



MLCC Application Notes

What is the Capacitance of this Capacitor?

Frequently asked questions regarding aging and its effect on capacitance.

Steve Maloy
TDK Components USA, Inc.

Abstract

TDK recognizes not all users of MLCCs are aware of dielectric aging and its effect on capacitance. This paper provides an explanation of aging and how TDK compensates for this natural phenomena in a question and answer format readers find most helpful.

What is the Capacitance of this Capacitor?

Frequently asked questions regarding aging and its effect on capacitance.

By Steve Maloy

Question 1 : What is “aging”?

Aging is generally referred to as a decrease in capacitance over time in EIA Class II capacitors. It is a natural and unavoidable phenomena that occurs in all ferroelectric formulations used as the dielectric material. Aging is reversible and occurs due to changes in the dielectric’s crystal structure with temperature and time. Aging is typically reported as a percent capacitance loss per decade of time. Because aging is logarithmic in nature, the loss of capacitance is greatest in the first 10 hours of age.

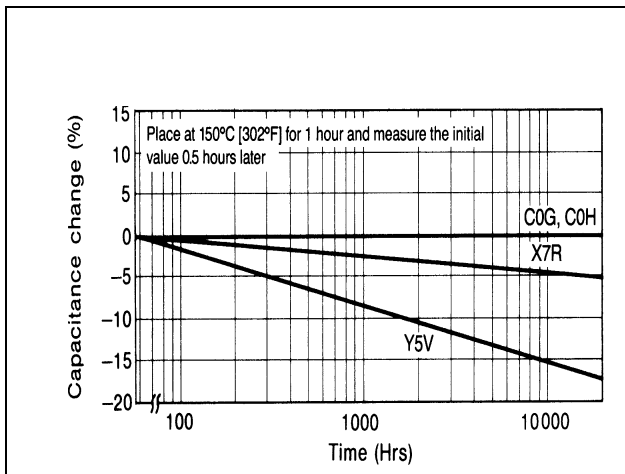


Figure 1 : Capacitance Aging Characteristic

(Taken from the TDK Chip Capacitor Catalog - Document ID: BBE-008B, 04/92)

Note : The dissipation factor also ages, decreasing several times faster than the capacitance. And, EIA Class III and IV also exhibit aging characteristics. Industry “official” definitions of aging can be found in EIA-521 and IEC-384-9.

Question 2: What is the difference between a Class I capacitor and a Class II capacitor?

A Class I capacitor¹ (C0G, C0H, C0K, etc.) is made from ceramic materials that are not sensitive to temperature changes, thus the capacitance value of a capacitor measured at a low temperature (example -25°C) will not significantly vary from the same capacitor measured at a higher temperature (ex. 75°C). EIA refers to these as “temperature compensating,” and are measured in ppm/°C. These capacitors typically have low capacitance values because of the ceramic material used to manufacture them but they exhibit nearly perfect capacitance stability regardless of their temperature, making them an excellent choice for applications in which frequency control is needed such as in radio or television tuners. An example of such is found below:

C0G = ±30 PPM over a temperature range of -55~+85°C

A Class II capacitor² (X7R, Y5V, Z5U) is made from ceramic materials that are derived from a barium titanate base which is temperature sensitive. Thus the various temperature classifications stating the extent of the sensitivity over a given temperature range. These capacitors allow for larger capacitance values in the small surface mount packages.

Examples of Class II *Temperature Characteristics*³ are below:

X7R = ±15% over a temperature range of -55~+125°C

Y5V = +22%, -82% over a range of -30~+85°C

Z5U = +22%, -56% over a range of +10~+85°C

Additionally, capacitors made from barium titanate bases (Class II, III, and IV) are ferroelectric and therefore susceptible to “aging” in which a capacitor’s ability to hold capacitance will decrease over time if left in an unheated and/or uncharged state. Class I capacitors are not ferroelectric and therefore do not age.

Question 3: Why and how do capacitors of barium titanate age?

Over time the internal molecular structure changes in such a way as to create an alignment of electrical dipoles. This alignment results in a molecular structure that can hold less electrical charge than when the molecules are in a totally random state, such as at the time of heating or mounting (soldering) on a printed circuit board.⁴

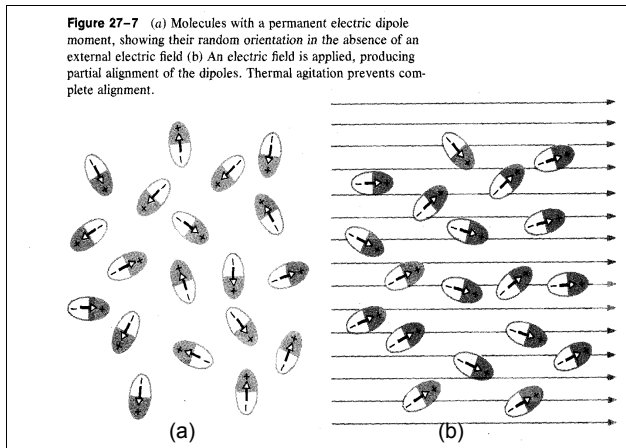


Figure 2 : Alignment of Electric dipoles

Question 4 : What is de-aging?

De-aging is a heat treatment used to reset the aging phenomena. Simply put, it restarts the aging process, but it does not prevent it. Heating the capacitor above its Curie Temperature causes the crystalline structure to return to its optimum unaligned configuration resulting in maximum capacitance. TDK recommends 150°C/1 hour for de-aging. Note : It is important to record the time of last heat (TOLH), or de-aging time, for future capacitance measurements.

Question 5: Is “aging” just a TDK phenomena?

No. The “aging” that is observed is common to all manufacturers of Class II, III, and IV ceramic capacitors. Since aging is formulation dependent, the aging rate will vary from manufacturer to manufacturer.

Question 6 : How does a capacitor manufacturer compensate for aging?

Since the capacitance of BaTiO₃ based capacitors changes with time, aging poses a unique problem for component manufacturers – that is, ‘what is the capacitance of this capacitor?’

Like voltage and frequency test conditions, the industry has long recognized the aging issue and has determined a standard by which all capacitors should be measured : IEC-384-9. Simply stated the capacitance must be within the specified tolerance at 1000 hours age (or TOLH).⁵

The capacitor manufacturer uses the material’s known aging rate and mathematically determines the capacitance tolerance limits for any point in time after de-aging (see figures 3 and 4 below). The components are 100% electrically sorting with respect to its aging rate and TOLH. For example, a +/- 10% tolerance part may be sorted at +13/- 7% if the dielectric material’s aging rate is 3%. By utilizing this technique manufacturers can guarantee all capacitors to be within cap tolerance at 1000 hours based on TOLH.

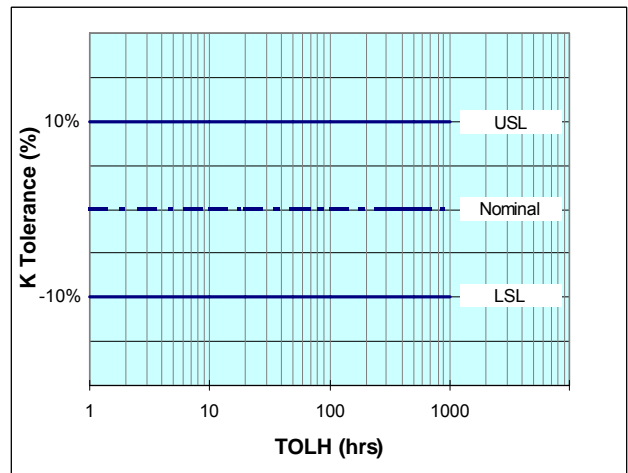


Figure 3 : Example sorting limits for Class I material, K Tolerance

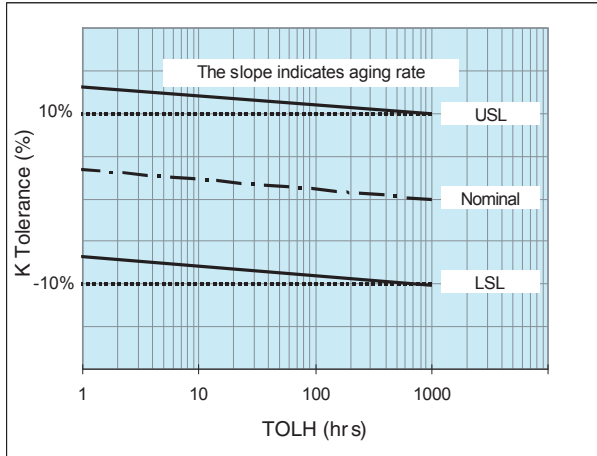


Figure 4 : Example sorting limits for Class II material, K Tolerance

NOTE : Because aging causes a decrease in capacitance over time, it is possible for the capacitance to be above the upper tolerance limit at times less than 1000 hours from TOLH, and less than the lower tolerance limit at times greater than 1000 hours from TOLH.

Question 7 : How should a capacitor user compensate for aging?

The capacitor user should expect the Class II, III, and IV capacitors to be within cap tolerance ~ 6 weeks (1000 hrs) from TOLH, the approximate lead time of most components from manufacturer to user. The capacitor user should not expect the Class II, III, or IV component to be within the cap tolerance immediately after solder, glue curing, or any other elevated temperature processes (capacitor will consequently de-aged).

In predicting aging/de-aging behavior, in circuit test systems may need to be widened to allow for capacitor aging.

References:

- ¹EIA-198-D, Page I-1
- ²EIA-198-D, Page I-1
- ³EIA-198-D, Page I-3
- ⁴Halliday and Resnick, Fundamentals of Physics, 2nd Edition, 1981, Page 492
- ⁵IEC-384-9 (1988), Appendix A

Acknowledgements:

- 1. Gene Williams, TDK Components USA, Inc.

End of Report

Contact one of the following TDK sales offices for further information or visit our website @www.tdk.com.

TDK CORPORATION OF AMERICA

1600 Feehanville Drive, Mount Prospect, IL 60056, U.S.A.
Phone: 847-803-6100
Fax: 847-803-6296

NEW JERSEY District Office

99 Wood Ave. South 5th Floor
Iselin NJ 08830
Phone: 732-494-0100
Fax: 732-494 5306

NEW ENGLAND Sales Office

20 Trafalgar Square
Nashua, NH 03063
Phone: 603-886-6600
Fax: 603-886-2888

GREENSBORO District Office

600 Green Valley Road, Suite 207
Greensboro, NC 27408
Phone: 336-292-0012
Fax: 336-292-3831

FLORIDA Sales Office

800 Fairway Drive, Suite 291
Deerfield Beach, FL 33441
Phone: 954-425-0095
Fax: 954-425-8287

DETROIT District Office

38701 Seven Mile Road, Suit 340
Livonia, MI 48152
Phone: 734-462-1210
Fax: 734-462-1193

INDIANAPOLIS District Office

4015 West Vincennes Road
Indianapolis, IN 46268
Phone: 317-872-0370
Fax: 317-872-2978

HUNTSVILLE District Office

250 Finney Road, Huntsville
AL 35824
Phone: 256-464-0222
Fax: 256-464-9963

CHICAGO District Office

1600 Feehanville Drive, Mount Prospect, IL 60056
Phone: 847-803-6100
Fax: 847-390-4325

MINNESOTA Sales Office

1875 Plaza Drive, Suite 201, Eagan
MN 55122
Phone: 612-894-8070
Fax: 612-894-7848

DALLAS District Office

511 E. Carpenter Freeway, Suite 690
Irving, TX 75062
Phone: 972-506-9800
Fax: 972-869-3353

HOUSTON Sales Office

3411 Garth Road, Suite 232
Baytown, TX 77521
Phone: 281-839-1097
Fax: 281-839-0121

AUSTIN Sales Office

11900 Metric Blvd., Suite J-144
Austin, TX 78758
Phone: 512-491-9010
Fax: 512-491-9023

SAN JOSE District Office

981 Ridder park Drive, Sutie 200
San Jose, CA 95131
Phone: 408-437-9585
Fax: 408-437-9591

PORTLAND Sales Office

1001 S.W. Fifth Avenue, Suite 1100
Portland, OR 97204
Phone: 503-220-2888
Fax: 503-220-2889

SAN DIEGO District Office

6165 Greenwich Drive, Suite 150
Sand Diego, CA 92122
Phone: 619-554-0999
Fax: 619-554-1861

LOS ANGELES Office

11137 Warland Drive, Cypress
CA 90630
Phone: 562-596-1212
Fax: 562-596-4841