frac{1}{(\omega_0 \cdot C)} = \omega_0 \cdot L \qquad \text{where} \quad \omega_0 = 2\pi f_0$$

fo is called resonant frequency and at frequencies > fo the inductive component of the capacitor prevails.
The inductance values indicated in the specifications are typical and referred to the resonant frequency, at 20±5°C.

B27- Insulation Resistance (IR) and Time Constant (s)

Insulation resistance consists of the insulation resistance of the dielectric (layer/ layer) and that of layer and case, which is determined by the quality of the insulating materials (insulating tapes, plastic boxes, sealing resins and so on).
IR is the ratio of an applied DC voltage to the current flowing after a specified time. It is dependent on temperature, voltage and time.

The time constant (s) of a capacitor is the product of IR and the Capacitance value

s= MΩ x μF

B28- Test Categories (reference: IEC 60068)

Capacitors can be graded in accordance with the following test categories which result from the test conditions according to which capacitors have been tested:

Test	Preferred values			
A (cold, °C)	-65	-55	-40	-25
B (dry heat, °C)	+70	+85	+100	+125
C (damp heat, days)	04	10	21	56

Example:
test A= -40°C; test B= +85°C, test C= 56 days.
Test category= 40/085/56

B29- Permitted Temperature and Humidity

They are dependent on capacitor type and are identified in accordance with DIN40040:

Permitted temperature and humidity in accordance with DIN 40400				
1st code letter	**E**	**F**	**G**	**H**
Minimum temperature (°C)	-65	-55	-40	-25
2nd code letter	**S**	**P**	**M**	**K**
Maximum temperature (°C)	+70	+85	+100	+125
3rd code letter humidity category	**G**	**F(E[3])**	**D**	**C**
Average relative humidity	≤65%	≤75%	≤80%	≤95%
30 days per year, continuosly [1]	-	95%	100%	100%
60 days per year, continuosly	85%	-	-	-
For the remaining days, occasionally[2]	75%	85%	90%	100%

[1] These days should be suitably spread evenly out over the year.
[2] Keeping the annual average.
[3] For humidity category E, rare and slight dew precipitations additionally permitted

IMPORTANT: capacitors prolonged exposure to combined high humidity and high temperature must be avoided and related critical environmental conditions carefully evaluated since potentially leading to a rapid deterioration of the performances and reliability

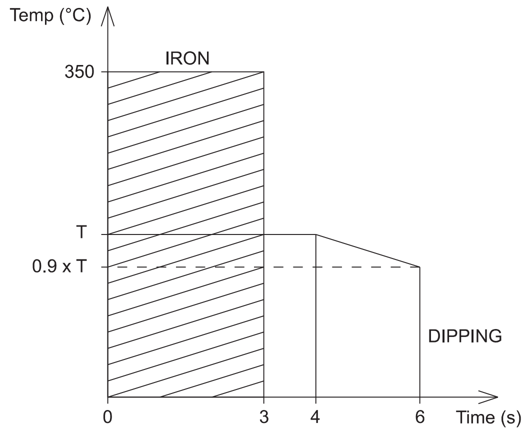
B30- Solder conditions for capacitors; terminals RoHS compliance

Solder bath (or soldering iron) temperature and time must be set to obtain good solderability avoiding the components damage.
The soldering temperature must be set keeping the temperature inside the capacitors below the following general limits:

+110°C for KP and MKP units (+100°C for radial units with leads pitch P≤ 7.5mm or axial units with body length L≤ 10.5mm)
+155°C for MKT, KC and MKC units (+145°C for radial units with leads pitch P≤ 7.5mm or axial units with body length L≤ 10.5mm)

General technical information

Temperature profile:



T= 260±5°C for 4s (general*)
* for KP/MKP P=5; 7.5mm and L=10.5mm: Tmax.= 250°C for 3s

Pre-heating: it must be made at +110°C max. for 1 min. max. (+100°C max. for KP/ MKP units with leads pitch P≤ 7.5mm or axial units with body length L≤ 10.5mm).
Avoid excessive termal stress which may result in the capacitors damage, in particular in case of small size units.
General soldering conditions:.
- if two solderings are needed, it is necessary a recovery time until the capacitors surface temperature is below +50°C
- reflow soldering by combining the leaded types with SMD ones must be avoided
- when fixing SMD parts in combination with leaded ones, any passing through adhesive curing oven must be avoided
- capacitors with radial terminals must rest on the PCBs.
- for axial terminals capacitors has to be kept a soldering distance of min. 6mm between the capacitor body and the solder connection
- it has to be kept a min. 1.5mm distance for vertical mounting

***Warning*: the permissible heat exposure on film capacitors is limited by upper category temperature. Long exposure to temperature levels above this limit may cause irreversible changes of the capacitor characteristics or its damage.**
In addition to solder bath temperature and the soldering process time, thermal load applied to the capacitor is also affected by pre-heating and post soldering temperature.
Since the soldering heat is mainly transmitted in the units through the leads, the process is more critical for small size capacitors.
For critical types capacitors soldering, in addition to checks of the process effect on the capacitors, a particular care is required; the keeping of maximum possible distance from solder bath, the use of solder resistant coatings and the forced ventilation cooling is suggested.
Moreover, if pre-heating cannot be avoided, the soldering process conditions should be possibly readjusted.
Particular assembly need, like welding on metal bars or other relevant mass conductors, requiring long time/ high heating levels exposition, potentially causing inner contacts damages or hidden deterioration must be avoided or made by taking the utmost care and attention.

Terminals RoHS compliance: terminals are Lead-free and Bismuth-free (made with massive copper with 100% Sn typical coating), in conformity with RoHS and REACH requirements (please refer to web site www.icel.it for detailed information).

B31- Dimensions, tolerances, terminals position and centring, lugs screws fixing torque and connection mode

Dimensions and materials may be subjected to reasonable variations due to available raw materials and normal fluctuations in the manufacturing process; moreover, high stress working conditions, like operation at maximum ratings and at the max. rated temperature, may cause dimensional variations which should be taken in account when designing capacitors placement in equipments and on PCBs.
Tolerances on dimensions are usually specified for every type in the series specifications.

Box with radial terminals capacitors:
Unless otherwise specified, the following tolerances on nominal box dimensions “Bd” declared must be taken in consideration:

Size tolerances	
Bd (mm)	Tolerance (mm)
≤ 10	±0.30
10 < Bd ≤ 18	±0.45
18 < Bd ≤ 32	±0.60
32 < Bd ≤ 42.5	±0.80
> 42.5	±1.0

Radial terminals position (wire terminals): the terminals off-set from the capacitors body longitudinal center-line is

To≤ d (d= terminals diameter)

but need not to be lower than 0,8mm; for 4 or 6 x terminals versions, the maximum terminals off-set from the simmetrical position from the capacitors body center-lines is Do= 1,7 x d (d= terminals diameter).

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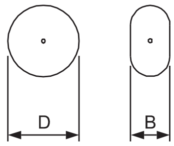
Axial terminals capacitors:

Axial terminals position and centring (99,7% of the pieces): the centring error from the capacitors body axis is

Ce ≤ (Y/X)+d

where d is the terminals diameter and Y is the nominal diameter or thickness.



Y = D or B (mm)	X
≤ 16	9
> 16 and ≤ 34	11
> 34	10

In any case, Ce need not to be lower than 2 x d (d= terminals diameter).
0,3% of the pieces may show terminals centring error up to 1,2 x the above limits.

Box capacitors with lug terminals:

Lugs position: within drawings quotes and tolerances specified for each type and lug style, the lateral shifting of lugs position referred to the box center-line must be ≤ 2.5mm, unless differently specified. A little lugs inclination, lacking of parallelism or lugs fixing surfaces laying on sligthly offset planes is admitted, if not affecting the fixing pitch and the correct mounting and fixing.

Lugs screws fixing torque: 5Nm max. The fixing must be enough to ensure the electrical connection and a stable positioning-contact against vibrations and mechanical stresses (it is necessary and enough that the connection is not loose, not allowing the capacitor body free moving; in excess torque is almost unuseful).

Lugs material: lugs are normally made with (tinned) massive copper (brass as a possible alternative)

WARNING: lugs bent, torsion, inclination or any change of the original design, shape, geometry and position for mounting and fixing of the capacitors onto equipments contacts is not admitted, since potentially causing lugs irreversible damage and mechanical weakening.

Box capacitors with cable terminals:

Cables position: within drawings quotes and tolerances specified for each type, the cables exit point position from the sealing is not ruled and standardized, even if typically located near the box head walls, almost at the centreline of the sealing, unless differently indicated in specifications upon agreement with customers.

Cables sealing: at the exit point from sealing, cables are not required to be exactly perpendicular to the sealing surface, unless differently indicated in specifications upon agreement with customers.

In any case the cable sheath is completely and permanently fixed and overed by the sealing, without showing unprotected or unsealed cables conductors.

B32- Standard Environmental Conditions for Test

Unless otherwise specified, all the electrical data stated in the specifications are referred to a temperature of +15÷35°C, an atmospheric pressure of 86÷106kPa (860÷1060 mbar) and a relative humidity of 25÷75% (reference: IEC 384-1 ed.4.0).

B33- Typical curves

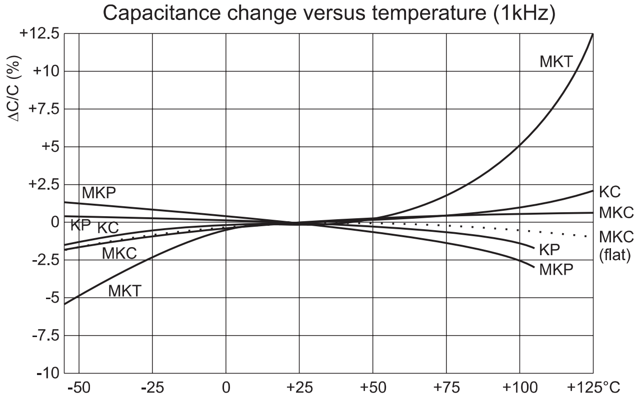
Main electrical parameters variation in function of temperature and frequency.

General data for comparison aims.

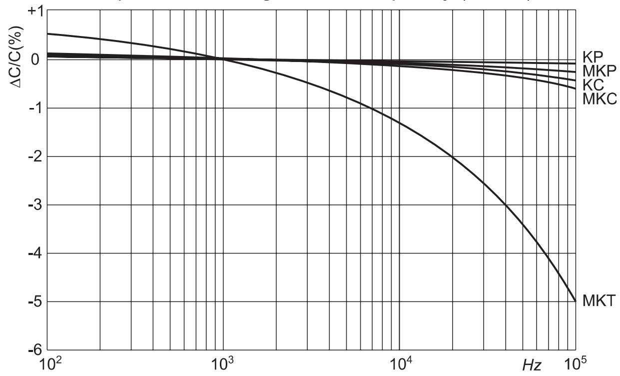
The real behaviour of each single capacitor and its parameters variations versus temperature and frequency may be quite different from the following typical curves, depending on capacitance value, execution, shape, design-construction and several other interacting factors.

MKT= metallized polyester
KP= film-foil polypropylene
MKP= metallized polypropylene
KC= film-foil polycarbonate
MKC= metallized polycarbonate

Capacitance change versus temperature (1kHz)

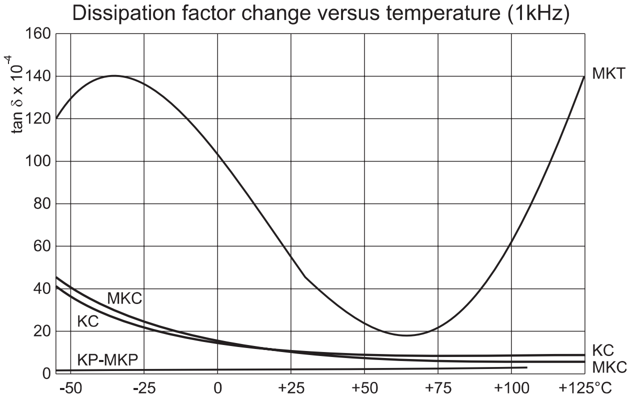


Capacitance change versus frequency (+25°C)

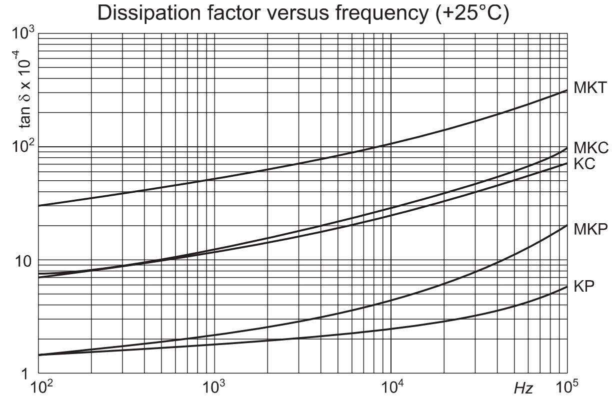


General technical information

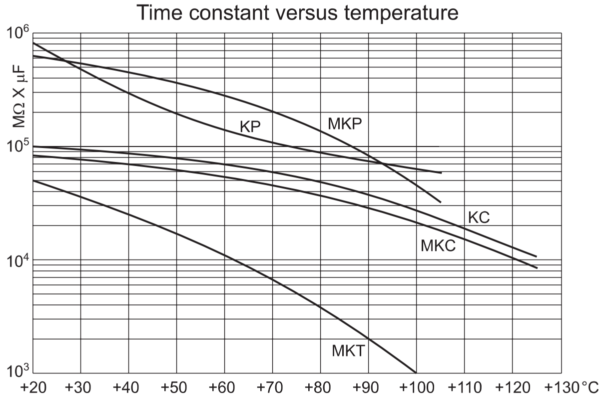
Dissipation factor change versus temperature (1kHz)



Dissipation factor versus frequency (+25°C)



Time constant versus temperature



B34- Reference Reliability and Failure Rate (λ)

The reference reliability states a component type fraction failure under a defined load / operating condition.
This fraction failure will not be exceeded within a specified operating time.
The reference operating condition to which the reliability and failure rate are referred is typically +40°C at 30% relative humidity with 0.5 x Ur (DC) continuously applied to the capacitor.

Failure rate λ is the fraction failure divided by a specified operating time and it is expressed in fit (failure in time), as follows:

1 fit= 1 x 10^{-9} / h (1 failure per 10^9 component hours)

Failure rate, when available, is referred to failure rate criteria like short or open circuit, main electrical parameters variation limits and so on, declared in each series specification.

Typical failure criteria:

- short or open circuit
- capacitance variation >±10%
- Dissipation factor variation > 2 x initial limits
- (possible additional criteria to be indicated in the type specification)

In order to estimate the typical expected failure rate in function of load / operation characteristics different from the one taken as a reference for nominal failure rate, following conversion factors (CF) may be used:

Working Voltage (Uw/Ur)	CF
1	x 20
0,75	x 4
0,5	x 1
0,25	x 0,4
0,1	x 0,2

Working Temperature(°C)	CF
≤ +40	x 1
+ 55	x 2,5
+70	x 6
+85	x 15
-	-

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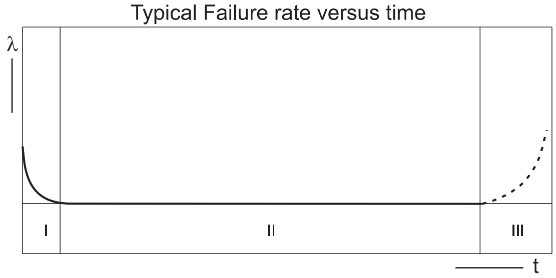
Typical components failure rate curve in function of time, shows three characteristic periods in the components life:
-a first period (I), when early failures occur
-a second period (II) during which the failure rate can be considered approximatively constant
-a third period (III) when failures increase due to aging wear:

Typical Failure rate versus time



Failure rates data at specifications are typically referred to the second period (II).

Warning: figures stated about expected life and failure rates are mainly based on application experience and accelerated ageing tests; they are referred to average production conditions and must be considered as mean values, based on statistical expectations for a large number of lots of identical capacitors.

The above information and data must be considered as general indications.
Always refer to the data listed in the specifications for each type of capacitor.

B35- Life expectancy (Le)

The Life Expectancy of the power capacitors series is referred to a reference nominal voltage Un and to the hot spot temperature of the capacitor case (unless differently specified, the typical reference temperature is T= +70°C).
The Life Expectancy may be improved derating the operating voltage and / or the operating temperature.

Life Expectancy as a function of operating voltage can be approximately obtained with the following formula:

$Lw = Le\ (Un / Uw)^{E}$

Lw (h)= life expectancy at the operating voltage Uw
Le (h)= life expectancy at the voltage Un (given in specifications)
Un (V)= reference voltage to which Le is referred
Uw (V) = operating voltage (Uw ≤ Un)
E = 8 (typical value; depending on capacitor design and construction)

Warning: a good approximation of the capacitor behaviour can be obtained at Uw values narrow to Un reference only. At Uw >Un the “E” value significatively encreases (up to double or more). **Do not operate capacitors over the allowed voltage.**

Life Expectancy as a function of the hot spot temperature of the capacitor case can be approximately obtained with the following formula:

$Lw = Le \times 2^{(T-Ths) / Ac}$

Lw (h)= life expectancy at the operating temperature
Le (h)= life expectancy at the reference temperature T (given at specification)
T (°C)= reference temperature (+70°C, unless differently specified)
Ths (°C)= hot spot case temperature at stationary working conditions (≤ +70°C, unless differently specified)
Ac (Arrhenius coefficient expressed in °C)= 7 (typical; depending on capacitor design and construction)

Warning: the above formula is derived from Arrhenius equation which describes the ageing of organic dielectrics as a function of the temperature. It gives a good approximation of the capacitor behaviour only if the temperature range taken in consideration is not too large.
Do not operate capacitors over the allowed temperature.

ICEL technical office shall be contacted in order to estimate life expectancy data, to ensure the use of the correct type of capacitor for the application and the adequate reliability level for the life time target reference.
In order to obtain long life and low failures incidence keep enough large safety margins on ratings compared to application operating conditions, when choosing capacitors.

B36- EN60252-1 normative Life Expectancy Classes

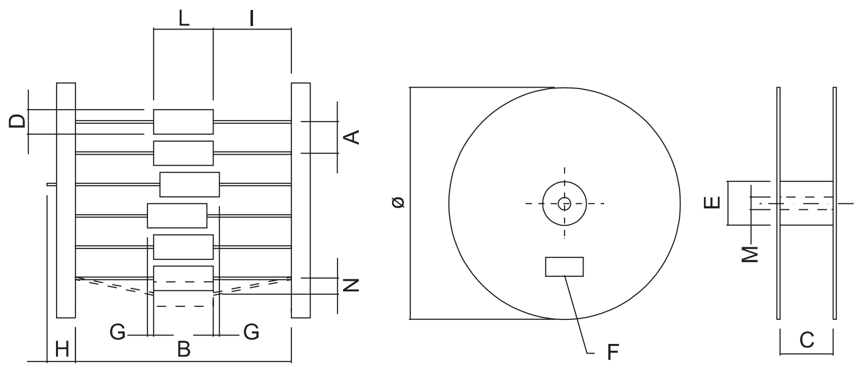
The following Life Expectancy Classes are used to rate the capacitors types approved in conformity with EN60252-1 normative:

Class A: 30000 hours
Class B: 10000 hours
Class C: 3000 hours
Class D: 1000 hours

The Life Expectancy Class is referred to an operating voltage, frequency, temperature and duty cycle related to the EN60252-1 approval obtained.
The Life Expectancy Class code is printed in EN60252-1 approved capacitors markings.

General technical information

B37- Taping specification for axial capacitors



Description	Symbol	Dimensions (mm)
Capacitor diameter	D	4,5 ÷ 19,5
Capacitor length	L	10,5 ÷ 32,0
Component pitch	A*	See table I
Reel core diameter	E	60
Arbor core diameter	M	16
Reel diameter	ø	340+5
Marking	F	See table II
Tape width	H	6±0,5
Body location (lateral deviation)	G	≤ 0,8
Body location (longitudinal location)	N	≤ 1,2
Tape spacing	B	See table III
Lead length from the capacitor body to the adhesive tape	I	≥ 20
Distance between reel flanges	C	See table III
* Cumulative pitch tolerance does not exceed 1.5mm over six consecutive components.		

Table I	
D (mm)	A (mm)
< 5	5
5 ÷ 9,5	10
9,6 ÷ 14,7	15
14,8 ÷ 19,5	20

Table II (reel marking)
- Manufacturer’s name - Capacitor type and code - Electrical values - Component quantity - Date

Table III		
L (mm)	B±2	C (mm)
≤ 13	53	75
19	63	86
> 19	73	95

Typical capacitor quantity per reel	
D (mm)	A (mm)
≤ 5	2000
5 ÷ 10	500 ÷ 1000
10,1 ÷ 19,5	125÷ 350

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B38- E series according to DIN41426 and IEC 60063 (preferred capacitance values; note: different, particular values may be adopted in specific cases or upon customer request**)**

E series according to DIN 41426 and IEC 63 (preferred capacitance values).											
Values	E96	E48	E24	E12	E6	Values	E96	E48	E24	E12	E6
	(±1%)	(±2%)	(±5%)	(±10%)	(±20%)		(±1%)	(±2%)	(±5%)	(±10%)	(±20%)
1,00	■	■	■	■	■	3,30			■	■	■
1,02	■					3,32	■	■			
1,05	■	■				3,40	■				
1,07	■					3,48	■	■			
1,10	■	■	■			3,57	■				
1,13	■					3,60			■		
1,15	■	■				3,65	■	■			
1,18	■					3,74	■				
1,20			■	■		3,83	■	■			
1,21	■	■				3,90			■	■	
1,24	■					3,92	■				
1,27	■	■				4,02	■	■			
1,30	■		■			4,12	■				
1,33	■	■				4,22	■	■			
1,37	■					4,30			■		
1,40	■	■				4,32	■				
1,43	■					4,42	■	■			
1,47	■	■				4,53	■				
1,50	■		■	■	■	4,64	■	■			
1,54	■	■				4,70			■	■	■
1,58	■					4,75	■				
1,60			■			4,87	■	■			
1,62	■	■				4,99	■				
1,65	■					5,10			■		
1,69	■	■				5,11	■	■			
1,74	■					5,23	■				
1,78	■	■				5,36	■	■			
1,80			■	■		5,49	■				
1,82	■					5,60			■	■	
1,87	■	■				5,62	■	■			
1,91	■					5,76	■				
1,96	■	■				5,90	■	■			
2,00	■		■			6,04	■				
2,05	■	■				6,19	■	■			
2,10	■					6,20			■		
2,15	■	■				6,34	■				
2,20			■	■	■	6,49	■	■			
2,21	■					6,65	■				
2,26	■	■				6,80			■	■	■
2,32	■					6,81	■	■			
2,37	■	■				6,98	■				
2,40			■			7,15	■	■			
2,43	■					7,32	■				
2,49	■	■				7,50	■	■	■		
2,55	■					7,68	■				
2,61	■	■				7,87	■	■			
2,67	■					8,06	■				
2,70			■	■		8,20			■	■	
2,74	■	■				8,25	■	■			
2,80	■					8,45	■				
2,87	■	■				8,66	■	■			
2,94	■					8,87	■				
3,00			■			9,09	■	■			
3,01	■	■				9,10			■		
3,09	■					9,31	■				
3,16	■	■				9,53	■	■			
3,24	■					9,76	■				

General technical information

C- Application notes, operation and safety conditions

Because of the many different types of capacitors and the many factors involved, it is not possible to cover, by simple rules, installation and operation in all possible cases.
The following information, in addition to single series specifications and to the data up to now listed in “General Technical Information” chapter, are given with regard to the most important points to be considered.

C1- Voltage applied and ionization effects

Higher voltage values than the rated voltage applied to the capacitor may cause permanent damage like the dielectric perforation, short circuit or, in case of metallized film capacitors, an Insulation Resistance progressive decrease and capacitance drop, with decrease of reliability and expected life.
If the capacitor may be subjected to higher voltages than the rated one, due to particular conditions like equipment malfunction, equipment test conditions or else, it migth be adequately protected.
Rated voltage (current) can be applied at temperatures ≤ rated temperature.
At higher temperatures than the rated one, an adequate voltage (and/ or current) de-rating must be applied in conformity with each series specifications. In order to guarantee an high reliability and long term life expectancy, power application capacitors should not be operated at maximum permissible voltage and maximum operating temperature contemporaneously: this should be considered an emergency operating condition, for short periods of time.
Capacitors rated voltage is usually specified DC. For AC application it is suggested to refer to series specifically designed for this kind of usage (do check the foreseen main applications at specifications and the “Capacitors selection guide”).
If a DC rated capacitor is used in AC applications, do not use higher AC voltages than the one stated at specification.
With the exception of series designed for power applications, the AC voltages stated at specifications are referred to sinusoidal waveform.
If DC rated capacitors are used in an application with not sinusoidal or different waveforms from what specified at catalogue, ICEL Technical Office must be contacted before using the capacitor. At high working voltage, ionization may cause a destructive process in the capacitor, often having consequences at medium-long term. The ionization phenomenon (also called corona effect) is due to air contained in the dielectric, bewteen the winding layers of the capacitor and present at the face ends of the capacitive element. If the electric field in the capacitor exceeds the air dielectric rigidity, micro-discharges migth take place in the winding, damaging the film metallization and / or the film itself. This usually causes capacitance drop and may cause overheating due to IR drop, up to short circuit in case of persistent ionization.
The voltage at which ionization phenomenon overcomes a reference limit is called corona on-set or corona off-set voltage in function of its taking place at the rising or at the decreasing of the voltage applied to the capacitor.
The grade of the phenomenon and the damage that ionization is able to cause depends on many different factors like the amount of air trapped in the capacitor, the type of dielectric and electrodes, the design and construction, the accuracy of manufacturing process and the working conditions.
In order to minimize potentially dangerous ionization effects, do always respect the voltage ratings and if possible, choose capacitors having higher voltage ratings than the foreseen application ones, in order to guarantee an enough high safety margin and better reliability.
In particular to ensure the respect of the following condition:

Vpp (peak to peak voltage)$\leq 2 \times \sqrt{2} \times$ Ur (AC)

C2- Pulse applications

In case of pulse applications, it is necessary to consider the following main capacitor characteristics and application data (which are the minimum conditions to be satisfied in order to prevent capacitors damages):

Vmax. (max. voltage) ≤ Ur (DC)

Vpp (peak to peak voltage) $\leq 2 \times \sqrt{2} \times$ Ur (AC)

du/dt or Ipeak ≤ specifications value

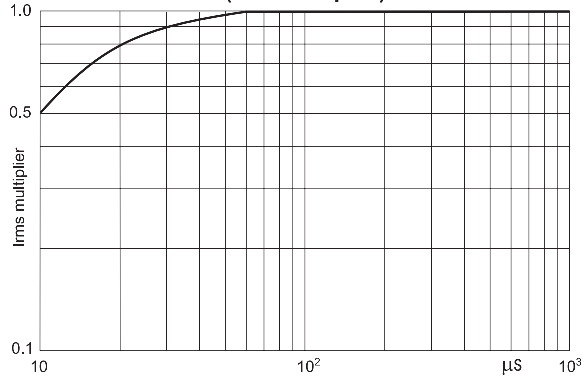
Ko ≤ specifications value

Ur.m.s., Ir.m.s. and waveform / pulse frequency (1/T): refer to permissible AC voltage versus frequency graphs

Upk and Ipk ≤ specifications value

Moreover, in case of short current pulse duration, also the skin effect in the contacts should be taken in account, in accordance with the following graph:

Rated rms current value versus pulse current duration (Irms multiplier)



General technical information

C3- Noises produced by capacitors

During pulse stresses or when submitted to complex waveforms having high frequency distorsion rate, capacitors migth produce buzzing noises due to coulomb forces generated between opposite poles electrodes.
This noise is usually proportional to the size of the stress and its characteristics and may be different with different capacitor construction and design. It is not dangerous for the capacitor and does not typically relate to any damage of the capacitor.

C4- Permissible current

The main effect produced by the current flowing through the capacitor is its heating. This heating, in addition to the ambient temperature, (Ttot.= Tamb.+ΔT/Tamb.) must be maintained lower than the maximum operating temperature for which the capacitors have been designed.
An excessive heating reduces capacitors reliability and migth cause capacitors deterioration up to a short or open circuit, body deformation and melting with smoke emission or fire danger, even if components are protected by flame retardant materials.
The fact that dissipation factor may encrease at temperature exceeding the max. rated temperature, causes a further dangerous heating effect which brings to a fast encrease of the risk of severe damage of the capacitor.
In addition to current linked with pulse operation (please refer to the related paragraphs), the effective currents (Ir.m.s.) due to periodic waveforms cause the entire capacitor body heating.
The combined effect of pulse and r.m.s. currents must be taken in consideration when evaluating the capacitor heating in order to avoid a global over-heating condition. Capacitors designed for high current operation show max. Ir.m.s. values at specification.
In any case, the maximum Ipeak and Ir.m.s. stated at specification must not be overcome. Please contact ICEL Technical Office for support in case of any doubt about application of capacitors subjected to high pulse and r.m.s. currents or particular waveforms.

C5- Operating temperature

A capacitor used in AC applications is submitted to heating due to currents flowing through it. The working conditions and the correct choice of the capacitor must ensure that capacitor working temperature and all the other parameters, remain within the limits stated in the specification.
Operating temperature in excess to the max. admitted or very rapid changes from hot to cold and viceversa may accelerate electrochemical dielectric degradation and cause physical damage to protecting materials (accelerated ageing , their breaking and detouching one from the other and so on).
The direct test of the capacitor heating over the ambient temperature (ΔT/Tamb.) and the Total operating temperature (Ttot.= Tamb.+ΔT/Tamb.) shall be made at load conditions equivalent to the real operating one, but also simulating the worst working conditions foreseen in the application.
The capacitor temperature must be measured at the hottest part of its body (typically in correspondence with contacts / near heads areas or areas having poor dissipation capability because of external reasons like particular disposal on PCBs, presence of other hot components in the surroundings and so on).
The dissipation factor (and the related E.S.R.) of the capacitor under evaluation should be measured and compared with specification data, taking in consideration the typical range of values that different units of the same lot and different lots of the same type may reasonably have.

IMPORTANT: the E.S.R. value does not only change with the frequency but also with the Capacitance value; tolerance on Capacitance must be taken in account: max. Irms ratings are typically referred to Capacitance tolerances ≤ ±10%.

In addition to working conditions in terms of electrical parameters, particular attention must be paid to the correct installation of the capacitor and its position on PCB and in the equipment.
Capacitors shall be placed where there is adequate dissipation by convection and radiation of the heat produced by capacitor losses.
The ventilation of the environment and the placement of the capacitor units shall provide good air circulation around each unit.
This is particularly important for units mounted in rows, one above the other: **always respect the suggested minimum distances between units.**
Extra heating, even if localized on parts of the capacitor body, could be caused by other components or parts in the immediate surroundings either as a consequence of their heating or as a consequence of strong magnetic fields inducing alternating magnetization and currents in metal parts. Capacitors should be situated at a safe distance from heavy current conductors.
The influence of other components near to the capacitor under operating conditions must be always carefully evaluated.

C6- Components fitting on PCBs and arrangement in equipments layout

Dimensional tolerances must be taken in consideration when designing capacitors fitting on PCBs and in the equipments (please also refer to B21 paragraph).
The fitting of capacitors on PCBs and their arrangements in equipments lay-outs with touching bodies or body faces in contact one with the other must be absolutely avoided, expecially if capacitors are positioned in rows, one above the other.
A not adequate distance between units would not allow the correct capacitors heat dissipation and cooling, expecially in case of power applications and in equipments where components are submitted to sensible heating. The contact between capacitors body may also cause phisical damage in case of mechanical stresses (vibrations, shocks) and small settlements of the units body which may occur at high temperature or in particular ambient conditions.

As a general indication, the suggested minimum distance between side by side elements should be at least about 1/12 of the diameter or thickness in case of axial terminals components and at least about 1/8 of the thickness in case of radial terminals capacitors and capacitors in box with lug terminals.

C7- Vibrations and mechanical shocks

Capacitor fixing method is very important in order to minimize detrimental effects due to vibrations or mechanical shocks.
In particular, when foreseen application will submit capacitors to mechanical stresses, axial leaded capacitors shall be adequately fixed to PCBs and capacitors having lug terminals should be positioned in order to guarantee additional body support against vibrations, shocks and mechanical stresses, (elastic silicon gluing, fixing bands etc.), expecially for units having big size and weight.
The mere lugs connection may not be enough to withstand relevant mechanical stresses or vibrations.

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Axial capacitors should have the body resting onto the PCB surface.
The vertical mounting of axial capacitors (resting on one head) should be avoided, adopted just in case of no alternative possibilities and taking in consideration the effects on mechanical stresses and vibration withstanding. Axial units vertical mounting need must be communicated to ICEL s.r.l. in order to adopt execution features preventing potentially problematic mounting and soldering to PCB.
Radial in box capacitors must rest onto PCBs surface (capacitor mounted on PCB with the box supporting area in contact with PCB surface).
If not differently declared or stated by normative taken as a reference in series specifications, the vibrations withstanding for radial in box capacitors is in accordance with IEC 60068-2-6 (test Fc, sinusoidal vibration):

f = 10÷500Hz for leads pitch P ≤ 22.5mm
f = 10÷55Hz for leads pitch P > 22.5mm

3 x 2 hours with 0.75mm amplitude (below 57.6Hz) or 98m/s² (above 57.6Hz), applied in three orthogonal axis No visible damage, no open or short circuit admitted.

Do not exceed the tested ability to withstand mechanical stresses and vibrations. Anyway, in case of possible particularly stressing vibration or mechanical shocks operating conditions an adequate test and behaviour evaluation under real working conditions must be made.

C8- Connections

The current leads into the capacitors (expecially when they are high section lugs, blades and so on) can dissipate heat from the unit but they may also transfer heat generated in outer connections into the capacitor.
For this reason it is necessary to keep the connections leading to the capacitors cooler than the capacitor itself.

Special care is necessary when designing circuits with capacitors connected in parallel or in series.
In parallel connections, the current splitting depends on slight differences of resistances and inductances in the current paths, then one of the capacitors may be easily overloaded. Moreover, when one capacitor fails by short-circuit or simply self-heal, the complete energy of the bank will be rapidly dissipated at the breakdown / clearing point with possible distruction of the unit; the global voltage withstanding capability of a bank of several capacitors connected in parallel is typically (slightly) lower than the performance of a single unit.
In series connections, because of variations in the circulation resistances of units, the correct voltage division between capacitors should be ensured by resistive voltage dividers. The insulation voltage of the single units shall be appropriate for the series arrangement.
The above must be taken in consideration when submitting equipments to over-voltage / over-load tests and evaluating potential equipment malfunctions or failure modes and conditions.

C9- Across the line and interference suppression applications

This type of capacitors is permanently submitted to mains voltage and additional surge or high pulse stress typical of this kind of application.
The capacitor must have an high safety margin, in conformity with related reference standards (EN134200, IEC60384-14 etc.).
For safety reasons, the use of approved components in conformity with the above mentioned standards is suggested and necessary.
In case of across the line application with pulses having Vpp exceeding 630V (for up to 275Vac rated capacitors), the use of additional surge suppressors in parallel to the capacitor is suggested.

C10- Special working conditions

Following special working conditions must be carefully evaluated before using a capacitor in the application:

- *humid ambient*: a capacitor used for a long time in a humid ambient might absorb humidity with gradual electrodes oxidation and medium-long term capacitor damage or failure. Moreover, the capacitor gradually modifies its characteristics according to environmental operating conditions.
The size of modifications and the speed of the process depends on the kind of dielectric, design and protecting materials; a certain capacitance variation takes place as a consequence of air humidity (the capacitance value typically encreases with the encrease of the environment humidity).
The combination of high operation temperature and high humidity levels is a particularly dangerous condition, potentially causing a fast ageing of the capacitor (re.: DIN40040 temperature-humidity graphs), with related relevant decrease of the expected life and increase of the failure probability. This should be taken in account, in particular if units are supposed to be used in tropical countries or at critical environmental and climatic conditions.

- *sealing resins*: chemical and thermal effects due to capacitors embedding in resins and curing process must be taken in account. Solvents contained in the resin migth cause capacitor characteristics deterioration and phisical damage to protection materials. The heat generated in the resin mass during polymerization process may bring to high temperatures and the resin shrinking during hardening may also cause leads breaks or physical damage of the capacitor.

- *immersion in oils-liquids*: oils or other insulating-protecting liquids may cause the damage of the capacitors protecting materials and/ or units destruction. In particular, they may attack the tape adhesive, causing the rapid flagging and detouchment of the insulating tape from the axial capacitors body. In general, immersion in any kind of liquids is not admitted: any need of immersion of the units in oils or other kind of insulating-protecting liquids must be communicated to ICEL s.r.l. for preventive evaluation.

- *adhesive curing*: the resin used to glue SMD components migth cause damage to capacitors dielectric (in particular to polypropylene film) if they are cured in the same oven, expecially when long curing time is combined with the heat necessary for the curing process. When polypropylene capacitors are used with SMD components, they must be fit after the SMD gluing process.

- *rapid mould growth, corrosive atmosphere and ambients with an high degree of pollution (very long permanence at stock before usage)*: carefully evaluate operating conditions which may cause capacitors damage or accelerated aging. Very long term permanence at stock before usage may cause oxidation or other chemical phenomena taking place on the terminals surface, in particular in ambients having high humidity levels, relevant temperature oscillations or presence of contaminating or reacting chemical substances.

- *operating altitude*: capacitors used at big altitudes are subjected to special operating conditions, in particular to potentially reduced heat dissipation efficiency related to the air density and characteristics variation.
For power capacitors, the maximum allowable altitude is typically 2200 meters.

General technical information

Following further unusual service conditions and misapplications may cause failures: superimposed radiofrequency voltages (units not suitable for radio interference suppression), unusual vibrations, bumps of mechanical shocks, abrasive particles, corrosive substances, explosive or conducting dust in cooling air and oil or water vapours, explosive gas or substances, radioactivity, rapid or excessive humidity or temperature changes of working ambient, unusual transportation or storage temperature and environmental conditions.

C11- Materials flame retardancy, RoHS and REACH normative compliance

Unless differently specified, ICEL products are protected with flame retardant materials.
Please refer to the series specifications for detailed information.
ICEL products are manufactured in compliance with RoHS and REACH normative requirements.
Related statements, data and additional information are available at the web site www.icel.it.

D-Storage conditions / Standard environmental conditions

In order to minimize the units ageing and electrical parameters variation before the units real use in the application, it is suggested to avoid capacitors storage where environmental conditions are different from the following (standard environmental conditions):

- Temperature: +15°C ÷ +35°C (ideal), up to +5°C ÷ +50°C admitted.
- Humidity (+25°C): average per year ≤ 60%, 30 days random distributed throughout the year ≤ 80%, other days ≤ 70%, dew not admitted.

These humidity levels should be reduced at ambient temperatures ≥ +25°C, of about 15% for every 5°C of ambient temperature increase, up to +50°C max.
Important: very long term storage may be related to surface oxidation phenomena or other chemical reactions on the copper exposed parts of the terminals (cutted sections); very long term storage, particularly in presence of humidity, may also reduce the terminals solderability.

Note: service life must be considered as the sum of operating hours, operating breaks, storage and testing time at users / customers facility and transport times.

E-Printing and production date code (resistance to solvents)

If not otherwise stated by reference normative, by approvals related to capacitors series or agreed with customers, the typical printing data shown on capacitor body are:

- ICEL trade mark or name
- Series or type
- Rated capacitance and measuring unit
- Tolerance on capacitance (shown in % or with correspondent letter code)
- Rated voltage
- Manufacturing date codes according to DIN41314 and IEC60062:

Year code		
1998= K	2004= S	2010= A
1999= L	2005= T	2011= B
2000= M	2006= U	2012= C
2001= N	2007= V	2013= D
2002= P	2008= W	2014= E
2003= R	2009= X	2015= F

Month code	
January = 1	July = 7
February = 2	August = 8
March= 3	September = 9
April = 4	October = O
May = 5	November = N
June = 6	December = D

Example: capacitors manufactured in October 2010 code= AO; capacitors manufactured in June 2011 code= B6.

Special production data code printing may be agreed ad adopted upon request, if necessary, in order to ensure an extra-detailed products traceability (for example if several, repeated productions and shipments are made in the same month or week, the std. code could be followed by the week number, obtaining a 4 digits code or other special identification codes could be managed, upon agreement).

In addition to above listed data, following additional printing are typically shown on approved series:

- Operating temperature range or climatic class
- Self-healing property
- Protection class
- Expected life class
- Operating frequency
- Approval references and approval Marks

Some of the above mentioned data may be lacking when capacitors shape, dimensions or available printing surfaces do not allow a complete data marking.

Printing resistance to solvents: the printing is usually made on capacitors body with dark ink, resistant to the main common solvents (like alcohol, fluorhydro-carbons and their mixtures) used for PCBs washing and flux residues removal.
Particularly aggressive solvents and cleaning agents based on chloroydro-carbons or ketones must not be used since they may damage the capacitors and their coating materials. ***In particular, any substance containing ketones will probably cause printing melting.***
Moreover also ***some kind of protecting and tropicalizating varnishes may cause printing melting*** and potential capacitors damage.

For this reason, before applying any varnish or protecting liquid or solvent onto capacitors surface, do test its effect on markings and coating materials. It is recommended to carefully dry the components after the cleaning.

F-General Warning (general rules and indications for problems and failures management or rejections)

Not respecting specifications and parameters limits, improper installation, use or application of ICEL products migth cause damage to the components, their characteristics modification and a decrease of their reliability and expected life.
This could bring to dangerous failures which may cause the destruction of the components and of the equipments where they are used, smoke, fire and explosion danger.
Before using ICEL products in any application, please read carefully the related specifications and all the information included in this catalogue.
Information and data contained in the chapter "General technical information", must be considered as a completing part of the single series specifications.
Overstressing and overheating shorten the life of a capacitor, therefore the operating conditions (like temperature, voltage, installation, operation and so on) should be strictly controlled.
Be sure that the component is proper for your application, that the application parameters do not overcome the limits stated at related specification and that all the warnings and instructions for use are correctly followed.
Do check in the intended application and operating conditions of the component before using it in any product or equipment, to ensure that the component is proper for your application.
In case of doubt about service conditions and correspondent capacitors characteristics and performances, or ***in case of application not foreseen or working parameters not stated at capacitors specifications, ICEL Technical Office must be consulted*** (please also refer to the "Application data questionnaire"; paragraph H).
Products manufactured by ICEL are made with maximum attention to quality, in order to be free from difects in design, materials and workmanship, following related series specifications and applicable national and international normative and approvals obtained requirements.
One of ICEL Q.A. system main aims is the prevention of defects occuring.

Cooperation between ICEL and customers is fundamental in order to solve any problem or failure occurring.
In particular, ***the tempestive and exhaustive communication at least of following main information will help ICEL to quickly respond to any complaint you may have***:

- detailed description of the failure / problem
- when and how the failure / problem was detected
- operating conditions and application description
- operating time before the failure / problem occurring
- number of defectives and their percentage on total quntity used / supplied
- original supplied lots data and references (production date, delivery date, qty. etc.)
- fisrt time usage / new application or long term / consolidated application (other lots previously supplied?)
- problems detected during tests or controls or during normal working / on field
- any additional information about particular conditions which may have been associated with the failure / problem occurring

Samples of defectives, if available, should be sent to ICEL for analisys, clearly identified and possibly separated by other "good" units or units damaged for other reasons.

ICEL liability shall be limited to replacement or repair free of charge, provided that notification of failures or difects is given to ICEL immediately when the same becomes apparent and after that returning conditions have been agreed with the customer or buyer and ICEL has analized the defectives and authorized the returning of goods.
Any components rejection of samples delivery must be packed and adequately protected in order to prevent any additional damage different from the originally detected failure or problem, anyway ensuring the material integrity and protection against environmental conditions.

ICEL is not responsible for any possible damages to persons or things, of any kind, derived from improper installation, use or application of ICEL products.
ICEL shall not be liable for any defect which is due to accident, fair wear and tear, negligent use, tampering, improper handling, improper use, operation or storage or any other default on the parts of any person other than ICEL.

In case of defective goods, ICEL shall not be liable, under no circumstances, for any consequential loss or damage arising from the goods sold.
ICEL shall not be liable for any cost due to the customer inappropriate or not effective traceability and products identification system.
The above limitations to ICEL liability for defective goods apply also to product liability: ICEL shall have no responsibility for injury to persons or damage to goods or property of any kind.
In case of any product liability claim from third parties against ICEL, not falling within ICEL liability in accordance with above statements, customer or buyer shall hold ICEL harmless.

G-Updating and validity of product specifications/ General data and information

All drawings, descriptions, characteristics, materials and performance data given by ICEL are as accurate as possible but have to be considered as a general information, so they are not binding on ICEL, unless specifically agreed in writing.

Unless otherwise stated, dimensions and materials may be subjected to reasonable variations due to available raw materials or normal manufacturing process tolerances.

The data and information given in the General Technical Information chapter must be considered a part of the single types and capacitors families specifications contained in this general catalogue.

Data and characteristics shown in this catalogue are subjected to modifications without notice.

Always refer to ICEL web site, www.icel.it, for products updated characteristics, last revision specifications, general data and information, products certifications and news.

General technical information

H-Application Data Questionnaire

In order to help ICEL Technical Office to correctly individuate the component suitable for your needs, please fill this questionnaire, giving us all the available information about the application and the working conditions.

Capacitance (1kHz): Tolerance (%):

Resistor value (Ω, for RC networks only): Resistor power (W, for RC networks only):

Rated DC voltage (Vdc): Operating DC voltage (Vdc):

Rated AC voltage (Vac): Operating AC voltage (Vac):

Repetitive Peak voltage (Vdc): Non Repetitive Peak voltage (Vdc):

Operating frequency (Hz):

Irms max.(A): , at frequency= Hz, at temperature= °C

Max. Pulse Rise Time (V/μs): Max. Repetitive Peak Current (A):

Max. Non Repetitive Peak Current (A):

Pulse width (s): Pulse repetition frequency (Hz):

Max. Dissipation Factor ($x10^{-4}$): tgd= at frequency= Hz; tgd= at frequency= Hz

Max. E.S.R.(mΩ): at frequency= Hz; at frequency= Hz

Insulation Resistance at+25°C (MΩ): after 1 minute at Vdc

Operation: continuous ☐ Intermittent ☐ with Cycle duration / Duty cycle:

Test voltage between leads: Vdc ☐ / Vac ☐, for s, notes:

Test voltage between leads and case: Vdc ☐ / Vac ☐, for s, notes:

Max. rated operating temperature (°C): Min. rated operating temperature (°C):

Max. ambient temperature (°C): Min. ambient temperature (°C):

Cooling: natural ☐; forced ☐, notes:

Climatic category (IEC60068-1 cold test / heat test / damp heat duration): / /

Ambient operating humidity conditions:

Other critical operating conditions:

Expected life (h): Failure rate ($x10^{-9}$ component hours):

Reference conditions: voltage applied= ; temperature= ; others=

Failure modes:

Preferred execution: axial cylindrical ☐, axial flat ☐, radial dipped ☐, radial in box ☐, radial with lugs ☐, other ☐

Notes:

Diameter (mm): , tolerance± mm Thickness (mm): , tolerance± mm

Heigth (mm): , tolerance± mm Length (mm): , tolerance± mm

Leads type: Leads dim. (mm): , tolerance± mm

Printing requirements:

Approvals:

Reference Normatives:

Packing requirements:

Reference / presently used components:

Additional technical information (please enclose drawings, schematic circuit diagram, voltage and current waveforms and application description if available):

Needed quantity: Foreseen order frequency:

Delivery terms: Target price:

Notes:

List of enclosed documents:

General technical information

I - Capacitors selection guide (Main Applications and Products destination)

ICEL TYPE	Blocking	Coupling/ Decoupling (low pulse)	Baypassing	Filtering/ Frequency discrimination	Timing and oscillation / high stability circuits	High DC voltage operation/ voltage multipliers	AC operation (general purpose)	Motor running	High frequency ripple filtering	High Irms current operation	High frequency operation	High pulse / Pulse coupling	Snubber/ protection in semiconductor circuits	Clamper in IGBT and MOSFET circuits	Resonant / Induction heating	Audio (high end)	DC-Link	Electronic Ballasts	Inverters/ Converters/ UPS	AC/DC motor controls	Elevators	Railway traction/ Electric vehicles	Battery chargers	Very low dissipation/ high thermal efficiency	Solar and wind generators	Welders
MTR MWR MWF MTB MSB MSR	X	X	X	X	O		Z	Z								O										
MWS						X																				
PW					X						X	X														
PWS				O	O	O				O	X	X	O		O	O		O						X		O
MPW-F	X	X	X	X	X											O										
MPL	O	O	O	X	X																					
MPB	X	X	X	X	X											O		O								
PPR	X^	X^	X^			O	O		O	O	X	X	X	O	O			O						X		X^
PPB	X^	X^	X^			O	O		O	O	X	X	X	O	O			O						X		X^
MPH	X	X	X	O					X	X	X			X	O	O	O									
DCB	X*	X*	X*	X*					X	X	X			O		O	X		X	X	X				X	Y
PHC	X*	X*	X*	X*					X	X	X			X			O		X	X			X			
PHB	X*	X*	X*	X*					X	X	X			X	O	O	O		X	X	X	X	X		X	Y
PMC	X*	X*	X*						X	X	X			X	O		O		X	X	X	X			X	Y
MHBA	X*	X*	X*	X*			X	O	X	X	X			X	O	O	X		X	X	X	X	X			Y
MHBS	X*	X*	X*	X*			X	O	X	X	X			X	O	O	X		X	X	X	X	X		X	Y
PPS	X°	X°	X°	X°		O	X	O	X	X	X	O	O	X	O				X	X				O		
PHS	X°	X°	X°	X°		O	X	O	X	X	X	O	O	X	X	O			X	X	X	X		O	X	
PMS	X°	X°	X°						X	X	X	O	O	X	X	O			X	X	X	X		O	X	
PPA	X^	X^	X^			O	O	O	O	X	X	X	X	X	X	O			X	X				X		X^
PSB RSB	X^	X^	X^			O	O	O	O	X	X	X	X	X	X	O		O	X	X	X	X		X		X^
PMB RMB	X^	X^	X^						O	X	X	X	X	X	X				X	X	X	X		X		X^
MAR	X*	X*	X*	X*			X	O	X	X	X			X	O	O	O		X	X	O		X			Y
MAB	O	O	O	O			X	X	O	O	O			O		O	O		O	O	O		X		X	
N1				K								O														
N3 - R3				K								O														

X= recommended/ designed for (X*= high frequency; X°= high frequency and medium-high pulse; X^= high frequency and high pulse)

O=possible choice / second choice

K= interference suppression/ sparks elimination

Y= for the DC link (not for the pulse section)

Z= very low voltage only