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[Introduction]

● "CAPAKOR" offers a comprehensive line of (RFI/EMI)noise suppression capacitors on AC mains.

The noise suppression capacitors are used mainly in industrial, consumer and lighting applications for RFI noise suppression and prevention of electric shock to humans.

①The noise suppression capacitors are used on across the line(line-to-line:class X) and line by-pass(line-to-ground:class Y)AC mains inputs to electronic or electrical equipment.

②The noise suppression capacitors are subjected to the rigors of the AC mains-not only is the supply voltage always applied,but also high voltage transient pulses, abnormal surges such as lightning is applied.

Thus, the noise suppression capacitors are designed,

1 to withstand the above stresses existing on the 50/60Hz AC mains and remain safe without degradation of performance.

2 to meet the requirements of IEC60384-14 as well as UL-1414 and UL-1283.

③The noise suppression capacitors are manufactured in self-healing metallized film.

[1] The need for (RFI/EMI)noise suppression

RFI stands for radio frequency interference and EMI stands for electro magnetic interference.

EMI/RFI is a high frequency/low energy noise,typically of a continuous nature that doesn't directly destroy electronic systems,but rather disrupts the proper function by overwhelming the normal signal information within the electrical circuitry,thus EMI/RFI means "decline in the performance of equipment,transmission channels or systems due to noise".

For example,if household vacuum cleaner is running and you are attempting to watch TV.

You may notice lines of interference on the TV screen or even sound distortion.

This interference on the TV is being conducted from the motor of vacuum cleaner through the power lines and into the TV.

Although you may be able to still see and hear the TV,it is not functioning correctly.

This interference may be minor to the TV,but imagine that same interference in medical equipment or an industrial computer controlling a manufacturing process.

That interference is not just a nuisance and could potentially cause a failure,which might injure a patient or damage a major manufacturing process.

To prevent such situations,each piece of AC operated equipment must have its noise signal filtered and attenuated to the levels established by various national agencies.

[2] Noise transmission

The RFI noise emanates from almost every kind of electronic equipment all around us,such as,radio,TV receivers,computers,switch mode power supplies,generators,oscillators,thermostats,neon tubes,household appliances,switching components,thyristors,triacs, commutators,depending on individual designs or modes of operation.

The noise generated by electronic devices is transmitted through many complicated paths,sometimes through a conductor and sometimes as radiation,as shown in below fig.1,and the noise can disturb other electronic equipment.

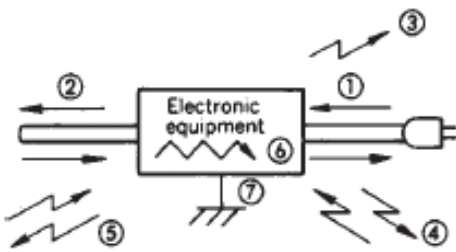


fig. 1

(1)Radiated noise

Frequencies > 30Mhz,the noise tends to radiate directly from the generating circuits.

Radiated noise is transmitted directly into the air from an electronic device,taking the form of an electric wave that interferes with other electronic devices in adjacent locations ,as shown in fig.1;

③radiated noise transmitted from an electronic device

④radiated noise picked up and generated by the power line which act as an antenna.

⑤radiated noise picked up and generated by the signal lines which act as an antenna.

(2)Conductive noise

Frequencies < 30Mhz,the noise is usually conducted by the AC line and other connections.

Conductive noise interferes with other components and devices by being transmitted along AC mains and the wiring of electronic circuits,as shown in fig.1;

①conductive noise from electric power line.

②conductive noise along the signal lines connecting electronic devices.

⑦conductive noise entering from the ground line.

And,⑥radiated noise and conductive noise produced from a source within the electronic device.

[3] Principle of noise suppression

The noise suppression is the reduction of the RFI noise.

The principle of noise suppression is to use;

- ①an AC input filter circuit for conducted noise
- ②shielding for radiated noise.

[4] What is a noise suppression capacitor?

Noise suppression capacitors are identified by various companies as RFI capacitor or radio-interference suppressor or safety recognized capacitor.

The noise suppression capacitor is a specially designed capacitor used in an AC input filter circuit on the AC mains input to electronic or electrical equipment,that is between the equipment and the AC mains.

The AC input filter circuit is usually required to meet the conducted noise limits,and the filtering is usually accomplished with the noise suppression capacitors,often in conjunction with chokes or transformers of various designs.

In the typical application,the noise suppression capacitors are a part of a simple L-C network.

The purpose of the noise suppression capacitors are;

- ①to stop the(RFI/EMI)noise from entering an electronic system and causing disruption:for protect the equipment from malfunction or failure,and to stop electrical equipment from putting the(RFI/EMI)noise onto the AC mains:for protect other electrical equipment.
- ②to protect the electrical system against the voltage surges and the voltage transients.

The voltage surges may be caused by lightning,and,in this case,the energy will be absorbed by the noise suppression capacitor and not by the electrical circuit.

The voltage transients are voltage spike to which the main voltage is subjected and which can easily occur several times a day in AC mains with amplitudes of 2000V and above,peak values can be as high as 6KV.

Noise suppression capacitor are used to block and attenuate these voltage spikes.

[5] Normal mode noise and Common mode noise

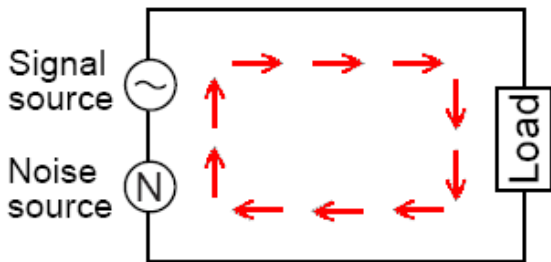
RFI noise is conducted on the AC line either symmetrically or asymmetrically.

And,conductive noise is classified into 2 types according to conduction mode;normal mode noise involving symmetrical noise components oscillating between lines,and common mode noise involving asymmetrical noise components transmitted a line and ground,as shown in fig.2-4.

Depending on how they are connected,X and Y capacitors are effective against these different kinds of noise.

(1)Normal(Differential)mode noise

As shown in the fig.2,normal mode noise is conducted on the signal line and electric power line in the opposite direction to each other.



*noise source:represents the high frequency current generated by switching transistor in SMPS,for instance.

*signal source:represents either a power source or desired signal source

fig. 2

This type of normal mode noise is suppressed by installing a X capacitor on across the line(=between the line phase),as shown in the below fig.3.

Thus,noise is returned to the noise source.

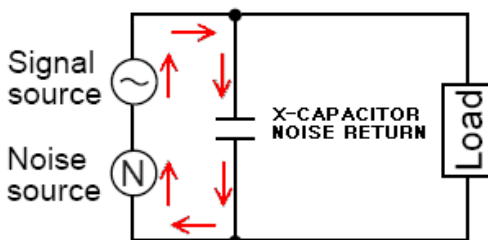
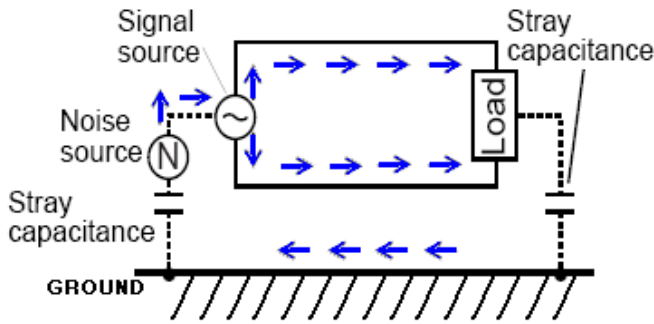


fig. 3

(2) Common mode noise

As shown in the fig.4, common mode noise is conducted on both lines in the same direction, through stray capacitance via ground.



- *noise source: represents the high frequency current generated by switching transistor in SMPS, for instance.
- *signal source: represents either a power source or desired signal source.
- *Stray capacitance: are formed whenever 2 conductors are in close proximity to each other, especially if they are running in parallel.

fig. 4

The circuit is floating from ground (earth potential), and there is a stray capacitance between this circuit and the case. The common mode noise is directly related to stray capacitance.

The occurrence and effects of stray capacitance- especially at very high frequencies- can lead to greater noise.

To suppress this type of common mode noise, as shown in the fig.5, shock protected, insulated, earthed, a metallic casing is connected to the all lines on which noise is conducted by using Y capacitors (=line bypass capacitors).

Thus, bridging the insulation of the equipment.

The noise is returned to the noise source in the following order, signal lines → Y capacitors → metallic casing → stray capacitance → noise source.

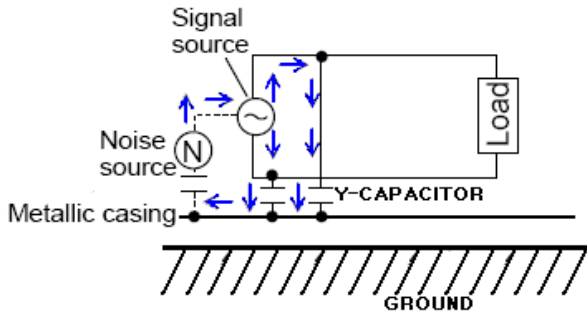


fig. 5

[6] Operating principle of noise suppression capacitors

The noise suppression capacitor is the most effective interference component.

Most noise emitted from electronic equipment is at frequencies higher than circuit signals.

The frequency becomes higher, the impedance of the capacitor becomes lower and short circuited.

Thus the noise is forced to go through the capacitors.

The below fig.6 shows an example of noise suppression on an AC power supply line.

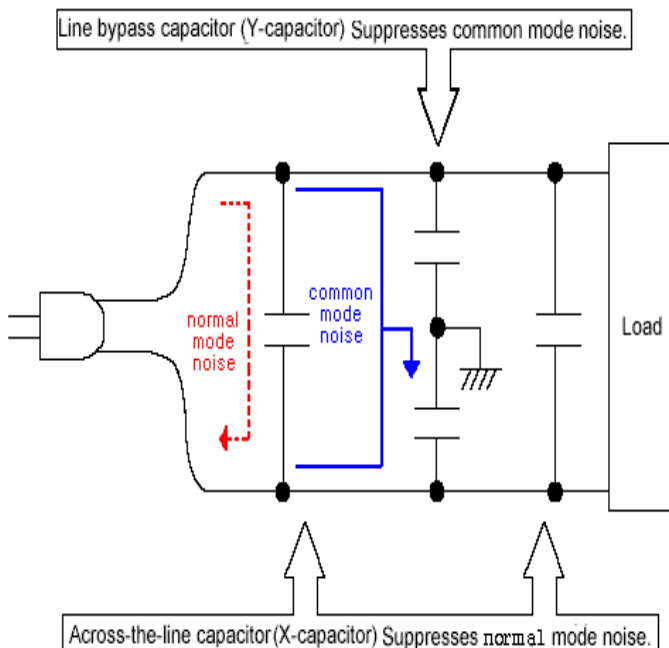


fig. 6



Most noise emitted from electronic equipment is at frequencies higher than circuit signals, and it is forced to go through noise suppression capacitors which are connected in parallel with the line, are used as side path to return high frequency noise back to the noise source.

The result is that normal mode noise passes through the X-capacitor and shunted back to the noise source.

The 2 X-capacitors perform the same function with the only difference, 1 is for; noise entering the equipment, where the other is for noise exiting the device.

In the case of common mode noise, the result is that the noise passes through the mid-point of the 2 capacitors to ground.

Depending on the particular design of the electronic or electrical equipment and its other components in the AC line input, various values of capacitance of the capacitor may be required to tune the AC input filtering performance.



【Noise Suppression capacitor agency approval】

A capacitor for RFI suppression must be approved by a relevant authority either as a noise suppression capacitor or as part of a complete unit of equipment.
The various agency requirements for noise suppression capacitors have important differences.
The EC has a different approach to noise suppression capacitors standards compared to UL and CSA.
The EN standard(EC unified or harmonized standards)is quite different in its requirements and rated voltage and it is applied to all types of AC operated equipment,not just a few selected categories such as UL.
Since most equipment is designed for worldwide use the EN standard is important to North American designers as well as to Europeans.

[1] USA(UL)



At the present time,there are 2 UL standards related to noise suppression capacitors;UL 1283 and UL 1414.

- ①UL 1283:actually a standard for potted RFI filters.
 - ②UL 1414:noise suppression for application-TV.radio and certain telecom.equipment.
- UL 1414 is specifically required for TV and radio receivers and certain telecommunications equipment.

	rated voltage	Max. capacitance	Max. operating temperature
UL 1283	>250VAC	>1.0 μ F	>+85 $^{\circ}$ C
UL 1414	either 125 or 250VAC	1.0 μ F	+85 $^{\circ}$ C

[2] Canada(CSA)



CSA requirements closely parallel that of UL,with CSA C22.2No.1 being equivalent to UL1414 and CSA C22.2No.8 being equivalent to UL1283.

UL and CSA have entered into cross-licensing agreement on a wide variety of standards.
For example,if UL is requested to evaluate an noise suppression capacitor for UL 1414 and CSA C22.2No.1,UL will conduct the tests common to both standards and those that are different,if any.
Such a capacitor will bear the UL mark and a new "cUL"mark that is fully accepted by CSA.

[3] IEC

The IEC is an international body which can pass recommendations but does not in itself have approval power in any country.
IEC 60384-14 is identical to the reference European standard EN132400.

[4] European Community(ENEC:Europe Norms Electrical Certification)



With the aim of harmonizing all the European national standards and only one standard of reference,the European Community has unified the standard of each country.
These unified, or "harmonized"standards are identified with an "EN"designation.
The European standard for noise suppression capacitor is EN132400 which is identical to IEC 60384-14.

The noise suppression capacitors are classified by EN132400 into 2 categories-class X and class Y-these designations are used by most European countries.

In North America, designations of Across-the-line capacitors, Line bypass capacitors and Antenna couplings refer to following applications.

<Class X: Across the line capacitors>

<Class Y: Line by-pass capacitors>

<Class Y: Antenna couplings>

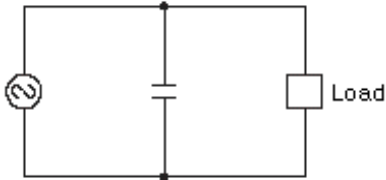


fig. 7

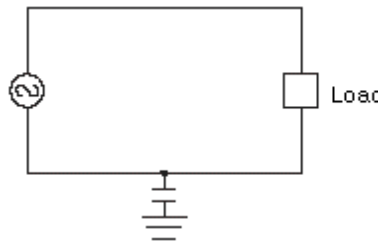


fig.8

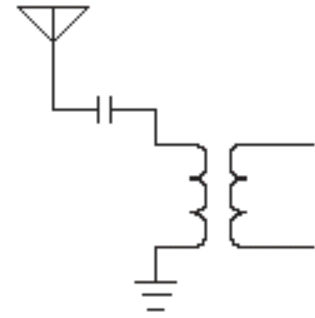


fig. 9

[1] Class X capacitors

①An X capacitor is used in Across-the-line applications, as shown in the fig.3,6 and 7.

②In this location, a failure of the capacitor will not cause anybody to electrical shock hazards and usually will open the fuse and turn the equipment off.

Therefore, the definition for "X" capacitor application is: "where damage to the capacitor will not lead to the danger of electrical shock".

③The X capacitors suppress "normal mode" RFI noise.

④Since, normal mode noise is low-frequency then, X capacitor values are 0.1~1.0 μF .

One would think that a capacitor with a larger constant should be used for suppression against normal-mode noise.

However, increasing the X-capacitor's capacitance causes a problem of increased reactive current.

[2] Class Y capacitors

①Class Y capacitor is used in Line-by pass applications, as shown in the fig.5,6 and 8.

②In this location, a failure of the capacitor will cause anybody to electrical shock hazards.

If lightning should strike the AC power line, Y capacitors would be the most likely to be subjected to damage.

If damage occurs, they will not activate any safety fuse.

And, the definition for Y capacitor application is: "where damage to the capacitor may involve the danger of electrical shock".

Thus, Y capacitor ratings are very conservative and high electrical and mechanical reliability intended to prevent short circuit in the capacitor for reasons explained above and considering that in production Y2 are tested at 3,000VDC/ μsec vs. 2,000VDC for X2.

Similarly, in the lightning simulation test, the Y2 suppressor must be approved at 5KV vs. 2.5KV for X2.

③The Y capacitors suppress "common mode" RFI noise.

④Since, common mode noise is high-frequency then, Y capacitor values are smaller, 0.001~0.0047 μF .

⑤Generally Y capacitors must be kept to smaller capacitance values.

The limitation of the capacitance of Y capacitors is; intended to reduce

①the energy content of the capacitor to a safe level, when DC voltage is applied.

②the current flowing through the capacitor when an AC voltage is applied.

Even if, Y capacitors are in a perfect condition, there is some current flowing through them from line to equipment ground.

And, Y capacitor value is indirectly restricted because each application has an allowable max. leakage current (which can range 0.25mA~3.5mA, depending on the AC mains connection).

If larger C values were allowed for Y capacitors, 50 or 60Hz leakage current to the ground would be too high for safety standards.

And a too high capacitance of Y capacitor is hazardous if the earth line should be open circuit or disconnected from the earth grounding or connected to earth through a too high resistance compared with human body.

While the X capacitor may be of any practical unlimited capacitance value.

[3] Sub class

EN132400 divides these X and Y classifications into following a total 7 sub-classes:

3 X classes and 4 Y classes, as shown in the below table.

The required class is determined by the equipment standards for the final product.

The most popular class are X2 and Y2.

①The class of X capacitor is determined according to;

①the equipment standard applicable to the device.

②the peak pulse voltage to which X capacitors are exposed in operation, in addition to the rated voltage.

This kind of impulse can be caused by lightning in overhead cables, switching surges in neighbouring equipment or in the device in which the capacitor is used to suppress interferences.

③the "installation category" meaning the type of connection to the AC line.

Installation category II: connection to ordinary wall outlets

Installation category III: connection to main power trunk lines within a building.

Sub-class	Peak pulse volt in service	IEC60664 category	Application
X1	>2.5Kv, ≤4.0Kv	III	High pulse: industrial printer, lightning ballast or minicomputer which is connected to a 3-phase line.
X2	≤2.5Kv	II	The most common class. General purpose: Computer, hair dryer, FAX, hand power tool which are plugged into ordinary wall outlet.
X3	≤1.2Kv	-	General purpose

② The class of Y capacitor is determined according to;

① Insulation grade being bridged: There are basic insulation, supplementary insulation, reinforced insulation and double insulation.

② Line voltage used

Sub-class	Peak impulse volt before test	Rated voltage	Type of insulation bridged
Y1	8.0Kv	≤250V	For bridging double or reinforced insulation.
Y2	5.0Kv	≥150V ≤250V	For bridging basic and supplementary insulation. Application: power supply used in data processing equipment.
Y3	none	≥150V ≤250V	For bridging basic and supplementary insulation.
Y4	2.5Kv	≤150V	For bridging basic and supplementary insulation.

【How select the (RFI/EMI)Noise suppression capacitors on AC mains?】

- ①The first consideration is the voltage requirements for the capacitor.
The value of URAC of the series in this catalog means that the capacitors are acceptable for use in any application with a voltage requirement up to and including the URAC of the series in this catalog.
- ②The next consideration should be the temperature rating.
- ③Finally,the capacitance value required will establish the insertion loss characteristics required for the application,and determine the physical size of the capacitor.

【Circuit design consideration】

- ①(RFI/EMI)Noise suppression capacitors are specifically designed for AC mains.
Thus,the capacitors should be used on AC mains,and not to use the capacitors on the secondary side of the AC mains such as,in an active filter circuit,charge-discharge circuit,high frequency circuit $\geq 70\text{Hz}$.
Under large currents,smoke,ignition and capacitance omission may occur if used in charge-discharge circuit,high frequency circuit.
- ②The life of a capacitor is affected significantly by operating temperature.
Be sure to operate capacitors within the specified operating temperature range.
The operating temperature is the temperature measured on the hottest point of the capacitor surface which sum of the ambient temperature(T_a) and capacitor's self heating temperature rise value(ΔT).
To prevent permanent damage, ΔT should not be allowed $\leq 5^\circ\text{C}$.
- ③In high speed circuits,the addition of the noise suppression capacitors may slow the response time of the circuit.
For best response characteristics,do not use a larger capacitor than is absolutely necessary to suppress the noise level.
- ④When,the noise suppression capacitors are connected across the AC mains,care must be taken that the resulting in-rush current does not cause the fuse or circuit breaker to open.
Special consideration must be given to both the capacitor value and the breaker ratings.
- ⑤The noise suppression capacitors are most effective when located close to the offending noise source.
Excessive lead length may cause abnormal oscillation and decrease the energy absorption capability of the capacitor.
- ⑥The noise suppression capacitors absorb AC mains surges.
However,they are not intended to absorb high-energy surges such as induced lightning.