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Accelerated life testing of nano ceramic capacitors and capacitor test boards using non-parametric method

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ABSTRACT

Engineers are searching for a reliable method to determine the time-to-failure (TTF) data of the electronic systems as cheaper as possible. Reliability plays a vital role in electronic devices marketing & sales, product quality, etc. Accelerated Life Test (ALT) and Highly Accelerated Life Testing (HALT) are the latest methodology in the field of life testing of engineering systems. The ALT can be conducted at higher stress level to generate more failure data within short duration of time. The parametric method and non-parametric method are used to convert the accelerated test condition to actual condition. In this paper, the most widely used C0G and X7R nano ceramic capacitor is selected to generate the time-to failure data at accelerated condition and non-parametric method is used to convert the accelerated condition data into actual condition.

1. Introduction

In today's challenging marketplace, engineering system and electronic product design teams are under pressure to reduce product qualification time. The product qualification test is usually performed through quantitative Accelerated Life Testing (ALT). Quantitative ALT is designed to quantify the life characteristics of the product under normal use conditions, and provide the reliability information, including the determination of the probability of failure of the product under use conditions, mean life under use conditions, and projected guaranty and warranty period. Ceramic capacitor is one of the important electronic components that are used in many complicated devices and systems. Multilayer nano ceramic capacitors (MLCC) are the most widely produced and used nano ceramic capacitors in electronic equipment that produces approximately one trillion pieces (1000 billion pieces) per year [1]. It is used in electronic industry for automotive applications, data processing, telecommunication applications, and other applications. As the reliability of a system or a device is mainly dependent on the reliability of its components, the evaluation of the reliability of the capacitors is very important to understand the reliable life of the overall systems and devices. In this study, the life of the ceramic capacitor is evaluated using accelerated life testing [2].

This study examines C0G and X7R nano dielectric systems of two leading edge Base Metal electrode. The temperature coefficient of capacitor (TCC) should be within range of ±15% for a −55 °C to 125 °C temperature range for the X7R Multilayer Ceramic Capacitor (MLCCs) type. For the temperature range of −55 °C to 125 °C the specification of C0G dielectric is that the change of capacitance from room temperature (25 °C) should be within 0 ± 30 ppm/°C. The reliability of the capacitor at accelerated conditions is characterized by performed accelerated life testing. The reliability behavior at highly accelerated test conditions to actual conditions is correlated using Prokopowicz and Vaskas (P–V) empirical equation [3,4]. P–V model is the most extensively used model for

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experiments involving testing and study of nano ceramic capacitor reliability [5–10]. Because there are lot of variations in activation energies and voltage coefficients, a range of case sizes and dielectric thickness coating values to be characterize for the dielectric system given by Eq. (1).

$$\frac{t_1}{t_2} = \left(\frac{V_2}{V_1}\right)^n e^{\left[\frac{E_a}{k}\left(\frac{1}{T_{1abs}} - \frac{1}{T_{2abs}}\right)\right]} \quad (1)$$

Eq. (1) represents the P–V formula.
where

t_i = time to failure under conditions i
V_i = voltage under condition i
n = voltage stress exponential
E_a = activation energy for dielectric wear out
k = Boltzmann's constant (8.62E−5 eV/K)
T_i = absolute temperature for condition i
i = index for failure

Due to the variations in activation energies and voltage coefficients, a range of case sizes and dielectric thickness coating values to be characterize for the dielectric system. This study examines the case sizes of 0603 and 1206 with the commonly used voltage ratings in the electronics industry such as 25 V and 50 V. Table 1 shows a summary of the nano capacitor values studied (see Fig. 1).

2. Experimental methodology

The experimental methodology is shown in Fig. 2 and explained below.

Step 1: Designing the Accelerated Life Test (ALT)

- Determining the failure mode and mechanism.
- Determining the stress types.
- Define the characteristics to be measured.
- Design the ALT.

Step 2: Conducting the Accelerated Life Test (ALT)

- Perform ALT as per the plan.
- Collect time to failure data.

Step 3: Evaluate the Mean Time to Failure (MTTF) under actual working conditions

- Finding the mean time to failure (MTTF) under accelerated conditions.
- Finding the mean time to failure (MTTF) under normal working conditions using suitable acceleration models.
- Estimating the reliability using non-parametric methods and comparing with parametric methods [11].

Table 1
Voltage rating and capacitance of nano ceramic capacitors.

	Case size	Voltage rating (V)	Capacitance (nF)
X7R	603	50	100
C0G	1206	25	100

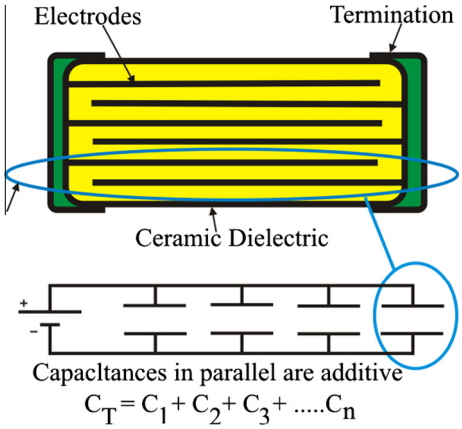

Fig. 1. Nano ceramic capacitor.

3. Experimental details

3.1. Accelerated Life Testing (ALT)

The testing of nano ceramic capacitors under accelerated condition were conducted in two types of experimental setup which are mentioned below

- Testing chamber (combined accelerated voltage and temperature).
- Capacitor test board (accelerated voltage).

3.2. Accelerated life testing in test chamber

The nano ceramic capacitors were placed on the test chamber and monitor the capacitance variation inside the chamber. The test chamber reliability system was based on measuring the current leakages in the electrical device, which consist of a ripple of source and the measuring part. The current circuit in test chamber measuring the leakage current of ceramic capacitor, and the resistor, which was connected in series, changed the comparable voltage from the passing current, which was noted in real time scenario. The capacitors were tested under accelerated testing condition with combined temperature and voltage stresses [12]. Total of 50 nano ceramic capacitors were tested and the time to failure data were obtained based on the failure mode observed in the capacitors.

The details of the capacitors are given below:

Type of capacitor: Ceramic capacitor.
Rated temperature: −55 °C to +100 °C.
Rated voltage: 25–50 V.

Fig. 3 shows the nano ceramic capacitor test chamber. The life tests were conducted at higher stress levels to generate more data in a short duration of time. So the capacitors are tested under constant accelerated conditions of 150 °C and 100 V to find out failure data in a short time.