FILM CAPACITORS

The dielectric material of a film capacitor is a plastic or paper film. In the table below, an overview is given of the film dielectrics used in Philips film capacitor products.

Film dielectrics used in Philips film capacitor products

PARAMETER	DIELECTRIC(1)						UNIT
	P	KT	KC	KPS	KS	KP	
Dielectric constant: at 1 kHz	3.0	3.3	2.8	3.0	2.4	2.2	
Dissipation factor ($\times 10^{-4}$) at 1 kHz at 10 kHz at 100 kHz at 1 MHz	 50 120 200 300	 50 110 170 200	 12 50 100 110	 3 6 12 18	 2 2 2 4	 1 2 2 4	
Volume resistivity	10^{+16}	10^{+17}	10^{+17}	10^{+17}	10^{+18}	10^{+18}	Ωcm
Dielectric strength	100	400	300	250	500	600	V/µm
Maximum application temperature	100	125	125	150	85	100	°C
Power density: at 10 kHz	67	50	21	2.5	0.67	0.6	W/cm^3

Note

1. P = paper; KT = polyethylene terephthalate; KC = polycarbonate; KPS = polyphenylene sulfide; KS = polystyrene; KP = polypropylene.

Because of their typical properties, the polyester and polycarbonate dielectrics are used in general purpose applications where a small bias DC voltage and small AC voltages at low frequencies are usual. The most important properties are the high capacitance per volume for polyester and, the capacitance stability over a wide temperature range for polycarbonate.

A rather new dielectric is polyphenylene sulfide (KPS). Its high melting point allows it to be used in a non-encapsulated SMD product. The properties of KPS determine the stability of the product characteristics.

Polypropylene and polystyrene films are used in high frequency or high voltage applications due to their very low dissipation factor and high dielectric strength.

Paper film is still used in capacitors for mains applications, as for example in interference suppression capacitors.

Typical properties as functions of temperature or frequency are illustrated in Figs 1 to 4.

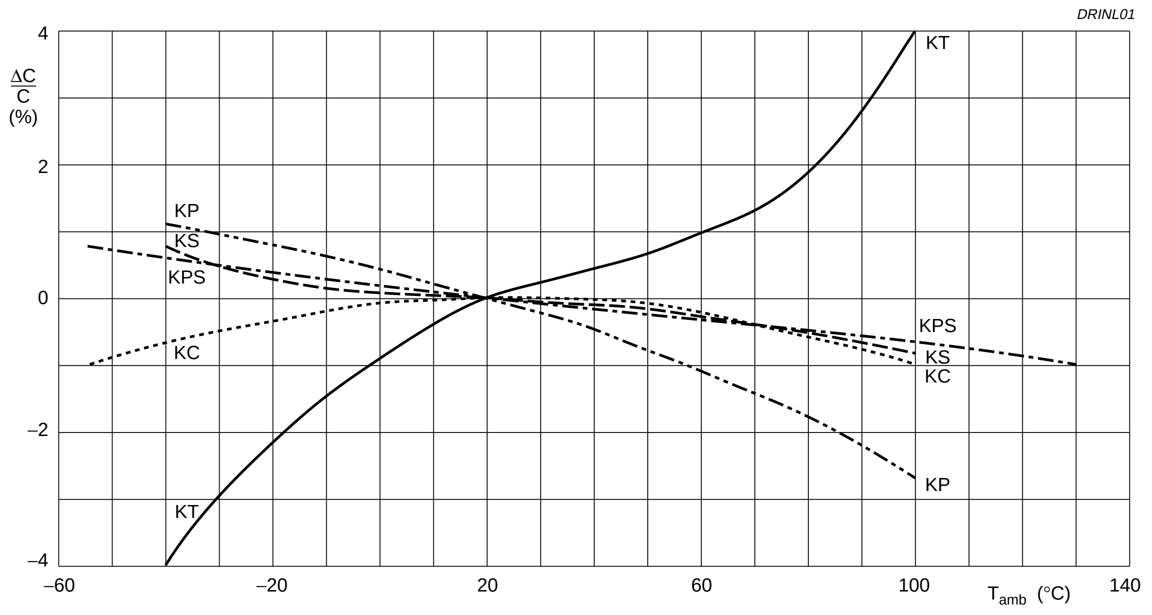

Fig.1 Capacitance change as a function of ambient free air temperature at 1 kHz; typical curves.

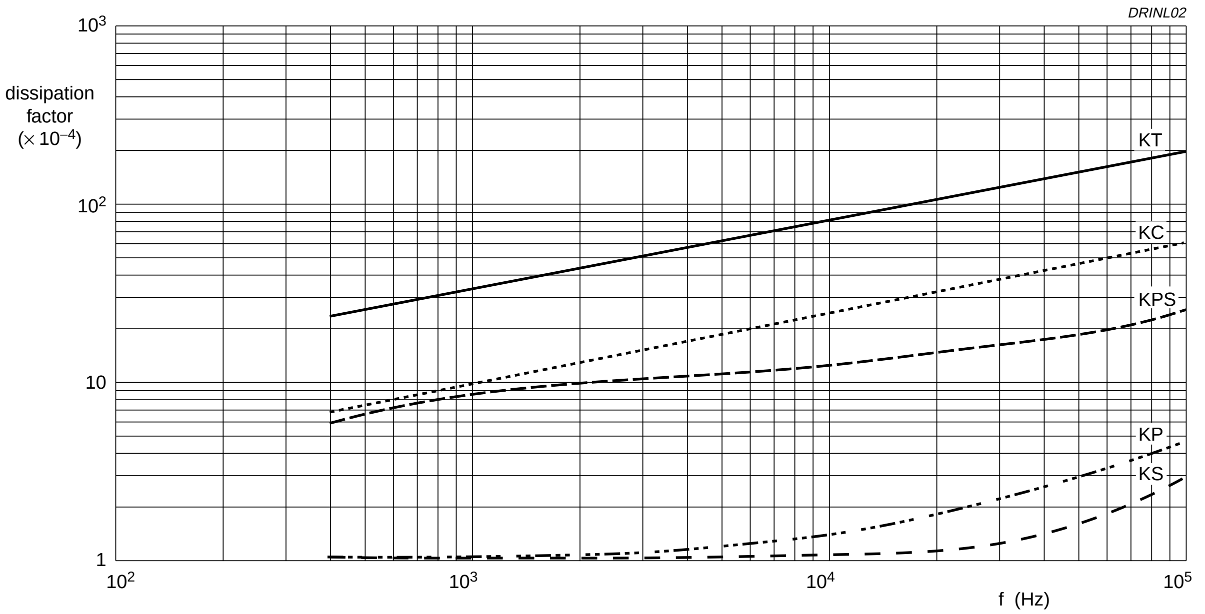

Fig.2 Dissipation factor as a function of frequency at 20 °C; typical curves.

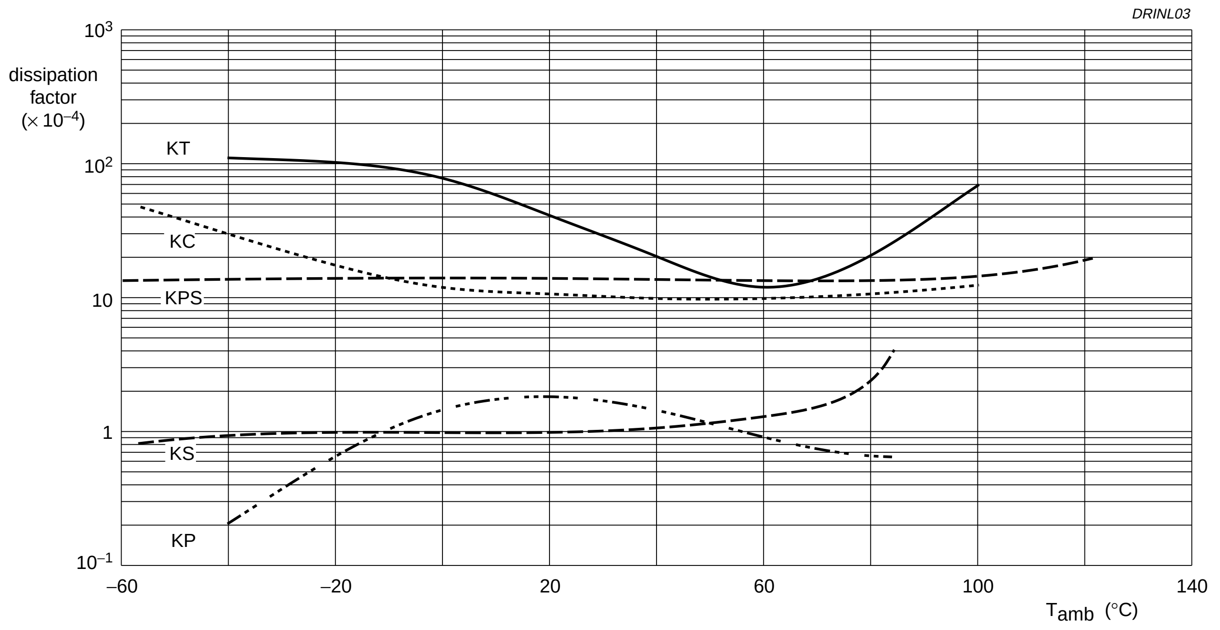

Fig.3 Dissipation factor as a function of ambient free air temperature at 1 kHz; typical curves.

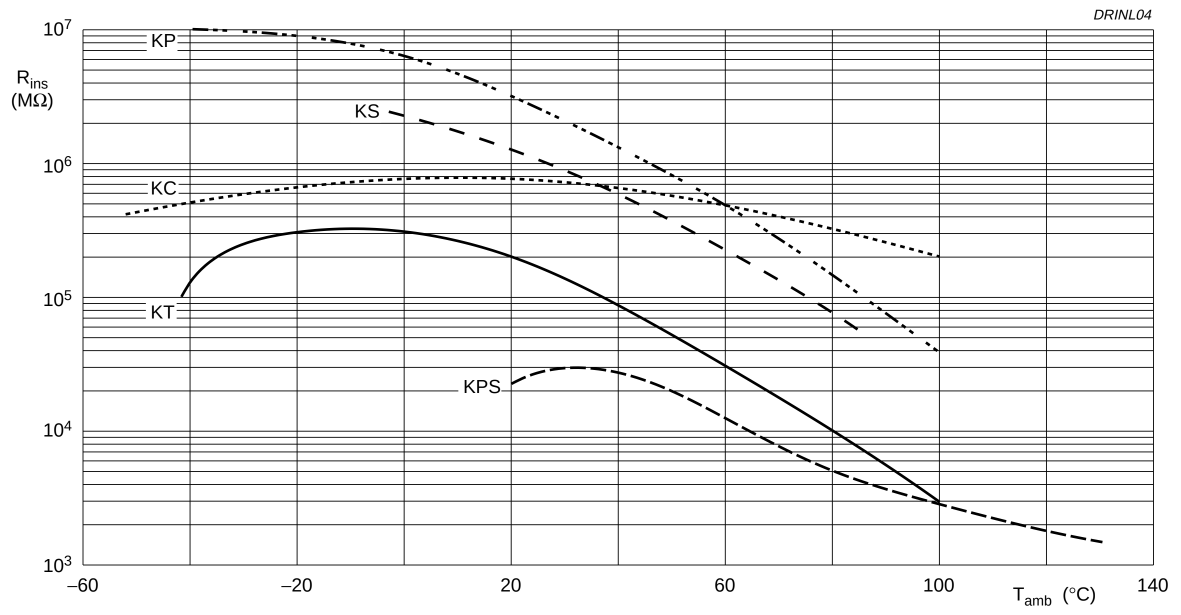

Fig.4 Insulation resistance as a function of ambient free air temperature; typical curves.

CONSTRUCTION OF THE CAPACITOR CELL

The type of electrode used determines whether the capacitor is a metallized film or film/foil type.

The electrodes used for metallized film capacitors consist of a thin metal layer with a thickness of approximately 30 to 50 nm. The electrodes of film/foil capacitors have discrete metal foils with thicknesses of approximately 5 to 10 µm.

Due to their construction, film/foil capacitors can carry higher currents than metallized ones, but are larger in volume.

Metallized capacitors have a self-healing behaviour as an intrinsic characteristic. All capacitor cells are low inductive wound, except for the SMD products which are produced by stacked film technology.

Depending on the AC voltage, single or series constructions are used. Single section capacitors are normally used for products with an AC rating up to 275 V (AC). Series constructions are used for higher voltages.

GENERAL DEFINITIONS

Rated voltage (U_{Rdc})

The maximum DC voltage (in V) which may be continuously applied to a capacitor at any operating ambient temperature below the rated temperature.

Category voltage (U_C)

The maximum AC voltage (or DC voltage) which may be applied continuously to a capacitor at its upper category temperature.

Rated AC voltage (U_{Rac})

The maximum RMS voltage (in V) of specified frequency (mostly 50 Hz), which may be continuously applied to a capacitor at any operating ambient temperature below the rated temperature.

Capacitance

The capacitance of a capacitor is the capacitive part of the equivalent circuit composed of capacitance, series resistance and inductance.

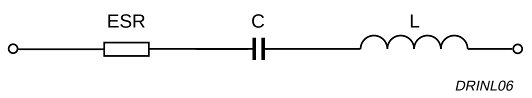

Fig.5 Simplified equivalent circuit.

Rated capacitance

The rated capacitance, normally marked on the product, is the value for which the capacitor has been designed.

Capacitance tolerance

The percentage of the allowed deviation of the capacitance from the rated capacitance is measured at a free air ambient temperature of 23 ±1 °C and RH of 50 ±2%.

Tolerance coding in accordance with *"IEC 62"*

PERCENTAGE OF DEVIATION	LETTER CODE
±1.0%	F
±2.0%	G
±5.0%	J
±10.0%	K
±20.0%	M

A letter "A" indicates that the tolerance is defined in the type specification or customer detail specification.

Temperature coefficient and cyclic drift of capacitance

The terms characterizing these two properties apply to capacitors of which the variations of capacitance as a function of temperature are linear or approximately linear and can be expressed with a certain precision.

TEMPERATURE COEFFICIENT OF CAPACITANCE

The rate of capacitance change with temperature, measured over the specified temperature range. It is normally expressed in parts per million per Kelvin (10^{-6}/K).

TEMPERATURE CYCLIC DRIFT OF CAPACITANCE

The maximum irreversible variation of capacitance observed at room temperature during or after the completion of a number of specified temperature cycles. It is usually expressed as a percentage of the capacitance related to a reference temperature. This is normally 20 °C.

Rated voltage pulse slope (dV/dt)

The maximum voltage pulse slope that the capacitor can withstand with a pulse voltage equal to the rated voltage. For pulse voltages other than the rated voltage, the maximum voltage pulse slope may be multiplied by U_{Rdc} and divided by the applied voltage.

The voltage pulse slope multiplied by the capacitance gives the peak current for the capacitor.

Dissipation factor and equivalent series resistance

The dissipation factor or tangent of loss angle (tan δ) is the power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage of specified frequency.

The equivalent series resistance (ESR) is the resistive part of the equivalent circuit composed of capacitance, series resistance and inductance.

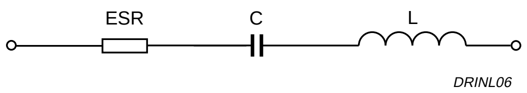

Fig.6 Simplified equivalent circuit.

Insulation resistance and time constant

The insulation resistance (R_{ins}) is defined by the applied DC voltage divided by the leakage current after a well defined minimum time.

The time constant is the product (in seconds) of the nominal capacitance and the insulation resistance between the leads.

Ambient temperature

The ambient temperature is the temperature of the air surrounding the component.

Climatic category

The climatic category code (e.g. 50/100/56) indicates to which climatic category a film capacitor type belongs.The category is indicated by a series of three sets of digits separated by oblique strokes corresponding to the minimum ambient temperature of operation, the maximum temperature of operation and the number of days of exposure to damp heat (Steady state - test Ca) respectively that they will withstand.

Category temperature range

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

Upper category temperature

The maximum ambient temperature for which a capacitor has been designed to operate continuously at category voltage.

Lower category temperature

The minimum ambient temperature for which a capacitor has been designed to operate continuously.

Rated temperature

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

Maximum application temperature

The equivalent of the upper category temperature.

Self-healing

The process by which the electrical properties of a metallized capacitor, after a local breakdown, are rapidly and essentially restored to the values before the breakdown.

Temperature characteristic of capacitance

The term characterizing this property applies mainly to capacitors of which the variations of capacitance as a function of temperature, linear or non-linear, cannot be expressed with precision and certainty.

The temperature characteristic of capacitance is the maximum reversible variation of capacitance, produced over a given temperature range within the category temperature range.
It is expressed normally as a percentage of the capacitance related to a reference temperature of 20 °C.

Storage temperature

The temperature range with a RH of maximum 80% without condensation at which the initial characteristics can be guaranteed for at least 2 years.

Maximum power dissipation

The power dissipated by a capacitor is a function of the voltage (U_{esr}) across or the current (I) through the equivalent series resistance ESR and is expressed by:

$$P = \frac{{U_{esr}}^2}{ESR}$$

$$P = ESR \times I^2$$

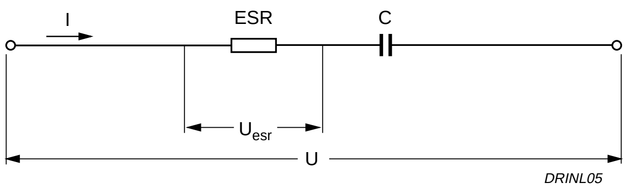

Fig.7 Simplified equivalent circuit.

$${U_{esr}}^2 = \frac{ESR^2}{ESR^2 + 1/\omega^2 C^2} \times U^2$$

Given that for film capacitors $\tan\delta = \omega \times C \times ESR \ll 0.1$ the formula can be simplified to:

$${U_{esr}}^2 = ESR^2 \times \omega^2 \times C^2 \times U^2$$

or with $ESR = \tan\delta / \omega C$

the formula becomes:

$$P = \omega \times C \times \tan\delta \times U^2$$

$$P = \frac{\tan\delta}{\omega \times C} \times I^2$$

For the tan δ we take the maximum value found in the specification, C is in farads and $\omega = 2\pi f$. U or I are assumed to be known.

The maximum permissible power dissipation (P_{max}), which depends on the dimensions of the capacitor and on the ambient free air temperature are given in the specification.

In applications where sinewaves occur, we have to take for U the RMS-voltage or for I the RMS-current of the sinewave.

In applications where periodic signals occur, the signal has to be expressed in Fourier-terms:

$$U = U_0 + \sum_{k=1}^{\infty} U_k \times \sin(k\omega t + \Phi_k)$$

$$I = \sum_{k=1}^{\infty} I_k \times \sin(k\omega t + \Phi_k)$$

with U_0 the DC voltage, U_k and I_k (the voltage and current of the k-th harmonic respectively) the formula for the dissipated power becomes:

$$P = \sum_{k=1}^{\infty} k \times \omega \times c \times \tan\delta_k \times \frac{U_k^2}{2}$$

$$P = \sum_{k=1}^{\infty} \frac{\tan\delta_k \times I_k^2}{2 \times k \times \omega \times C}$$

and tan δ_k is the tan δ at the k-th harmonic.

TEST INFORMATION

Robustness of leads

TENSILE STRENGTH OF LEADS (Ua)
(LOAD IN LEAD AXIS DIRECTION)

Lead diameter 0.5, 0.6 and 0.8 mm: load 10 N, 10 s.

BENDING (Ub)

Lead diameter 0.5, 0.6 and 0.8 mm: load 5 N, 4 × 90°.

Lead diameter 1.0 mm: load 10 N, 4 × 90°.

TORSION (Uc) (FOR AXIAL CAPACITORS ONLY)

Severity 1: three rotations of 360°.

Severity 2: two rotations of 180°.

Rapid change of temperature (Na)

The rapid change of temperature test is intended to determine the effect on capacitors of a succession of temperature changes and consists of 5 cycles of 30 minutes at lower category temperature and 30 minutes at higher category temperature.

Dry heat (Ba)

This test determines the ability of the capacitors to be used or stored at high temperature. The standard test is 16 hours at upper category temperature.

Damp heat cyclic (Db)

This test determines the suitability of capacitors for use and storage under conditions of high humidity when combined with cyclic temperature changes and, in general, producing condensation on the surface of the capacitor.

One cycle consists of 24 hours exposure to 55 °C and 95 to 100% relative humidity (RH).

Cold (Aa)

This test determines the ability of the capacitors to be used or stored at low temperature. The standard test is 2 hours at the lower category temperature.

Damp heat steady state (Ca)

This test determines the suitability of capacitors for use and storage under conditions of high humidity.
The test is primarily intended to permit observation of the effects of high humidity at constant temperature over a specified period.
The capacitors are exposed to a damp heat environment which is maintained at a temperature of 40 °C and a RH of 90 to 95% for the number of days specified by the third set of digits of the climatic category code.

Soldering conditions

With regard to the resistance to soldering heat and the solderability, our products comply with *“IEC 384-1”* and the additional type specifications.

For our precision capacitors where capacitance stability is important, we refer to the paragraph “Soldering conditions” in the type specification.

In the tables *“Quick reference test requirements”* an overview is given for the various soldering parameters per product type.

Solvent resistance of components

Soldered capacitors may be cleaned using appropriate cleansing agents, such as alcohol, fluorhydro-carbons or their mixtures. Solvents or cleansing agents based on chlorohydrocarbons or ketones should not to be used, as they may attack the capacitor or the encapsulation.

After cleaning it is always recommended to dry the components carefully.

Special attention should be given to non or partially encapsulated products (e.g. KS 424 ... 431).