Failure Prediction and Reliability analysis of Multi-layer Ceramic Capacitor for ground mobile applications

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Abstract

Although Multilayer Ceramic Capacitors are known for its better frequency performance and voltage handling capacity, but under various environmental conditions, its reliability becomes a challenging issue. The mean time between failure (MTBF) as well as Failure-In-Time (FIT) values for Multilayer Ceramic Capacitor (MLCC) are calculated using military handbook MILHDBK-217F. Extreme cases of input parameters such as voltage, temperature and effective resistance between capacitance and power supply are considered, whereas Failure-in-time is calculated using military handbook. The average value of failure-in-time is observed as 0.6 failures per 10^9 *hours. With the increase in temperature, failure rate also increases in proportionate rate. The prediction of failure well before the actual fault, can save the entire component and device.*

Keywords: *MTBF, FIT, MILHDBK-217F, MLCC, Reliability*

I. Introduction

As now-a-days, an integrated chip is comprised of thousands of electronic components, whose performance is integrated to all components. So, failure of one component can initiate the complete failure of the whole system or device. A capacitor is a passive electronic component, which has extensive range of use in various spectrum of life(Longland, Hunt, and Brecknell 1984). The multilayer ceramic capacitors also known as MLCC, are the type of capacitors in which small value capacitance is required. It is surface mounted device type capacitor, which is widely used in industrial applications. The main application of multilayer capacitor is in operational amplifier and as bypass capacitor(Takahashi and Kozawa 1980). The performance of capacitor is depending on the amount of electrical charge it can store. The advantages of MLCC are better frequency characteristics as well as more power to withstand the voltage (Caswell 2013).

Figure 1. Multilayer Ceramic Capacitor

Various environmental conditions are applicable for the performance of capacitor. In this paper, reliability prediction of MLCC in ground mobile applications are targeted(Nazir, Khan, and Stokes 2015). When the capacitors are deployed in mobile field, it came across various environmental conditions as well as electrical parameters, which make the life of the component vulnerable(Cherry Bhargava, Vijay kumar Banga, and Singh 2018). In the ground mobile conditions, the capacitor is used in the wheeled vehicle and it is transported for the use, for example mobile communication, satellite etc. The more variation in the electrical parameters, the more is the chances of failure of the component or low performance(O'Connor 1990).

In this paper, KEMET capacitor of 22µf is taken and various inputs are applied on the capacitor and observe the failure in time, using MILHDBK-217F.

2. Failure Prediction using Military Handbook MILHDBK-217F

There are various empirical standards, which are used as reliability standards by users. The military handbook is also one of the defense handbooks, which has procedures, practices, technical specifications and failure rates of various electronic components under various environmental conditions(Kurzweil, Hildebrand, and Weiß 2015). The military handbook is developed by department of defense, Washington. In this paper, revised version of MILHDBK is used(Handbook 1995). Part stress and part count are types of reliability measurement as observed by defense and recorded in military handbook MILHDBK 217F(Venet et al. 2002).

The military handbook deals with various environmental operating conditions, which are described as in table 1.

Table 1. Various Operational Environmental Conditions

Environment	Symbol	Description
Ground, Benign	Gb	Non-movable and controlled by temperature and humidity
Ground, Fixed	Gf	Moderately controlled environments
Ground, Mobile	Gm	Mobile conditions such as satellite, fire tracking
Naval, Sheltered	Ns	Includes sheltered or below deck conditions on surface ships
Naval, Unsheltered	Nus	Unprotected surface shipborne equipment
Airborne, Cargo	Ac	When the various environmental conditions such as pressure, temperature, are minimum.
Airborne, Fighter	Af	For high performance fighters
Airborne, Winged	Aw	For earth orbital conditions, same as ground benign.
Space, Flight	Sf	Environmental conditions of power missiles.
Missile, Flight	Mf	Conditions for flight missiles.
Missile, Launch	Ml	Extreme conditions for missile launch
Cannon, Launch	Cl	Extreme Severe conditions related to cannon launch

The 22µf KEMET manufacturer Multilayer Ceramic Capacitor (MLCC) is taken for the performance evaluation(Neri, Allen, and Anderson 1979). Under the various environmental conditions and electrical parameters, the capacitor failure rate using MILHDBK-217F can be calculated as:

$$\lambda_p = \lambda_b \pi_T \pi_C \pi_V \pi_{SR} \pi_Q \pi_E \quad (1)$$

The equation (1) shows the failure rate of capacitor, where the

λB is base failure rate=0.002

ΠT is temperature factor=8.3

ΠC is capacitor factor=1.3

ΠV is voltage factor=0.5

ΠSR is voltage stress ratio=1

ΠQ is quality factor=0.001

ΠE is environmental factor=1

The different set of voltages, temperature and effective resistance between capacitance and power supply is taken and failure rate of Multilayer Ceramic Capacitor (MLCC) is calculated(Cherry Bhargava and Banga 2013).

3. Reliability Calculation Tools

Failure rate of the component of device can be calculated as total number of failures divided by stipulated time period of the operation.

$$FIT = \frac{Number\ of\ failures}{Total\ components\ X\ Test\ time\ X\ Acceleration\ factor} \tag{2}$$

Where, test time is the time taken by the experiment or operation and failures represent the malfunctioned components. The acceleration factor is derived from the Arrhenius equation(Bhargava, Banga, and Singh 2018).

A reliability term, known as MTBF is mean time between failure, indicates the time between the failure or in other words, it is the expected failure time(Zhao et al. 2009). An important factor to analyze the reliability of a device or a component, MTBF is used in predicting failure by end user(Zhao, Chen, and Xu 2009)

$$MTBF = MTTR + MTTF \tag{3}$$

Here, Mean time to repair is indicated by MTTR and Mean time to failure is shown by MTTF(Martin 1999).

The another way of reliability statistics, is Failure In Time (FIT) which reports the number of expected failures per 10^9 hours of experiment for any component or device (Ye, Lin, and Basaran 2002).

$$FIT = Failure\ rate\ X\ 10^9 hours \tag{4}$$

The Failure in Time (FIT) for Multilayer Ceramic Capacitor (MLCC) can be calculated by inserting the values of base rate and standard factors in equation (1).

Table 2. FIT of Multilayer Ceramic Capacitors using MILHDBK 217F

S. No	Input			Output
	Voltage	Temperature	Effective Resistance	FIT (per 109 hours)
1	0.5	80	80	0.03
2	0.6	85	90	0.09
3	0.7	90	100	0.17
4	0.8	95	80	0.21
5	0.9	100	90	0.23
6	1.0	105	100	0.33
7	1.1	110	80	0.47
8	1.2	115	90	0.54
9	1.3	120	100	0.67
10	1.4	125	80	0.74
11	1.5	130	90	0.88
12	1.6	135	100	0.90
13	1.7	140	80	1.17
14	1.8	145	90	1.24
15	1.9	150	100	1.33

4. Results and discussion

The 22µf multilayer capacitor of KEMET manufacturer is taken for the experimental process. The Multilayer Ceramic Capacitor (MLCC) is subjected to changes in voltage, temperature and effective resistance between power and capacitance and mean time between failure is noted (Ross 1996). A graphical representation of temperature versus failure is shown in figure 2.

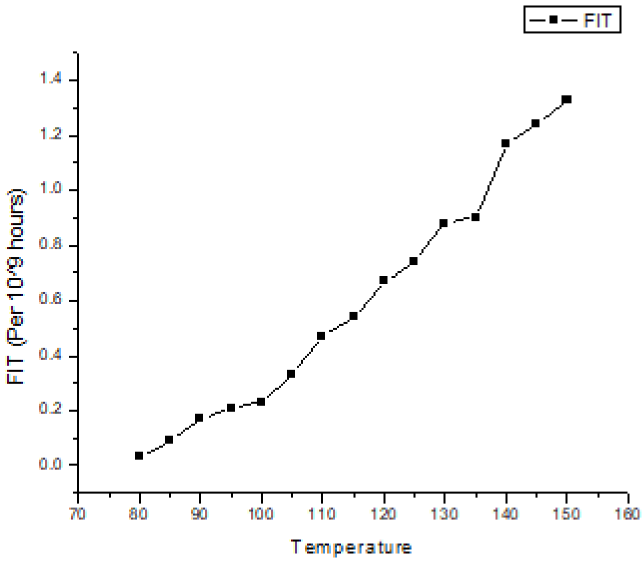

Figure 2. Graphical representation of temperature versus failure

As the temperature increases, the mean time between failure (MTBF) as well as failure in time (FIT) also enhances proportionally(Ooghe and Balcaen 2015).

5. Conclusion and future scope

Reliability analysis of multilayer ceramic capacitor (MLCC) is a critical issue, as it has wide range of applications in security as well as aircraft domains. Military handbook is proven as boon to predict the failure of multilayer ceramic capacitor (MLCC) at various input parameters. By varying the temperature between 80 ºC to 150ºC and voltage 0.5V to 1.9V, the average range of failures in time is recorded as 0.6 failures per 10^9 hours. In future, experimental setup can be designed to verify the results of military handbook.

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