Radio Interference Suppression Capacitors Introduction

RADIO INTERFERENCE SUPPRESSION

1. Origin and Spreading of Interference:

There are two main sources of radio interference:

- Devices, which due to their construction produce RF energy. These include generators for use in industry, medicine and science, as well as oscillators, radio and TV receivers etc.
- Devices, which produce a wide spectrum of frequencies, due to rapid variations in electrical current intensity. These include devices with switching components, thyristors, triacs, commutators and similar.

Interference from source to receiver is spread in three ways:

alonwiring
by coupling, and
by radiation

To frequencies of 30MHz approximately, interference is spread mainly along the installed electrical wiring. In this range inductive and capacitive coupling also occurs between the wiring and other metal parts of the devices acting as supports of interference transfer.

Frequencies higher than 30MHz are spread by radiation since interference source dimensions and terminal wiring are in order of size to the wave length of the radiated interference. The metal parts therefore act as antennas.

The device connected to the mains supply produces two kinds of interference currents, running along wiring as seen in figure A.

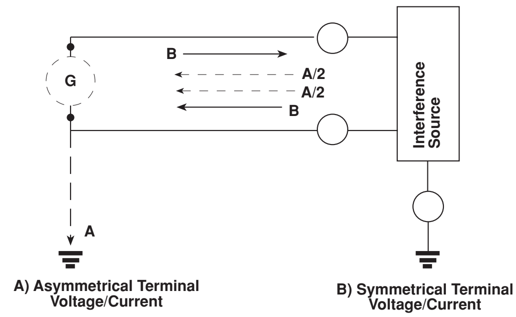
Symmetrical interference current B runs in different directions in the phase and neutral wires.

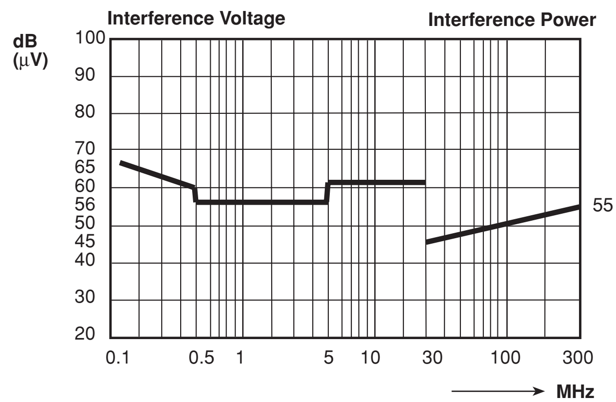
Asymmetrical interference current A runs in the same direction in both leads and ends in the same device via the earthing connection. An earthing connection can either be an earthing wire or capacitance between the device and the surrounding.

Interference on long or medium radio waves is generally greater if the device is earthed. In this case impedance to the surrounding is short circuited and the asymmetrical interference current increases.

The two types of interference appear according to duration time; continuous interference and discontinuous interference. The latter occurs as impulses with less effect than continuous interference. They are treated and suppressed from continuous interference separately. Exact definitions are given in the regulations e.g.

EN 55 011	CISPR 11,
EN 55 014	CISPR 14-1





2. Maximum Permitted Interference Limits:

In order to guarantee good operation of communicational and other equipment, radio interference must be tolerably limited. Interference produced from the source are measured as follows:

- Up to frequency 30MHz, interference voltages are measured which spread along the terminal in the supply network.
- Above 30MHz, strength of radiated field or radiated power on the terminal in the supply network is measured.

Permitted levels of interference are given in the national and international regulations. Recommendations given by CISPR (Comité International Spécial de Perturbation Radioélectriques) are as follows:

EN 55 011	CISPR 11,
EN 55 014	CISPR 14-1 etc.

3. Suppression Components

3.1 Capacitors Class X and/or Y ?

The suppression capacitor is the most effective interference component. Its impedance decreases with the frequency, so that we have a short circuit between the mains terminals and/or between the terminals and ground at high frequency. Capacitors for applications between the mains terminals are called:

X-Capacitors

Class X-capacitors, X-capacitors for short, are capacitors with unlimited capacitance for use where their failure due to a short circuit would not lead to the danger of an electric shock.

Capacitors for applications between terminals and ground are called:

Y-Capacitors

Class Y-capacitors, Y-capacitors for short, are capacitors, which serves to reduce the asymmetrical interference voltage, and are located between a live conductor and the metal case which may be touched.

NOTE: The high electrical and mechanical reliability intended to prevent short circuits in the capacitors. The limitation of the capacitance of all Y-capacitors is intended to reduce the AC Voltage of the current flowing through the capacitor and in the case of DC voltage the energy content of the capacitor to a safe level.

In fulfilling their technical function in electrical equipment, machines and installations, Y-capacitors bridge industrial insulating systems whose reliability, in conjunction with an additional protection measure prevents danger to human beings and animals.

They are intended for use in circumstances where failure of the protection measures of the equipment could lead to a danger of electric shocks.

Normally X- and Y-capacitors combined in the same case are called:

XY-Capacitors

Examples: Examples of radio interference suppression with X- and Y-capacitors.

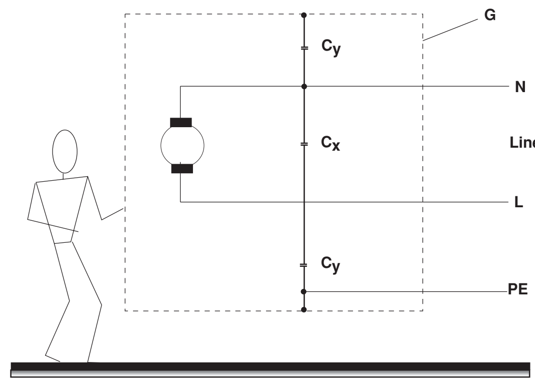


Figure a) An example of radio interference suppression with X- and Y-capacitors used in equipment belonging to protection class I.

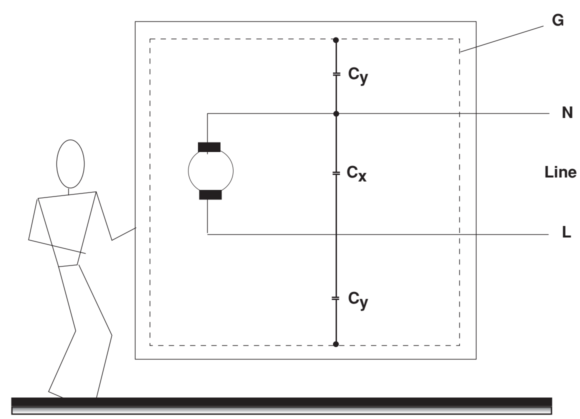


Figure b) An example of radio interference suppression with X- and Y-capacitors used in equipment belonging to protection class II.

Figure a) shows the radio interference suppression of the motor of a piece of electrical equipment (vacuum cleaner, portable drill, etc.) of protection class I. Capacitor Cx, which is used for reducing the symmetrical interference voltage, is located between the conductors of the mains and is therefore an X-capacitor. Its failure through a short circuit causes no danger of an electric shock.

Figure b) shows an appliance or protection class II where no protective conductor is connected to the metal case “G”.

In both instances, a short circuit of the Y-capacitor will only endanger a person touching the appliance if at the same time, either the protective conductor of protection class I is broken or the casing insulation is damaged in the case of protection class II.

The capacitor C_X, which is used for reducing the symmetrical interference voltage, is located between the conductors of the mains and is therefore a class X-capacitor. First failures through a short circuit cause no danger of an electric shock.

3.1.1. Regulations according to IEC 60384-14, second edition, 1993-07, and/or EN 132 400, 1994

According to these rules capacitors are subdivided into two classes, class X and class Y.

Class X-Capacitors

Class X-capacitors, X-capacitors for short, are subdivided into three subclasses, class X1, class X2 and class X3 corresponding to the peak voltages of the impulses superimposed on the mains voltage to which they may be subjected to in services. Such impulses may arise from lighting strikes on outside lines, from switching in neighboring equipment, or switching in the equipment in which the capacitor is used.

SUB CLASS	PEAK IMPULSE VOLTAGE IN SERVICE	IEC 664 INSTALLATION CATEGORY	APPLICATION	PEAK IMPULSE VOLTAGE U_P APPLIED BEFORE ENDURANCE TEST
X1	> 2.5kV ≤ 4.0kV	III	High Pulse application	When $C_R \le 1\mu F$ U_P = 4kV When $C_R > 1\mu F$ $U_P = 4\sqrt{C_R}$ in kV
X2	≤ 2.5kV	II	General purpose	When $C_R \le 1\mu F$ U_P = 2.5kV When $C_R > 1\mu F$ $U_P = 2.5\sqrt{C_R}$ in kV
X3	≤1.2KV	-	General purpose	None

NOTE: C_R is in µF

Class Y - capacitors
Class Y - capacitors are further subdivided into four subclasses Y1, Y2. Y3 and Y4

SUB CLASS	TYPE OF INSULATION BRIDGED	RANGE OF RATED VOLTAGES	PEAK IMPULSE VOLTAGE U_P BEFORE ENDURANCE TEST
Y1	Double Insulation or Reinforced Insulation	≤ 250 V	8.0kV
Y2	Basic Insulation or Supplementary Insulation	≥ 150 V ≤ 250 V	5.0kV
Y3	Basic Insulation or Supplementary Insulation	≥ 150 V ≤ 250 V	None
Y4	Basic Insulation or Supplementary Insulation	≤ 150 V	2.5kV

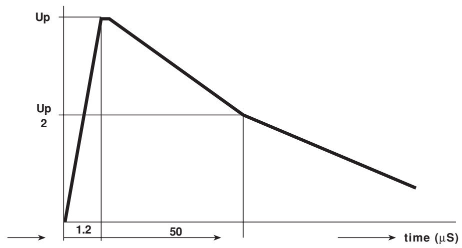
NOTE: For definitions of basic, supplementary, double and reinforced insulation see IEC 60536, sub-clauses 2.1, 2.2, 2.3 and 2.4.

One Y-capacitor may bridge basic insulation. One Y-capacitor may bridge supplementary insulation. If combined basic and supplementary insulations are bridged by two Y2, Y3 or Y4 capacitors in series, they shall have the same nominal value.

According to the regulations IEC 60384-14, second edition, 1993-07, and/or EN 132 400, 1994, all capacitors subclass X2 have to withstand the following types of test, they shall have the same nominal value:

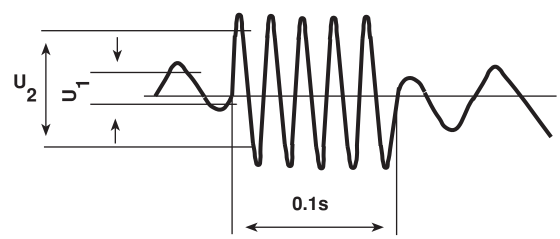
Impulse voltage test with U_P = 2.5kV:

(this test has to be performed before the endurance test)



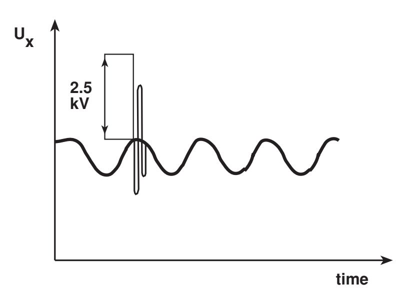
Endurance Test:

All capacitors have to be tested for 1000 hours at the upper category temperature with a voltage of 1.25 times rated voltage (U_R). Every hour the test voltage has to be increase up to 1000 V_{RMS} for a time period of 0.1 second.



Active Flammability Test:

All capacitors have to be tested with the rated voltage (U_R). At the frequency 50Hz with superimposed 20 pulses at 2.5kV with an interval between the successive discharges of 5 seconds. The capacitor shall be individually wrapped in at least one but not more than two complete layers of specified cheese-cloth. After finishing the test, the cheese-cloth shall not burn with a flame.



3.2. Suppression Filters

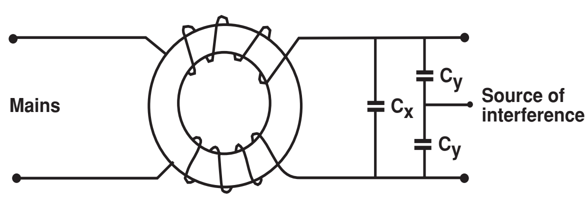
Suppression filters result from a combination of:

capacitors, chokes and a resistor in one unit.

Such filters will be installed in all cases in which the application of several components is not sufficient. The basic type shown below is ideal for these applications:

In this example the symmetrical noises are short circuited by the capacitors C_x, whereas the unsymmetrical noises are attenuated by the current. Compensated choke L and the two C_y capacitors. As in four-pole capacitors, for the filters, the noise attentuation is measured as a guide for the suppression efficiency. Depending on the suppression conditions, variations of the basic type can used.

If the type of suppressor used does not reduce the interference sufficiently, then it may be necessary to shield any leads and components which could radiate the interference. The materials used for this purpose are wire mesh, metal foil or sheet metal dependent upon the degree of screening required. Steel or copper are the primary metals used.



4. Terms and Definitions:

4.1. Rated Voltage U_R

The rated voltage U_R is either r.m.s. operating voltage of rated frequency, which may be applied to the terminations of a capacitor at any temperature between the upper and lower and upper category temperature.

4.2. Climatic Category

The climatic category defines the lower rated temperature, the upper rated temperature, and the humidity class.

4.3. Upper Category Temperature

The maximum surface temperature for which the capacitor has been designed to operate continuously.

4.4. Lower Category Temperature

The minimum surface temperature for which the capacitor has been designed to operate continuously.

4.5. Rated Temperature

The rated temperature is the maximum ambient temperature at which the rated voltage can be continuously applied for.

4.6. Insertion Loss

The ratio of the voltage before and after insertion of the suppressor as measured at the terminations.

NOTE: When measured in decibels the insertion loss is 20 times the logarithm to base 10 of the ratio stated.

4.7. Main Resonant Frequency

The lowest frequency at which the impedance of the capacitor is a minimum when applying a sinusoidal voltage.

4.8. Impulse Voltage

An impulse voltage is an aperiodic transient voltage of a defined waveform as described in IEC publication 60060-1.

4.9. Passive Flammability

The ability of the capacitor to burn with a flame as a consequence of the application of an external source of heat according to CEI IEC 60384-1 and IEC 60695-2-2.

All plastic case materials used comply with UL-class 94V-0.

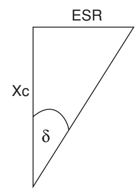
CATEGORY OF FLAMM-ABILITY	SEVERITIES FLAME EXPOSURE TIME (s) FOR CAPACITOR VOLUME (V) (mm^3)				MAX PERMITTED BURNING TIME (s)	ADD-ITIONAL REQUIRE-MENTS
	$V \leq 250$	$250 \leq V \leq 500$	$500 < V \leq 1750$	$V > 1750$		
A	15	20	60	120	3	Burning drop lets or glow-ing parts falling down shall not ignite the tissue paper.
B	10	20	30	60	10	
C	5	10	20	30	30	

4.10. Active Flammability

The ability of the capacitor to burn with a flame as a consequence of electrical loading.

4.11. Dissipation Factor, tan δ

The dissipation factor, tan δ (in %) is the power of the loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage of specified frequency.



The tan δ reflects the polarization losses of the dielectric film and the losses caused by the contact resistance (terminals - schooping - electrodes) of the capacitor. Parallel losses can, due to the high insulation resistance of film capacitors, be neglected. The tan δ is temperature and frequency dependent.

$$\tan \delta = \frac{ESR}{Xc}$$

The reciprocal value of tan δ is also known as Q-factor.

$Q = 1/\tan \delta$

4.12. Peak Voltage U_s

A peak voltage U_S is a temporary, pulse-shaped voltage with a peak value U_S, such as can in particular occur when switchinginductances.
NOTE: Within the scope of this standard form of a VDE Specification, it is assumed that peak voltages only occur sporadically and up to a maximum of 5 times per hour.

4.13. Rated Capacitance C_R

The rated capacitance C_R of the capacitor is the capacitance value characterising its rating for a temperature of 20°C and by which it is described.

4.14. Self Healing

If a conducting particle or a voltage surge punctures the dielectric, an arc occurs at the point of failure melting the surrounding metal and insulating the area of the breakdown.

4.15. Soldering Conditions

Unless otherwise specified the solderability of capacitors are tested according to DIN IEC 60068, part 2-20. The following details apply:

<u>For Single Sided PC Boards:</u>

Solder bath temperature / time: 270°C / 5 sec.

<u>For Double Sided PC-Boards:</u>

Solder bath temperature / time: 260°C / 5 sec.

4.16. Test Voltage

Repeated high voltage test should as far as possible be avoided as it is more or less destructive regardless of type of dielectric or manufacturer.

According to IEC 60384-14, repeated voltage tests must be carried out at 66% of the voltage required for the type approval tests.

D.C. is preferable to AC. The ionisation caused by AC voltage increases the risk of permanent impairment of the tested capacitor.

The test equipment has to be designed to avoid unspecified stresses of the capacitor, e.g. transients, when connecting or disconnecting the voltage.

A DC test equipment must not have a tank capacitor. The test voltage must be applied with a certain rise time which is normally specified in the relevant IEC standards.

The specified test voltage is used as a factory test and unless something else is specified, the user can apply the same voltage only 1-2 times during the specified time.

4.17. Corona Starting Voltage:

The corona starting voltage is defined as detectable electrical discharges resulting from the ionization of air on the surface or between the capacitor layers. Its value is dependent upon the internal design of the capacitor element, the dielectric material, and the thickness of the film. The usage of series wound capacitors increases the corona voltage level.

All capacitors listed in this catalog have been designed in such a way that the corona starting voltage will be above the specified AC-voltage rating.

The corona starting voltage is typically measured with a sensitivity of 2 pC (Pico-Coulomb).

4.18. Insulation Resistance (R_{IS}) and Time Constant (τ):

The R_{IS} is the ratio of an applied DC voltage to the resulting leakage current (flowing through the dielectric and over its body surface) after the initial charging current has ceased. The R_{IS} is typically measured after one minute. ± 5 s at 20°C and a relative humidity of 50 ± 2%.

$R_{IS} = U_{pc} / \text{Leak}\ (\Omega)$

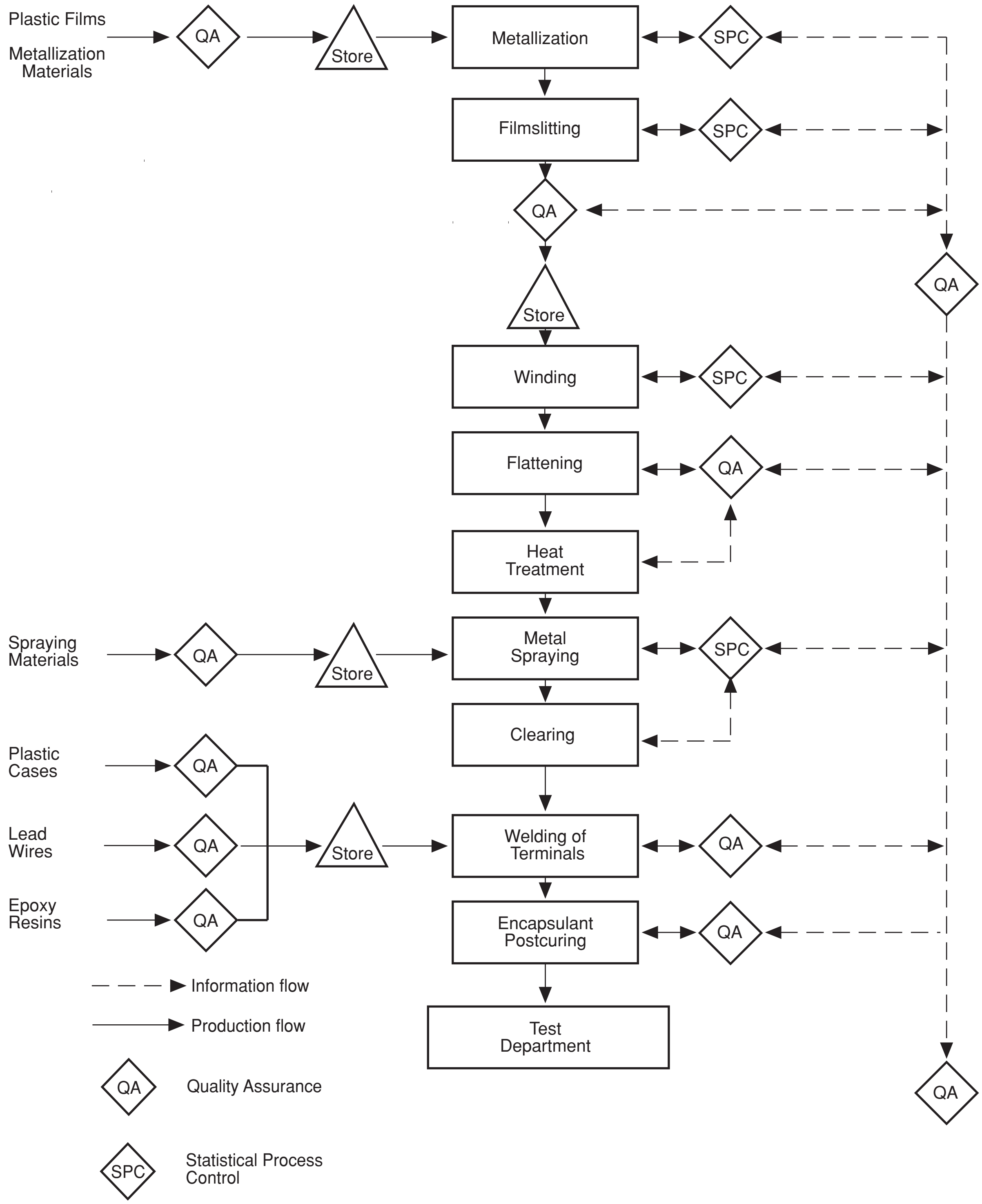
The insulation resistance is determined by the property and the quality of the dielectric material and the capacitor's construction.

The R_{IS} decreases with increasing temperature. A high relative humidity may decrease the insulation resistance. R_{IS} changes due to moisture are reversible.

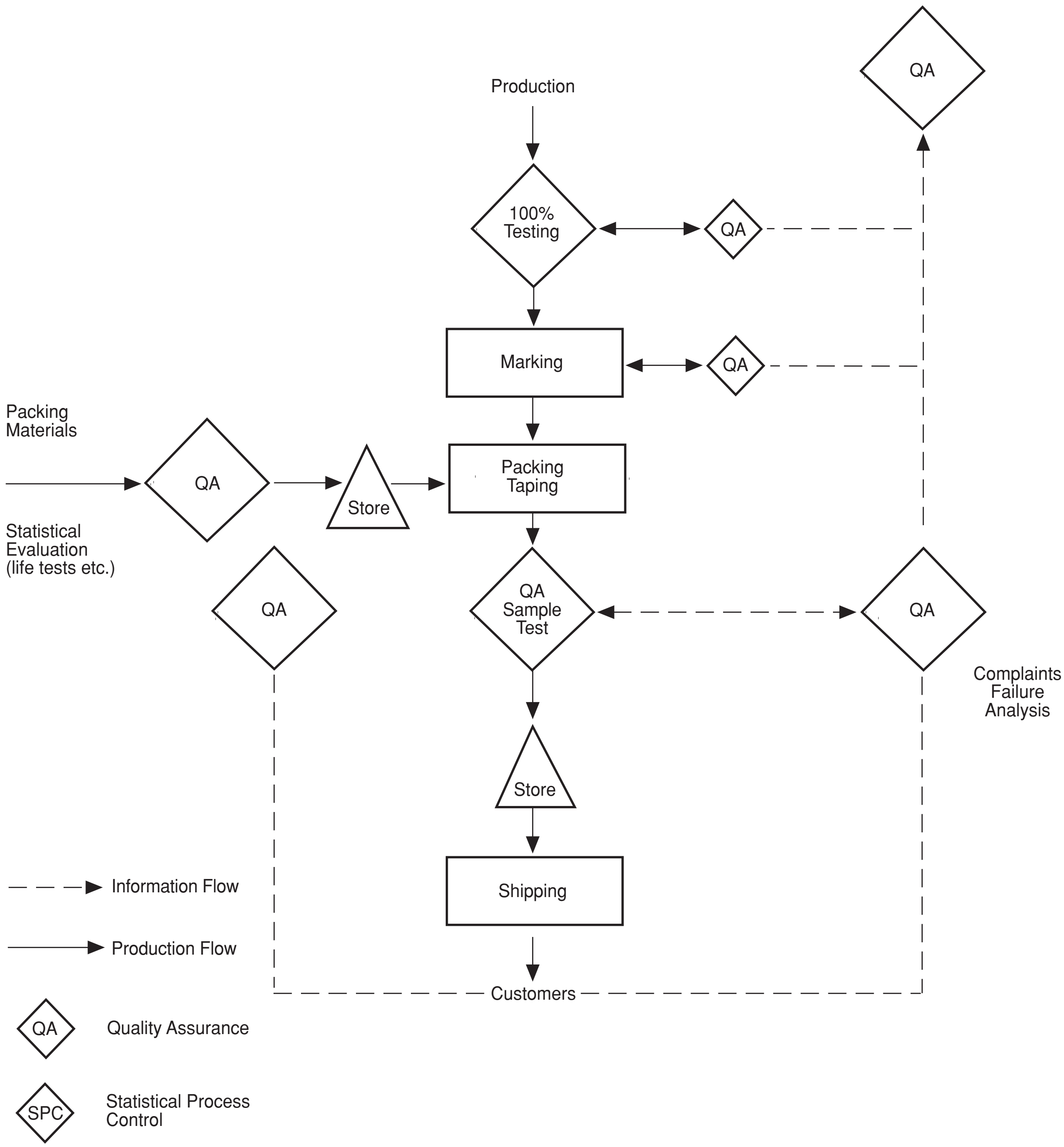
For capacitor values > 0.33µF the R_{IS} is shown as time constant (τ). It is the product of insulation resistance and capacitance and is expressed in seconds or Megohm x µF.

$$\tau = R_{IS} \times C \text{ (Megohm x µF)}$$

Metallized Plastic Film Capacitors
Radial Types



Metallized Plastic Film Capacitors
Radial Types



Film Capacitors

1. **Alcohols**
   Methanol
   Ethanol
   Propanol
   Butanol
   Isopropyl
2. **Esters**
   Acetic Acid Ethylester
   Acetic Acid Butylester
   Methylglycolacetate
   Ethylglycolacetate
3. **Aqueouse Cleaning Solvents**
   Tests will be performed upon request.
4. **Glycolether**
   Propyleneglycolether

CLEANING PROCEDURE

The influence of higher temperatures or vapor accelerates the purifying but also the destructive process.

Please consult Vishay Roederstein if you have doubts about the usage of your cleaning solvent or if the cleaning process exceeds a solvent temperature of + 40°C and a cleaning time of one minute.

NOTE: For the protection of the environment chlorinated and fluorinated hydrocarbons as well as related mixtures (e.g. Trichloroethane, Trichlorofluoroethane, Tetrachlorohydrocarbon) shall no longer be used.

The usage of these substances is in Germany and most other countries, is by law prohibited!

SUITABLE CLEANING SOLVENTS

CAPACITOR VERSION	ITEM
Plastic Box and Epoxy End-Sealed	1, 2, 3 or 4
Plastic Molded	1, 2, 3 or 4
Plastic Wrapped and Epoxy End-Sealed (Polycarbonate Wrapping)	Will be tested on request
Plastic Wrapped and Epoxy End-Sealed (Yellow or White Adhesive Tape)	1, 2, 3 or 4

According to IEC 60062

YEAR	LETTER CODE
1986	U
1987	V
1988	W
1989	X
1990	A
1991	B
1992	C
1993	D
1994	E
1995	F
1996	H
1997	J
1998	K
1999	L
2000	M
2001	N
2002	P
2003	R
2004	S
2005	T
2006	U

MONTH	LETTER / NUMBER CODE
January	1
February	2
March	3
April	4
May	5
June	6
July	7
August	8
September	9
October	O
November	N
December	D

A) Two Figure Code (Year/Month)

The production code is indicated with 2 code letters or with one code letter and one code number. The 1st figure indicates the year and the 2nd figure indicates the month.

Examples:

1994	July	= E7
1995	August	= F8
1996	May	= H5
1997	October	= JO
1998	November	= KN
1999	August	= L8
2000	June	= M6
2001	August	= N8
2002	January	= P2
2003	February	= R2
2004	December	= SD
2005	March	= T3
2006	April	= U4

B) Four Figure Code (Year/Week)

The production code can also be indicated with 4 code numbers. The 1st and 2nd code numbers indicate the year and the 3rd and 4th code numbers indicate the week.

Examples:

18th	Week 1994	= 9418
50th	Week 1995	= 9550
32nd	Week 1996	= 9632
41st	Week 1997	= 9741
27th	Week 1998	= 9827
45th	Week 1999	= 9945
13th	Week 2000	= 0013
3rd	Week 2001	= 0103
15th	Week 2002	= 0215
33rd	Week 2003	= 0333
48th	Week 2004	= 0448
10th	Week 2005	= 0510
21st	Week 2006	= 0621

E-Series according to IEC 60063

E6 ± 20%	E12 ± 10%	E24 ± 5%	E48 ± 2%	E96 ± 1%
1.0	1.0	1.0	1.00	1.00
				1.02
			1.05	1.05
				1.07
		1.1	1.10	1.10
				1.13
			1.15	1.15
				1.18
	1.2	1.2	1.21	1.21
				1.24
			1.27	1.27
				1.30
		1.3	1.33	1.33
				1.37
			1.40	1.40
				1.43
			1.47	1.47
1.5	1.5	1.5		1.50
			1.54	1.54
				1.58
		1.6	1.62	1.62
				1.65
			1.69	1.69
				1.74
			1.78	1.78
	1.8	1.8		1.82
			1.87	1.87
				1.91
			1.96	1.96
		2.0		2.00
			2.05	2.05
				2.10
			2.15	2.15
2.2	2.2	2.2		2.21
			2.26	2.26
				2.32
			2.37	2.37
		2.4		2.43
			2.49	2.49
				2.55
			2.61	2.61
				2.67
	2.7	2.7	2.74	2.74
				2.80
			2.87	2.87
				2.94
		3.0	3.01	3.01
				3.09

E6 ± 20%	E12 ± 10%	E24 ± 5%	E48 ± 2%	E96 ± 1%
			3.16	3.16
				3.24
3.3	3.3	3.3	3.32	3.32
				3.40
			3.48	3.48
				3.57
		3.6	3.65	3.65
				3.74
			3.83	3.83
	3.9	3.9		3.92
			4.02	4.02
				4.12
			4.22	4.22
		4.3		4.32
			4.42	4.42
				4.53
			4.64	4.64
4.7	4.7	4.7		4.75
			4.87	4.87
				4.99
		5.1	5.11	5.11
				5.23
			5.36	5.36
				5.49
	5.6	5.6	5.62	5.62
				5.76
			5.90	5.90
				6.04
		6.2	6.19	6.19
				6.34
			6.49	6.49
				6.65
6.8	6.8	6.8	6.81	6.81
				6.98
			7.15	7.15
				7.32
		7.5	7.50	7.50
				7.68
			7.87	7.87
				8.06
	8.2	8.2	8.25	8.25
				8.45
			8.66	8.66
				8.87
		9.1	9.09	9.09
				9.31
			9.53	9.53

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