ISSUE: March 2020

Determining Whether A Film Capacitor Can Handle One AC Voltage Imposed On Another

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Customers reach out to KEMET on a daily basis to help them determine whether or not a particular capacitor series or an individual part number will work in their circuit. More often than not, answering the question requires us to learn a little about the circuit and the type of environment in which the capacitor is expected to operate.

A common question that we receive from customers is along these lines: "I am wondering whether I can use a C44BXFP4100ZB0J, C44BXFP4150ZA0J or C44BXGP4200ZA0J with a 60-Hz 720-Vrms ac voltage imposed on 10% 16-kHz pk-pk ripple?" To determine whether a capacitor can handle two applied ac voltages, we need to know more about the operating conditions in the application and its life expectancy as will be explained in this article.

Factors That Determine Capacitor Ratings

This type of customer question leads us to ask the following:

- What is the ambient temperature of the application?
- What life expectancy is required?
- What is the application type?
- Is there any dc bias applied to this part?

Depending on whether the application is ac or dc, and which technology the customer is inquiring about, there may be different or additional questions that we must ask. In this case, we are discussing metallized polypropylene film capacitors.

For this type of capacitor, there are two main reasons why we need to know the ambient temperature. The first is to ensure that the ambient temperature is within the rated temperature range of the capacitor. KEMET does not recommend using one of our components outside of a rating whether that is temperature, voltage, ripple current or any other specification.

The second reason is that the life of the capacitor is related, in part, to the temperature. Humidity combined with temperature can deteriorate the internal film metallization causing a capacitance drop and an increased dissipation factor. The graph in the figure below shows the voltage ratio versus lifetime expectancy with respect to the temperature of our F862 series capacitor.

Though the F862 series is not the one used in our customer's application, the same theory hold true. It is important to mention that the temperature range of the F862 series is -40°C to 110°C, while the temperature range of our C44B series is -40°C to 85°C. As shown in the graph, the life expectancy of the F862 series capacitor begins to decrease at higher temperatures even though they are being used at temperatures below the rated temperature.

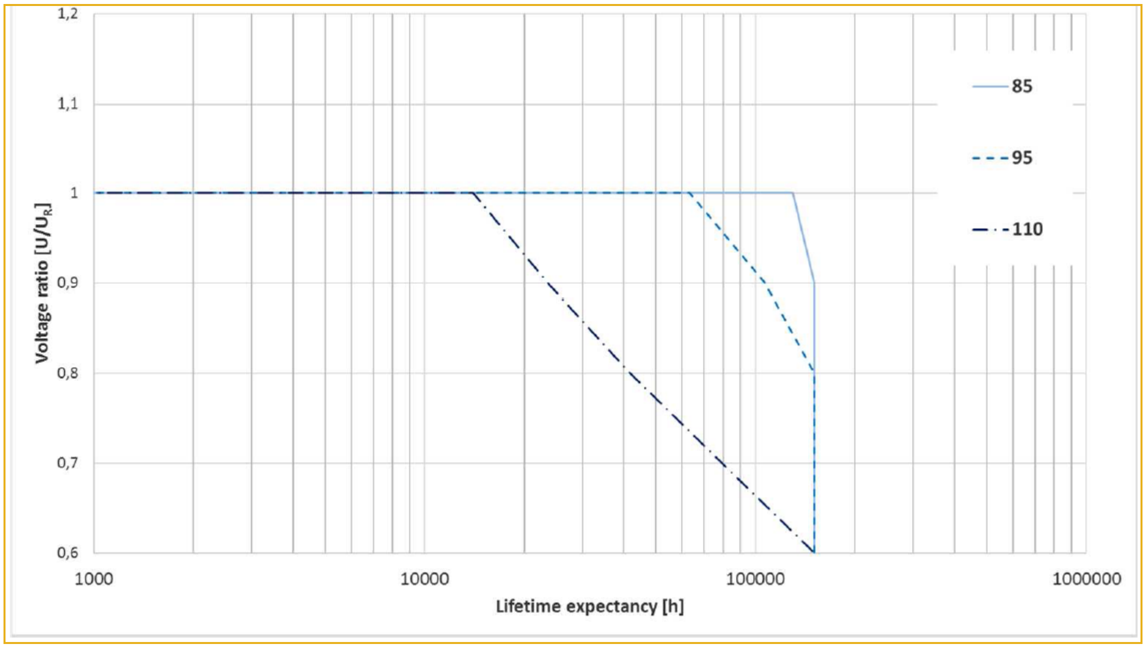

Figure. Lifetime expectancy for a film capacitor is a function of the voltage ratio of the applied operating voltage to the rated voltage and of the ambient temperature as plotted here for the F862 series.

Our next point is the life expectancy. Based on the ambient temperature, we should be able to tell whether the capacitor will be able to last the required lifetime determined by the customer.

"What is the application type?" is one question that we ask every customer no matter what component they are inquiring about. We need to confirm that the customer has chosen the correct part type based on the application. For our capacitors, we have many different designs made for specific applications such as dc links, snubbers, filters, and EMI suppression. Choosing the wrong capacitor type can lead to a failure.

For this particular series, we need to know if there is any dc bias being applied to this capacitor since this series does not have a dc rating. When a dc current is applied we must consider the ac portion, which is called ripple current. This application did not have a dc bias. If it did, we would have to take the ripple current generated into consideration.

In the example we also needed to confirm what the 10%, 16 kHz pk-pk was referring to. A misunderstanding could have lead us to believe that the 10%, pk-pk is of the 720 Vrms, 60-Hz fundamental. The pk-pk of that 60 Hz fundamental is roughly 2,040 Vpk-pk. If we take 10% of that signal, then we are looking at 204 Vpk-pk at 16 kHz, which is 72 Vrms at 16 kHz. It turns out that the 10%, 16-kHz pk-pk was referring to 16-kHz, 72 Vpk-pk.

Based on the additional information from the customer, we decided to calculate whether the 2-µF part, C44BXGP4200ZA0J, would work in the circuit. Below is a list of that part's specifications pulled directly from the spec sheet.

Table. Key specifications for the C44BXGP4200ZA0J film capacitor.

Specifications	
Capacitance:	2 uF
Capacitance Tolerance:	5%
Voltage AC:	1000 VAC
Voltage DC:	2400 VDC
Temperature Range:	-40/+85C
Rated Temperature:	70C
Max dV/dt:	500 V/us
Resistance:	2.5 mOhms (TYP)
Ripple Current:	22 Amps, 1000 Amps (Peak)

Below are our calculations for the 2-µF part.

A ripple waveform of 72 Vpk-pk at 16 kHz will have an RMS value of

$$Vrms = \frac{1}{2\sqrt{2}} * Vpkpk = \frac{1}{2\sqrt{2}} * 72\ Vpkpk = 25.45\ \text{Vrms at 16 kHz}$$

The ripple current produced by that voltage will then be

$$Irms = \frac{Vrms}{X_C} = \frac{Vrms}{\left(\frac{1}{2\pi f C}\right)} = \text{Vrms}* 2\pi f C\ = 25.45\ Vrms *\ 2\pi * 16\ kHz * 2\ \mu F = 5.1\ \text{Arms}$$

Meanwhile, the main ac voltage of 720 VRMS at 60 Hz will produce a ripple current through the capacitor of

$$Irms = \frac{Vrms}{X_C} = \frac{Vrms}{\left(\frac{1}{2\pi f C}\right)} = \text{Vrms}* 2\pi f C\ = 720\ Vrms *\ 2\pi * 60\ Hz * 2\ \mu F = 0.6\ \text{Arms}$$

The total effective rms current through the capacitor will therefore be:

$$\sqrt{5.1^2 + 0.6^2} = 5.135\ \text{Arms}$$

Total voltage:

$$\sqrt{25.45^2 + 720^2} = 720.45\ \text{Vrms}$$

According to the *datasheet*, the capacitor can handle the rated RMS voltage for 30,000 hours and the rated ripple up to an 85°C hot spot. According to the *specsheet*, which provides the ratings for a particular part number, this capacitor can handle 1000 Vac for 30,000 hours and 22 Arms up to an 85°C hot spot.

The voltage derating turned out to be 720.45/1,000 = 72.045%. The current capability (22 Arms) is greater than what is applied (5.135 Arms) to the capacitor. The conclusion is that this part is okay for the application and can be considered overdesigned for the purpose.

Acknowledgements

The author would like to thank Hector Nieves for his contributions to this article.

Reference

KEMET Part Number: C44BXFP4100ZB0J spec sheet.

About The Author

Samuel Accardo is a field application engineer at KEMET. The FAE position gives him the opportunity to use the knowledge and training he gained from his degrees in electrical engineering and mass communication from Louisiana State University.

For further reading on capacitors, see the How2Power Design Guide, locate the Component category and select "Capacitors".