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Full Length Article

Comparison of reliability techniques of parametric and non-parametric method

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ABSTRACT

Reliability of a product or system is the probability that the product performs adequately its intended function for the stated period of time under stated operating conditions. It is function of time. The most widely used nano ceramic capacitor C0G and X7R is used in this reliability study to generate the Time-to failure (TTF) data. The time to failure data are identified by Accelerated Life Test (ALT) and Highly Accelerated Life Testing (HALT). The test is conducted at high stress level to generate more failure rate within the short interval of time. The reliability method used to convert accelerated to actual condition is Parametric method and Non-Parametric method. In this paper, comparative study has been done for Parametric and Non-Parametric methods to identify the failure data. The Weibull distribution is identified for parametric method; Kaplan–Meier and Simple Actuarial Method are identified for non-parametric method. The time taken to identify the mean time to failure (MTTF) in accelerating condition is the same for parametric and non-parametric method with relative deviation.

1. Introduction

Reliability of the electronic component or engineering system can be determined from the failure rate using many techniques. These techniques are broadly classified as parametric method and non-parametric method. Non-Parametric methods are generally used for estimating the reliability characteristics. This method is very easy to use. The limitation of this method is that the results cannot be accurately extrapolated beyond the last reported failure rate. Parametric method is desirable to fit the failure rate to any statistical distribution, such as the exponential, normal, Weibull, or lognormal. This will result in a better understanding of the failure mechanisms, and the resulting model can be used for analytical evaluation of reliability parameters for the whole lifespan of the system.

Ceramic capacitor is one of the important electronic components that are used in many complicated devices and systems. Multilayer 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, telecommunication applications, data processing, 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, reliability techniques are compared to evaluate the life of the ceramic capacitor using accelerated life testing [2]. Fig. 1 represents the nano ceramic capacitor.

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 the range of ±15% for a temperature range of −55 °C to 125 °C for the X7R Multilayer Ceramic Capacitor (MLCCs) type. The Accelerated Life Testing (ALT) is used to identify the time to failure (TTF) of the nano ceramic capacitor under accelerated condition [3,4]. The highly accelerated reliability test conditions to actual reliability conditions are correlated using Prokopowicz and Vaskas (P-V) empirical equation. For nano ceramic capacitor reliability experiments and studies, the most extensively used model is the P-V model [5–12]. Because there are a lot of variations in activation energies and voltage coefficients, a range of case sizes and dielectric thickness coating values to be characterized for the dielectric system is given by Eq. (1).

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

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

t_1 = Actual time to failure
t_2 = Accelerated time to failure

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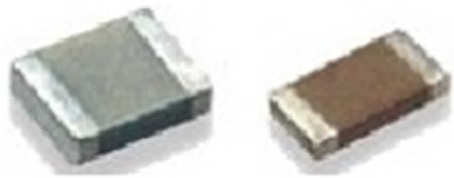

Fig. 1. Nano ceramic capacitor.

Table 1
Capacitance and voltage rating of nano ceramic capacitors.

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

V_1 = Voltage under Actual condition
V_2 = Voltage under Accelerated condition
n = Voltage stress exponential
E_a = Activation energy for dielectric wear out = 0.5 eV
k = Boltzmann's constant (8.62 E-5 eV/K)
T_1 = Absolute temperature
T_2 = Accelerated Temperature

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 the summary of nano capacitors values studied.

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 [13].

3. Experimental details

3.1. Accelerated life testing in test chamber (combined accelerated voltage and temperature)

The nano ceramic capacitor is placed in the test chamber, and capacitance variations are monitored in the visual display unit of the Test 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 [14]. A 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 V to 50 V

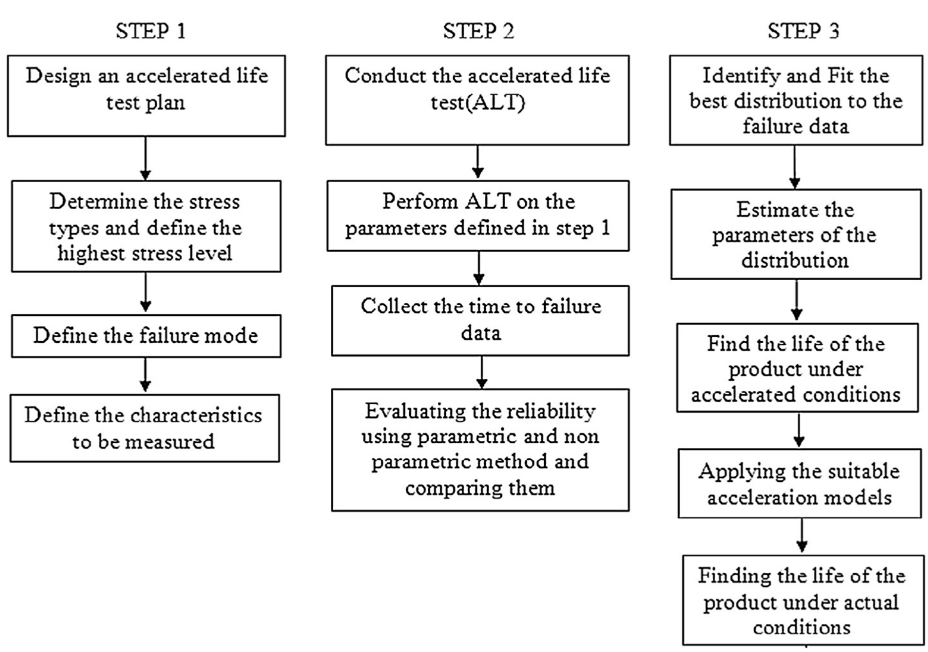

Fig. 2. Experimental methodology.