



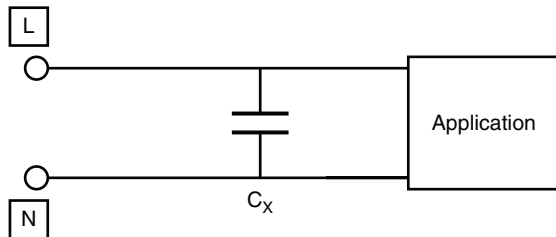
# AC Film Capacitors in Connection with the Mains

Because of the high energy availability and the severe environment of surge voltages and pulses, applications of capacitors in connection with the mains must be chosen carefully. Two kinds of connections and thus two kinds of applications can be distinguished. One is where the

capacitor is directly connected in parallel with the mains without any other impedance or circuit protection, and another where the capacitor is connected to the mains in series with another circuitry.

## CAPACITORS DIRECTLY CONNECTED IN PARALLEL WITH THE MAINS WITHOUT ANY OTHER IMPEDANCE OR CIRCUIT PROTECTION (ACROSS THE LINE OR X CLASS CAPACITORS)

To help reducing emission and increasing the immunity of radio interference, electromagnetic interference suppression film capacitors (EMI capacitors) are playing a major role in all kind of applications. These capacitors are put directly parallel over the mains at the input of the appliances.



Several functions are combined in these small components: excellent high frequency properties for short circuiting radio interference, being continuously stressed by the AC mains voltage and not at least having the ability to sustain transient voltages, caused by for example lightning strikes, switching, superimposed on this line.

For EMI capacitors it is a very difficult job to keep fulfilling the stringent requirements for safety and at the same time to

miniaturize for offering customers benefits in terms of costs, functionality and mounting possibilities.

Five main characteristics can be seen for EMI-capacitors:

- Excellent capacitive filter: Low inductance and equivalent series resistance are preferred
- Withstanding pulse loads: Uncontrolled mains switching must be sustained
- Continuous biased by the mains voltage: A powerful energy supply is always available
- Withstanding surge voltages: High energy surge voltages could destroy the capacitors
- Safe end of life behavior

It has been noted by several national authorities that safety is top priority for these components. Therefore international safety standards have been developed like IEC 60384-14 (world standard) and UL1414 (US standard). National authorities prescribe that EMI capacitors to be connected directly in parallel with the mains must be proved to fulfill these standards. Approved products receive safety certificates and are allowed to have following safety marks:

COUNTRY	SAFETY STANDARD	APPROVAL MARK
U.S.A.	UL 1283 and/or UL 1414	
Canada	CSA-C22.2 No. 8 and/or No. 1	
U.S.A. and Canada	Combination Mark	
China	CQC	
Europe	EN 60384-14 and IEC 60384-14	

APPLICATION NOTE

## AC Film Capacitors in Connection with the Mains

Based on many years of experience Vishay has brought several EMI product series fulfilling these strong safety standards for across the line applications.

Depending on the customer's application needs following product series are recommended:

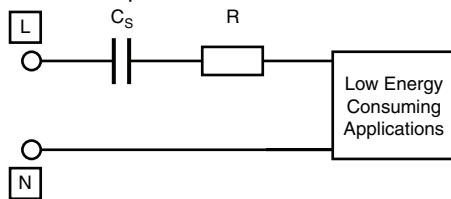
CLASS	X2	X1
VOLTAGE	≤ 310 V <sub>AC</sub>	≤ 480 V <sub>AC</sub>
Standard across the line applications, stability grade as per IEC 60384-14 <sup>(2)</sup>	339 339 M 336 2 338 2 1778	338 1
For continuous <sup>(3)</sup> across the line operation, higher stability grade than per IEC 60384-14 <sup>(2)</sup>	1772	new 338X1 480 V <sub>AC</sub> <sup>(1)</sup>

**Notes**

- (1) Presently in development; expected 1<sup>st</sup> half 2011
- (2) IEC 60384-14 endurance test conditions require ± 10 % capacitance change after 1000 h testing
- (3) Continuous in the meaning of uninterrupted connected to the mains, 24 h/day during several years

### CAPACITORS CONNECTED TO THE MAINS IN SERIES WITH ANOTHER CIRCUITRY (SERIES IMPEDANCE APPLICATION)

In many appliances a low voltage supply is needed for simple low energy consuming functions like sensing, phase detection,... To reduce the voltage, reactive impedances are used like film capacitors.



In this case the capacitors are connected in series with the application to the mains and now the functions to be fulfilled are:

- Stable voltage dropper: a stable capacitance must be guaranteed over the total lifetime of the application
- An adjusted tolerance: To guarantee a well defined current supply
- Continuous biased by almost the mains voltage: Internal ionization must be avoided

But what about withstanding surge voltages? And what about safety?

As these caps are connected through another circuitry, the equivalent impedance of this circuit can protect the capacitor. A film capacitor could be destroyed when a high

energy pulse is applied and the self healing properties are failing (self healing is the ability to recover after a breakdown). As general rule for standard capacitors, not approved according international standards for EMI capacitors, this can happen if surges occur higher than the guaranteed proof voltage. This is in general 1.6 times the rated DC voltage or 4.3 times the rated AC voltage. As it is generally accepted that surge voltage (1.2 μs rise time/50 μs duration) can occur at the entrance of appliances being 2.5 kV for installation category II and 4 kV for installation category III (IEC 60664-1), it must be verified by the customer that the impedance in series with the capacitor limits the over-voltage to these values. In general this will be the case because it can easily be calculated that equivalent impedances will be in the range of 220 Ω to a few kΩ depending on the low voltage application and by this the surge will be topped off to a few hundred volts maximum.

In all other conditions still an approved safety component must be used, but here the extra functions as stable capacitance and adjusted tolerance must be fulfilled as well. This can only be guaranteed by a different capacitor construction wherein two capacitor sections are internally connected in series.

Also for these series impedance applications Vishay can offer a wide range of products fulfilling customer's needs and requirements:

CLASS	WITHOUT SAFETY APPROVALS <sup>(4)</sup>	WITH SAFETY APPROVALS	
VOLTAGE	≤ 275 V <sub>AC</sub>	≤ 310 V <sub>AC</sub>	≤ 480 V <sub>AC</sub>
Standard and continuous <sup>(5)</sup> in series with the mains operation	<sup>(6)</sup>	1772	new 338X1 480 V <sub>AC</sub> <sup>(7)</sup>

**Notes**

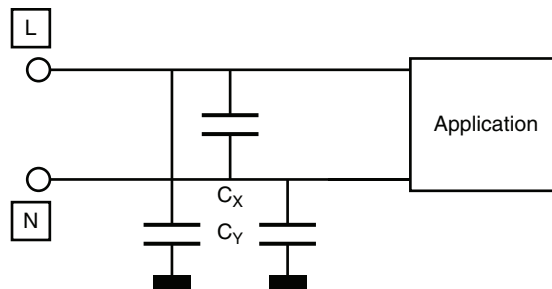
- (4) The applicant must guarantee that the maximum continuous mains voltage is lower than the rated AC voltage and that maximum temporary over-voltages (< 2 s) are lower than 1.6 rated DC voltage or 4.3 times AC rated voltage. Instructions can be found in the application notes and limiting conditions in the detail specifications.
- (5) Continuous in the meaning of uninterrupted connected to the mains, 24 h/day during several years
- (6) For the right choice of the component, contact [RFI@vishay.com](mailto:RFI@vishay.com)
- (7) Presently in development; expected 1<sup>st</sup> half 2011

## AC Film Capacitors in Connection with the Mains

### CAPACITORS DIRECTLY CONNECTED IN PARALLEL BETWEEN THE MAINS AND GROUND (LINE BYPASS OR Y CLASS CAPACITORS)

To help reducing common mode electromagnetic interference, capacitors are connected between mains and ground. For these applications only approved safety

components are allowed. Different safety classes and standards are defined in the same IEC 60384-14 and UL1414 standards.



Vishay has following products in its film capacitor portfolio, adapted for the specific customers need:

CLASS	Y2
VOLTAGE	$\leq 305 V_{AC}$
Standard line bypass applications	1710
Line bypass application for continuous operation <sup>(8)</sup>	338 6

**Note**

<sup>(8)</sup> Continuous in the meaning of uninterrupted connected to the mains, 24 h/day during several years