



12 THINGS TO KNOW ABOUT PREVENTING OVERLOADS WITH SAFETY CAPACITORS

1 THE CLASS OF CAPACITOR YOU NEED DEPENDS ON WHETHER YOU'RE DOING DIFFERENTIAL MODE OR COMMON MODE FILTERING



DIFFERENTIAL MODE INTERFERENCE

Differential mode interference is where pulses run along the wires (L-N) in opposite directions. For differential-mode filtering, you need Class X capacitors connected between the lines, effectively returning high frequency interference back to its source



COMMON MODE INTERFERENCE

Common mode interference is where pulses run in the same direction in both wires (L-N) in the same device. For common-mode filtering you need Class Y capacitors connected between the wires and ground, bypassing the interference pulses from the wires to the ground

2 SAFETY REQUIREMENTS DIFFER DEPENDING ON THE TYPE OF CAPACITOR



The noise level in all electronic/ electric devices has to be kept below a certain level, which is defined in the particular device standards

Filtering is done by components such as capacitors or chokes or a combination of these components

Since safety capacitors operate directly connected to the mains, they have to meet the requirements of the IEC 60384-14 safety standard



The safety requirements are much higher for Y capacitors, because a short/failure of such a component could lead to an immediate danger of an electric shock (see below)

3 WHILE CAPACITOR SHORTS IN CLASS X1/X2/X3/X4 APPLICATIONS AREN'T A BIG DEAL, THEY CAN LEAD TO ELECTROCUTION IN CLASS Y1/Y2/Y3 APPLICATIONS DUE TO HIGHER SURGE LEVELS

Failure of an **X** or a **Y** capacitor will lead to the malfunction or destruction of the device



A crack in a surface-mount part, built by putting two capacitors in series, can result in diminished capacitance rather than a short, since a short can occur in one section without affecting the other

Since **X** capacitors connect line and neutral, failure would not lead to the danger of an electric shock, but it could open safety fuses or circuit breakers and in an extreme case catch on fire

Y capacitors are located between a live conductor and the metal shielding, which someone could touch, so failure can cause electric shocks



4 THERE ARE PROS AND CONS TO USING FILM CAPACITORS

PROS

Film capacitors offer higher capacitance values compared to other technologies. For example, Vishay offers film capacitors with these ratings:

TYPE	UP TO
X2	40 μ F at 310 V _{AC}
X1	8.2 μ F at 480 V _{AC}
Y2	1.0 μ F at 305 V _{AC}

Film capacitors have the ability to **recover from a dielectric breakdown** with just a **tiny decrease in capacitance**. This is called a "self-healing" effect. It happens because the arc created during a dielectric breakdown evaporates the metallization layer and thus clears the fault condition

The capacitance and dissipation factor of film capacitors are highly stable across a wide temperature range from **-40 °C to +110 °C**.

The internal series construction of X2 film safety capacitors helps the device to **last longer** and **maintain capacitance** in series impedance or across-the-line applications



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CONS



Film safety capacitors are through-hole devices, and if the application uses SMD components, they may need a different soldering process than the other components on the board

Film capacitors are usually more expensive than ceramic capacitors

5

THERE ARE PROS AND CONS TO USING CERAMIC CAPACITORS

PROS

Leaded ceramic capacitors have **highest dielectric** and pulse strength of all technologies

Leaded ceramic capacitors are the only ones available in the **X1/Y1 safety classification**

Leaded ceramic capacitors can handle pulses up to **10 kV**



Surface-mount ceramic capacitors are available with a capacitance value of **1 nF** and an **NPO temperature coefficient of capacitance**



Leaded ceramic capacitors are usually **less expensive** than film capacitors

CONS

Ceramic capacitors have relatively low capacitance values compared to other technologies, so there are some applications where they can't be used

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HOW YOU ARRANGE COMPONENTS ON THE BOARD HAS AN EFFECT ON WHETHER YOU'RE MEETING SAFETY REQUIREMENTS

The market is always driving toward smaller components, but compliance with IEC 60384-14 means safety capacitors need to follow guidelines for creepage and clearance distances



For X1/Y1 capacitors, the **minimum allowed creepage and clearance distance is 8 mm**

Surface-mount capacitors also need to meet certain standards for termination-to-termination creepage

Vishay's surface-mount capacitors meet the strict **4 mm** test that competing devices don't



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SURFACE-MOUNT CAPACITORS HAVE A LOWER TOTAL IMPLEMENTATION COST THAN THROUGH-HOLE CAPACITORS

Through-hole devices may be less per piece, but they cost more to assemble

As a rough estimate, it costs less than \$ 0.01 to assemble an SMT part versus \$ 0.05 to assemble a through-hole part



8

NOT ALL SINGLE-LAYER CAPACITORS ARE EQUAL REGARDLESS OF WHAT THEIR DATASHEETS MAY SAY 3 EXAMPLES

1

Although it is sufficient for a X1/Y1 capacitor to withstand 8 kV pulses according to IEC 60384-14, Vishay guarantees a pulse strength of 10 kV for our VY1...C series

2

In terms of reliability, Vishay's AY2 and VY1...C series are qualified with a biased 85/85 1000 h test, although this is not required by the IEC standard (which requires only 40/95 500 h)

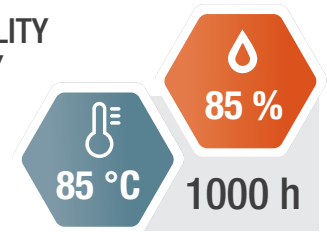
3

The switch from silver to copper electrodes in our new VY1...C series also results in an improved component lifespan, since it eliminates the negative effects of silver migration



12 THINGS TO KNOW ABOUT PREVENTING OVERLOADS WITH SAFETY CAPACITORS

- 9 BOTH FILM AND LEADED CERAMIC CAPACITORS ARE AVAILABLE WITH THE ABILITY TO WITHSTAND HARSH TESTING CONDITIONS (85 °C/85 % RELATIVE HUMIDITY FOR 1000 h AT THE RATED VOLTAGE)



- 10 IT'S IMPORTANT TO PAY ATTENTION TO HUMIDITY



The latest edition of the IEC 60384-14 standard includes a “humidity grade” which reflects the components’ ability to operate in high humidity environments

The highest grade (Grade III) can be fulfilled by Vishay’s AY2 and VY1...C series, which are qualified using a 85/85 1000 h test procedure

Vishay’s F340 family features X1, X2 and Y2 devices which comply with Grade III B, meaning the capacitor must withstand 85 °C/85 %/1000 h at rated voltage with limited degradation of capacitance and dissipation factor

- 11 YOU CAN USE MULTIPLE CAPACITORS IN A SINGLE LOCATION TO ADD TO TOTAL CAPACITANCE

Restrictions of the leakage current limit the capacitance value of Y1 capacitors to 4.7 nF, but there are applications that require higher capacitance values. In these applications, two or more capacitors can be used in parallel



When using capacitors in parallel, voltage derating may be required depending on the number of capacitors involved



Vishay offers X1/Y1 capacitors up to a uniquely high capacitance value of 20 nF with our 440LS20-R, saving board space and assembly costs, while lowering the risk of failure



- 12 THERE IS A LOWER COST SINGLE-LAYER CAPACITOR OPTION WHERE Y5V DIELECTRIC IS GOOD ENOUGH

Y5V temperature coefficients are available for both X1/Y1 and X1/Y2 capacitors

Y5V devices save space because of their higher dielectric constant (making the components smaller)

Y5V devices cost less since less ceramic material is used

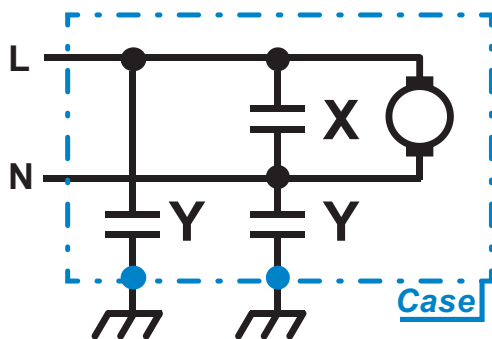
In many applications, operation temperatures are pretty predictable and low – and even at higher temperatures, a certain minimum capacitance value can be sufficient for filtering

RFI CAPACITORS FROM VISHAY

Safety Capacitors

Safety-Rated RFI Capacitors From Vishay

Typical Circuit

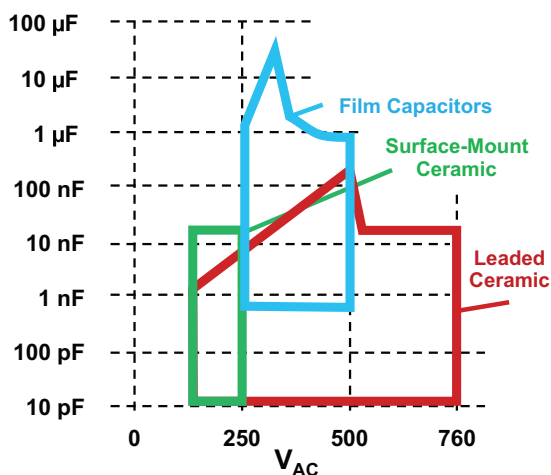


CLASS X

Differential Mode Filtering
Across the Line

Sub Class	Peak Impulse Voltage	Typical Application
X1	4.0 kV	High Pulse
X2	2.5 kV	General Purpose
X3	1.2 kV	General Purpose

Safety Capacitor Environment



CLASS Y

Common Mode Filtering
Line to Ground

Sub Class	Peak Impulse Voltage	Typical Application
Y1	8.0 kV	High Pulse
Y2	5.0 kV	General Purpose
Y3	Not pulse rated	General Purpose
Y4	2.5 kV	General Purpose

BENEFITS FROM VISHAY

- All three capacitor technologies available from one source
- Wide product range
 - X2 from 10 pF up to 40 μ F
- C0G (NP0) material available up to 1 nF nominal capacitance value in surface-mount capacitor
- Surface-mount product meets IEC 60384-14 min. 4 mm creepage at 1 nF in X1 / Y2 with COG (NP0)
- Y1 leaded ceramic up to 10 kV pulse strength guaranteed
- AEC-Q200 qualification available for film and leaded ceramic
 - AY2 leaded ceramic 3000 temp cycles from -55 $^{\circ}$ C to +125 $^{\circ}$ C
- F1772S withstands THB testing: 85 $^{\circ}$ C / 85 % RH / 240 V_{AC} / 1000 h
- VY1*C withstands THB testing: 85 $^{\circ}$ C / 85 % RH / 500 V_{AC} / 1000 h

A **WORLD OF**
SOLUTIONS



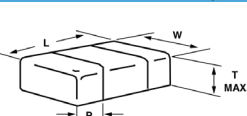
RFI CAPACITORS FROM VISHAY

Safety Capacitors

RFI X and Y Film Capacitors								
Series	Rated AC Voltage (V)	Capacitance Min. (μF)	Capacitance Max. (μF)	Rated Temperature (°C)	Construction	Agency Approvals	Pitch	
 F1772SX2	310	0.01	2.2	110	Series	IEC / EN / UL / CSA	15 mm to 27.5 mm	
X2 and series impedance applications; 85 °C / 85 % RH, 240 V _{AC} for 1000 h								
 MKP339X2	310	0.001	4.7	110	Mono	IEC / EN / UL / CSA / CQC	7.5 mm to 27.5 mm	
AEC-Q200 Automotive Grade X2 class capacitor								
 F340X2	305	1	20	105	Mono	IEC / EN / UL / CSA	27.5 mm to 52.5 mm	
X2 class capacitor for high robustness under high humidity. THB grade III B-SOP Q3 2017								
 F340Y2	305	0.001	1	105	Mono	IEC / EN / UL / CSA / CQC	10 mm to 37.5 mm	
Y2 class capacitor for high robustness under high humidity. THB grade III B-SOP, Q3 2017								
 F340X1	480	0.22	8.2	105	Mono	IEC / EN / UL / CSA / CQC	22.5 mm to 52.5 mm	
X1 class capacitor for high robustness under high humidity. THB grade III B-SOP, Q3 2017								
 F339X1 480 V_{AC}	480	0.001	1	110	Series	IEC / EN / UL / CSA / CQC	10 mm to 27.5 mm	
X1 capacitor for high capacitance stability; 85 °C / 85 % RH, 400 V _{AC} for 500 h								
 MKP3386Y2	300	0.001	0.47	105	Series	IEC / EN / UL / CSA	7.5 mm to 27.5 mm	
AEC-Q200 Automotive Grade Y2 class capacitor								
 F1773X2	253	0.01	2.2	100	Series	IEC / EN / UL / CSA	-	
Axial X2 capacitor for low building height applications								

Loaded Ceramic Safety Capacitors						
Series		Voltage		Capacitance	Tolerance	Temperature Characteristics
		Y Rating	X Rating			
	VY1 Series	500 V _{AC}	760 V _{AC}	10 pF to 4.7 nF	± 10 % / ± 20 %	U2J / Y5S / Y5U / Y5V
	AC-line rated ceramic disc capacitors; class X1: 760 V _{AC} ; class Y1: 500 V _{AC} ; this series includes mini sized VY1...Y5V					
	VY1 Compact Series	500 V _{AC}	760 V _{AC}	470 pF to 4.7 nF	± 20 %	Y5U
	Compact size and high pulse strength; AC-line rated ceramic disc capacitors; class X1: 760 V _{AC} ; class Y1: 500 V _{AC}					
	VY2 Series	300 V _{AC}	440 V _{AC}	10 pF to 10 nF	± 10 % / ± 20 %	U2J / Y5S / Y5U / Y5V
	AC-line rated ceramic disc capacitors; class X1: 440 V _{AC} ; class Y2: 300 V _{AC} ; this series includes mini sized VY2...Y5V					
	AY2 Series	300 V _{AC}	440 V _{AC}	10 pF to 4.7 nF	± 10 % / ± 20 %	U2J / Y5S / Y5U
	AC-line rated ceramic disc capacitors for automotive applications; class X1: 440 V _{AC} ; class Y2: 300 V _{AC}					
	WKP Series	500 V _{AC}	760 V _{AC}	33 pF to 4.7 nF	± 10 % / ± 20 %	U2J / Y5S / Y5T / Y5U
	AC-line rated ceramic disc capacitors; class X1: 760 V _{AC} ; class Y1: 500 V _{AC}					
	WYO Series	250 V _{AC}	440 V _{AC}	1.0 nF to 12 nF	± 20 %	Y5U
	AC-line rated ceramic disc capacitors; class X1: 440 V _{AC} ; class Y2: 300 V _{AC}					
	440L Series	500 V _{AC}	760 V _{AC}	10 pF to 20 nF	± 10 % / ± 20 %	C0G / U2J / P3K / R3L
	AC-line rated ceramic disc capacitors; class X1: 760 V _{AC} ; class Y1: 500 V _{AC}					

Surface-Mount Ceramic Capacitors							
TCC	Rating	Rated AC Voltage	Body Size	Capacitance (pF)		Rated Temperature	Agency Approvals
				Min.	Max.		
C0G(NP0)	X1 / Y2	250	2008	10	220	-55 °C to +125 °C	IEC EN CAN/CSA cCSAus ANSI/UL
			2012	18	470		
			2220	47	1000		
	X2		2008	10	390		
			2012	18	470		
X7R	X1 / Y2	2008	100	1000			
		2012	150	1200			
		2220	270	4700			
	X2	2008	100	2700			
		2012	150	5600			
		2220	270	12,000			

DIMENSIONS in inches (millimeters)							
	Body size	Length (L)	Width (W)	Maximum Thickness	Term. (P)		
					Min.	Max.	
	2008	0.200 ± 0.010 (5.08 ± 0.25)	0.080 ± 0.010 (2.03 ± 0.25)	0.086 (2.18)	0.010 (0.25)	0.030 (0.76)	
	2012	0.200 ± 0.010 (5.08 ± 0.25)	0.126 ± 0.008 (3.20 ± 0.20)	0.086 (2.18)	0.010 (0.25)	0.030 (0.76)	
	2220	0.220 ± 0.008 (5.59 ± 0.20)	0.200 ± 0.010 (5.08 ± 0.25)	0.086 (2.18)	0.010 (0.25)	0.030 (0.76)	

CAPABILITIES

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2/2



DID YOU KNOW?

BIASED HUMIDITY TEST WITH SAFETY CAPACITORS

We all want our electronics to function properly. In addition to vehicles, outdoor equipment such as energy meters and solar inverters face harsh environmental conditions that can result in field failures. To ensure that electronic components will perform reliably in these conditions, many environmental tests are performed. Amongst them, biased humidity tests have increased in importance.

The most severe humidity test is the so-called biased 85 / 85 or temperature humidity bias (THB) test. It is an accelerated life test in which the capacitors are exposed to moisture at high temperature and rated voltage. The automobile industry first introduced this test with an extremely demanding duration of 1,000 hours in its AEC-Q200 standard. The extreme parameter values were chosen to simulate long term environmental influences – this can span decades – within a short period of time.

85 / 85 Test Conditions in the AEC-Q200:

T	Temperature	85 °C ± 2 °C
H	Humidity	85 % ± 5 % relative humidity
B	Bias	@ rated voltage
	Duration	1,000 hours

The international industrial standard IEC 60384-14.4 (Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains) defines requirements and test conditions for safety capacitors. The new Annex I allows for classification of components in terms of moisture resistance.

	Class I	Class II	Class III
Denomination	Resistance at moisture conditions	Resistance at increased moisture conditions	Increased resistance at increased moisture conditions
Test condition A	40 °C / 93 % RH / 21 d	40 °C / 93 % RH / 56 d	60 °C / 93 % RH / 56 d
Test condition B	85 °C / 85 % RH / 168 h	85 °C / 85 % RH / 500 h	85 °C / 85 % RH / 1,000 h
Remark	@ rated voltage Test condition B is a substitutional accelerated test for test condition A		

The table above shows that the conditions of the THB test defined in AEC-Q200 are equivalent to those of Class IIIB of the IEC 60384-14.4 standard.

Even under harsh conditions in outdoor applications, Y1 and Y2 safety capacitors must not fail, because this might lead to life-threatening events like electrical shocks. Therefore, it is important to know the 85 / 85 performance of those capacitors.

Vishay's VY1...C (X1 / Y1) and AY2 series (X1 / Y2) meet the highest class of moisture resistance, the biased 85 / 85 1,000 hour test. The VY1...C is the industry first X1 / Y1 safety capacitor to meet the challenging Class IIIB specifications of IEC 60384-14.4. The AY2 is specified according to AEC-Q200.