Ceramic Capacitor Aging: What to Expect

KEY TOPICS

Aging effect, Aging rate, Referee time, Curie point, Deaging, MLCC Classes

AGING PHENOMENON

For all Class II and III capacitors (X7R, X5R, etc.), there is an unavoidable phenomenon where capacitance changes at a constant rate over time. The effect is called aging and this Tech Topic will provide answers to the following questions:

What is aging?
What causes aging?
Is aging reversible?

Aging is not a property of capacitor reliability and is not related to the overall lifetime in the application. Aging is a phenomenon where the capacitance changes over time and is an important factor that designers need to consider when using ceramic capacitors. Aging occurs in all Class II and Class III X7R, X5R, Y5V, Z5, etc. Capacitors from any manufacturer and is related to the material properties of the dielectric.

WHAT CAUSES AGING?

MLCCs (Multilayer Ceramic Capacitors) are constructed using alternating layers of ceramic dielectric and metal electrodes. Figure 1 shows the calculation of capacitance for an MLCC where the A is the active area of the electrodes, K is the relative dielectric permittivity, N is the number of electrodes and d is the dielectric thickness. By increasing either A, K, or N, the net result will be an increase in capacitance.

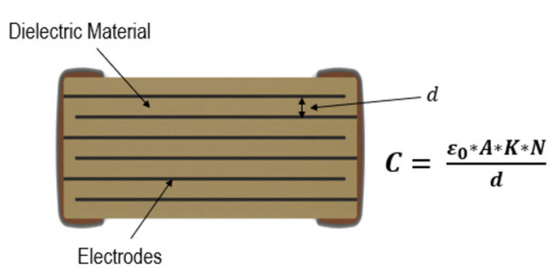

Figure 1 - Cross Section of MLCC

Class II MLCCs are made from BaTiO3, a ferroelectric material which has a crystalline structure containing Barium, Titanium and Oxygen atoms. Above its curie point (~130°C), BaTiO3 has a cubic crystal structure but as it cools down below its curie point, it transitions into a tetragonal shape. See Figure 2. The effect is an immediate spontaneous polarization of the material, forming dipoles which arrange into domain regions. This causes a spike in the effective permittivity which results in high capacitance.

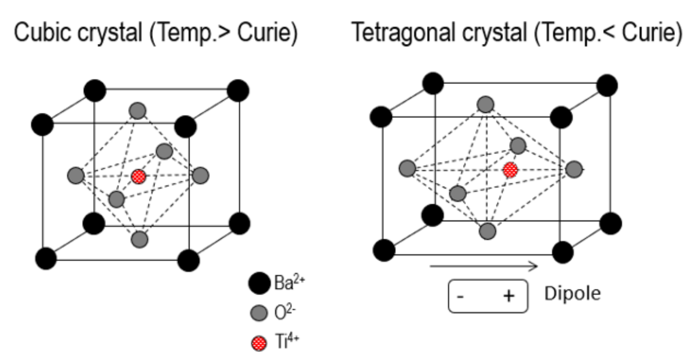

Figure 2 - $BaTiO_3$ above and below Curie Point

After spontaneous polarization occurs, the domains will begin to relax and realign within the material causing a gradual decrease in the relative permittivity. The effect is a loss of capacitance over time which is normally expressed as % Capacitance change per decade-hour after the last heat above curie point.

CALCULATING AGING

For Class II and Class III capacitors, manufacturers provide Aging rate and Referee times within the electrical specifications of the part. See Table 1 for typical aging rates and referee times for MLCCs. Aging rates are expressed in % and specify the percent capacitance loss per decade-hour indefinitely. Referee time refers to the number of hours after the last heat where the capacitance is stated to be within specification. The nominal capacitance stated in the specification sheet is the capacitance at the referee time. Last heat is the condition where the MLCC cools down below the curie point (~130°C) and aging begins (t = 0). Last heat can occur during KEMET's manufacturing process or a solder reflow process.

EIA Code	Typical aging (%/decade hrs.)	Typical referee time (hrs.)
C0G	0%	N/A
X7R	3%	1,000
X5R	5%	48

Table 1 – Typical Aging rates and referee times for MLCCs

To give an example, if a 10uF ±5% X7R capacitor is soldered to a PCB, the capacitor will see temperatures exceeding the curie point and the $BaTiO_3$ will transition into a cubic crystal structure. As the capacitor cools below the curie point, the $BaTiO_3$ will transition to the tetragonal shape and the relative permittivity will be high. The time at which the part cools below the curie point is where aging begins, and capacitance starts to decrease around 3% per decade-hour as seen in Figure 3.

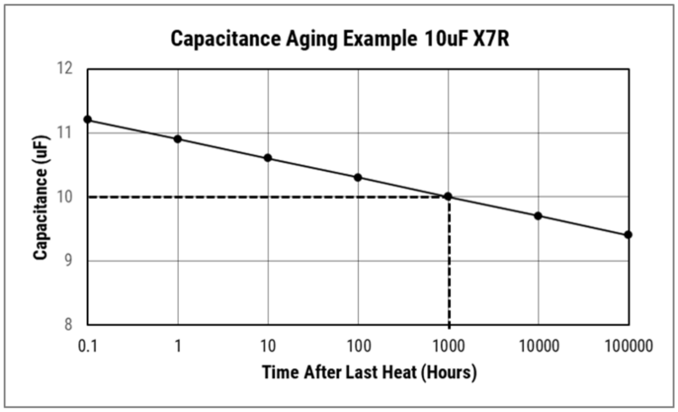

Figure 3 – Aging Example: 10uF X7R

At 0.1 hours after last heat, the capacitance is 11.2 uF which is out of specification. Therefore, manufacturers provide a referee time for customers to know how long after the last heat the capacitance will be within the specification. In the case of the 10 uF X7R capacitor example, the capacitance is within specification at 1,000 hours after last heat.

AGING FACTOR FORUMLA

Equation 1 shows the calculation for capacitance vs time (t) given the Aging Rate (A), Referee Time (tr), and Nominal Capacitance (Cr). Each of these parameters are available on the KEMET specification sheet and can be used by engineers to determine the effects of aging over the lifetime of the capacitor.

$$C = C_r\left[1 - \left(\left(\frac{A}{100}\right) \cdot \log_{10}\frac{t}{t_r}\right)\right]$$

Equation 1 – Aging Rate Calculation

To aid engineers in calculating aging effects, KEMET has created an Aging Rate Calculator on Engineering Center.

REVERSING AGING – "DEAGING"

When capacitors are shipped from KEMET, they've gone through a last heat at some point during the manufacturing process. The last heat at KEMET's manufacturing facility is time at which the aging process began. It's not uncommon for customers to receive capacitors and have them sit on the shelf for many months or even years before mounting to a PCB. At that point, the capacitor is far along the aging curve and may be reading lower capacitance than the specifications. However, when the capacitor is mounted to the PCB, it will go through a solder reflow process in which it will see temperatures above the curie point. By going above the curie point, the capacitor will go through the crystal structure change again and reset back to its original aging rate start time (t = 0). The process that the capacitor goes through when resetting the aging process is called deaging.

Soldering is a common process for deaing ceramic capacitors but is not the only way to perform deaging. Another common and equally effective method is to place the capacitors in a 150ºC oven for a minimum of 30 minutes. The time above the curie point is not critical and once the capacitor reaches above the curie point, deaging occurs. However, KEMET specifies 30 minutes at 150ºC to allow enough time to exceed the curie point.

MEASUREMENTS CONSIDERATIONS

It is common for our customers to verify capacitance of the MLLC after it has been mounted to the PCB using ICT (In Circuit Testing) technology. If direct capacitance measurements are performed after the deage process, the capacitance can read high and out of specification. However, by using the aging rate calculator, customers can determine what the capacitance should be at any point along the aging curve. KEMET does recommend that customers should wait at least 24 hours prior to making the capacitance measurement.

WANT TO FIND OUT MORE?

For more information about EIA Classification (Class I, II, and III), take a look at this article available in Engineering Center:
Here's What Makes MLCC Dielectrics Different

Check out the rest of our product line up on

COMPONENTEDGE