AC Capacitor Application Guide

This guide covers Cornell Dubilier's AC capacitor types in depth and discloses the latest information on performance and application.

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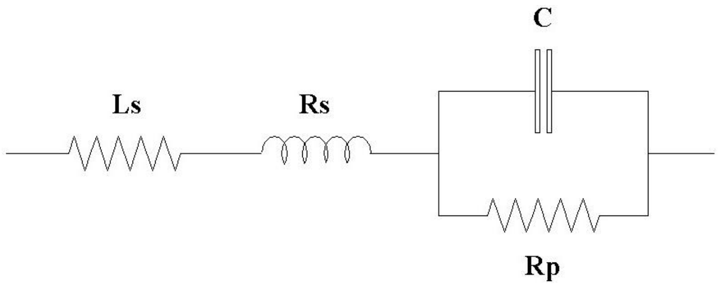
AC CAPACITOR CONSTRUCTION

Cornell Dubilier's AC capacitors are constructed with biaxially oriented metallized polypropylene film wound into a cylindrical roll. End contact is formed by zinc metal spraying all of the layers on each side of the winding which assures low ESR and low inductance. Metallized polypropylene film provides a self healing mechanism in which a dielectric breakdown "clears" away the metallization and isolates that area of the capacitor within microseconds. These capacitors boast low losses where very low Dissipation Factor and ESR allow for relatively high current density.

CAPACITOR SERIES EQUIVALENT CIRCUIT MODEL



PARAMETRIC CHARACTERIZATION

The table below shows useful capacitor parameters for the series equivalent-circuit model shown schematically in **Figure 1**.

Parameter	Unit	Symbol	Formula	Approx.
Capacitance	farads (F)	C		
Capacitive Reactance	ohms (Ω)	Xc	$1/(2\pi fC)$	Z
Current	amperes (A)	I	C(dV/dt), Vz/Z	
Dissipation Factor	none	DF	Rs/Xc, $2\pi f$CRs, tan(δ), cot(θ)	PF
Energy	Joules (J)	E	$\frac{1}{2}CV^2$	
Equivalent Series Resistance	ohms (Ω)	Rs	$DF/(2\pi fC)$	
Frequency	hertz (Hz)	f		
Impedance	ohms (Ω)	Z	$[Rs^2+(Xc-X_L)^2]^{1/2}$	Xc
Inductance	henries (H)	Ls		
Inductive Reactance	ohms (Ω)	X_L	$2\pi f$Ls	
Loss Angle	degrees (°)	δ	$\tan^{-1}$(DF)	
Phase Angle	degrees (°)	θ	$\cot^{-1}$(DF)	
Power	watts (W)	P	I^2Rs	
Power Factor	none	PF	Rs/Z, sin(δ), cos(θ)	DF
Quality Factor	none	Q	Xc/Rs, 1/DF, cot(δ), tan(θ)	1/PF
Self-Resonant Frequency	hertz (Hz)	ω_o	$1/[2\pi(LC)^{1/2}]$	
Voltage	volts (V)	V	Vc=IXc, Vz=IZ	
Volt-Amperes	V-A	VA	IVz, I^2Z	

DEFINITIONS

RATED TEMPERATURE

The rated temperature is the range in temperature in which the capacitors will perform to their full rated service life objective. Typically AC capacitors will have a rated temperature of –40 to +70 °C for a motor run application and -40 to +90 °C for a power supply type application.

RATED CAPACITANCE

The rated capacitance is the nominal capacitance and it is specified between 50Hz to 120Hz and a temperature of 25 °C. The rated capacitance is also the capacitance marked on the unit.

DISSIPATION FACTOR (DF)

Dissipation factor is the measurement of the tangent of the loss angle (tan δ) expressed as a percentage. It is also the ratio of the ESR to the capacitive reactance and is thus related to ESR by this equation:

$$DF = 2\pi fC(ESR)/10{,}000$$

Where DF is a unit-less number expressed in percent, test frequency f is in Hz, capacitance C is in µF and ESR is in Ω.

EQUIVALENT SERIES RESISTANCE (ESR)

The equivalent series resistance (ESR) is a single resistance representing all of the ohmic losses of the capacitor and connected in series with the capacitance.

RMS CURRENT

AC capacitors with ¼" x 0.032" blade style terminals can handle a maximum RMS current of 15 Arms, including harmonics, 60Arms for the enclosed block terminals.

LEAKAGE CURRENT

When energized between their shorted terminals and the capacitor case at a potential of 115 Vac 60 Hz their leakage current shall not exceed the following:

Nominal Capacitance	Leakage Current
0 - 14 µF	60 µA
14.1 - 20 µF	70 µA
20.1 - 35 µF	100 µA
35.1 - 80 µF	150 µA

INSULATION AND GROUNDING

AC capacitors are manufactured to minimize electrical leakage from terminal to terminal and terminal to case. Due to the non ideal nature of all insulating materials a maximum allowable leakage current to the case as well as between terminals has been established.

Grounding of the metal case is recommended.

VOLTAGE WITHSTAND TESTS

AC capacitors are designed and 100% tested to withstand a potential difference equal to 1.75 X rated AC voltage between terminals and 2 X rated AC voltage plus 1,000 volts for one second between terminals and case.

SELF RESONANT FREQUENCY

The self-resonant frequency is the frequency at which the capacitive reactance (1/2πfC) equals the inductive reactance (2πfL). At this point, where its impedance approaches zero, the capacitor can be considered to be purely resistive. At frequencies above self resonance, the capacitor is inductive.

DIELECTRIC ABSORPTION

Is a property of an imperfect dielectric material that allows the capacitor utilizing this material to absorb and accumulate a certain amount of energy even after being completely discharged. These charges will accumulate in the dielectric body and not on the capacitor plates (electrodes). Dielectric absorption can be approximated by the ratio of the voltage before discharge to the self recharged (absorbed) voltage level.

VIBRATION WITHSTANDING CAPABILITY

AC capacitors are manufactured to withstand a test outlined in the EIA 186-7E STD of (10 to 55Hz per plane) test method III with modification to the duration time which is reduced to 30 minutes from of 120 minutes equating to 5G.

SAFETY CONSIDERATIONS

The built in protection mechanism requires that there is a minimum of 0.5" of clearance above the capacitors terminals to allow for case expansion. This clearance distance should be carefully observed.

RELIABILITY AND LIFETIME

AC capacitors are rated for a full service life of 60,000 h with an estimated 94% survival rate when operated at full rated voltage, 60 Hz and rated ambient temperature.

FAILURE MODES

AC capacitors feature an internal mechanical pressure Interrupter that disconnects the capacitor winding from the voltage source in the event of failure. Failure occurs in open circuit mode.

In either event the capacitor will remain in an open circuit mode.

EARLY LIFE FAILURES

Early-life failures are mostly associated with short-circuit failures from imperfections in the dielectric system. Incidences can be reduced with extended aging or burn-in.

WEAR-OUT

Wear-out failures are mostly open-circuit failures where the integral Pressure Interrupter mechanism has been activated due to material fatigue (wear-out).

OPERATING LIFE

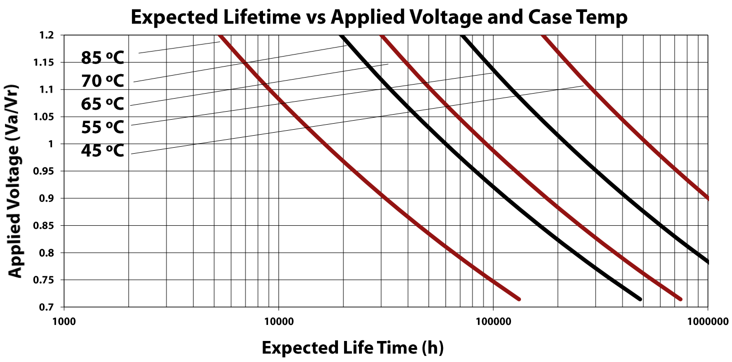
Onset of wear-out is determined mainly by the capacitor's rated voltage and temperature and is relative to the actual applied voltage (both at the fundamental frequency and any harmonic content) and ambient temperature. Operating life can be expressed as

$$L_o = L_r \times 2^{(T_r - T_o)/10} \times \left(\frac{V_r}{V_o}\right)^{6.2}$$

Where

L_{rated} is the rated operating life in h, (60,000 h)
$L_{operation}$ is the expected operating life in h,
T_{rated} is the rated operating temperature in °C,
$T_{applied}$ is the actual temperature applied to the capacitor in ºC,
V_{rated} is the capacitor's rated voltage in Vrms,
$V_{applied}$ is the actual voltage applied to the capacitor in Vrms.

In addition the chart below can be utilized to estimate service life when AC capacitors are to operate at specific conditions outside of the rated specified conditions.



SHELF LIFE

AC capacitors are expected to perform for their full service life objective after being exposed to a maximum shelf life of 10+ years when stored in a controlled environment.

MOUNTING

AC capacitors are manufactured in round and oval metal cases which can be fastened and mounted by a variety of methods. These capacitors can be secured to a chassis or mounting plate by means of a mounting bracket (hardware) or by an optional M8 or M12 mounting stud provided at the bottom of the capacitor case. Please note that the capacitor case will be at the voltage potential of the chassis or mounting plate. A minimum of 0.5" of clearance above the capacitors terminals is required to allow for proper activation of the mechanical pressure interrupter in the event of failure, end of life or over load.

TYPICAL APPLICATIONS

Motor Run

AC capacitors are utilized to provide the necessary starting torque to split phase motors by introducing a phase shift on a secondary motor winding. Motor-run capacitors also provide the necessary power factor correction during the run stage for a more energy efficient motor operation.

Power Supply

AC capacitors are utilized in power supply circuits where noise suppression, voltage regulation and line current reduction is required. These applications typically expose the capacitor to higher order harmonics. The sum of the fundamental and all harmonic currents must not exceed the capacitor's maximum current rating.

Power Factor Correction

AC capacitors are also utilized in power factor correction circuits where they supply leading reactive power (KVAR) to correct the lagging current caused by inductive loads. The circuit is said to be running at unity power factor if the capacitive reactance of the applied capacitors exactly matches the inductive reactance of the load.

PF = KW / KVA

KW = (HP x 0.746) / % efficiency

KVA = KW / PF = $\sqrt{(KW)^2 + (KVAR)^2}$

KVA = V I / 1000 (single phase)

KVA = V I / 577 (three phase)

C = (KVAR x 10^3) / (2 π F $(KV)^2$)

KVAR = (2 F C $(KV)^2$) / 1000