Accelerated Life Testing of Ceramic Capacitors and Integration of its Reliability Test Data with PLM Solutions

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Abstract— *As the market for an electronic device continues to grow and expand, it has become evident that product reliability must remain a top priority for electronic device manufacturers. The Electronic Device manufacturing industry is now under increasing pressure to maintain their places in the market. To improve their ability to innovate, get products to market faster, and reduce errors, the manufacturers have been continuing to improve their product reliability and product development. time. Product reliability is considered as a prime contributor to quality and competitiveness. The reliability of the product is usually determined by testing the product to failure and collection of time to failure (TTF) data. For some products the test time to evaluate reliability is usually very longer, if it is tested under actual working condition of the products. Hence the accelerated and highly accelerated life testing (HALT) testing method is employed to accelerate to stress condition on the product to quicken the degradation of products performance. The obtained performance data when analyzed, yields its reasonable estimates of products life under actual conditions. In this study, the ceramic capacitor are evaluated for it reliability using HALT. The capacitors are considered to be failed when its insulation resistance dropped. The product lifecycle management (PLM) integration methodology adopted in this study is based on 3-tier client server architecture. The software tool like Java, HTML (HyperText Markup Language) and SQL (Structured query language) are used to create the front and back end 3-tier architecture.*

Index Terms— *Highly Accelerated life Testing, Time to Failure (TTF), Product Lifecycle Management (PLM), Server Architecture.*

I. INTRODUCTION

Reliability costs money, but poor quality and reliability usually Cost more than good quality and reliability [1]. Reliability has to do with a product's entire life-cycle [2]. Prediction of reliability is very important for electronic components like capacitors, diodes and resistors as they are used in variety of telecommunication systems. Reliability testing aims to discover and remove failures before the product is introduced. Generally accelerated life tests are conducted on products to accelerate its time to failure due to accelerated stress applied on the products during testing. They aim to predict the future performance of a product based on a fraction of its actual service life [3].

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Multilayer ceramic capacitors (MLCCs) are widely used in the electronic industryfor telecommunication applications, data processing, automotive applications and other applications. With the recent tendency in miniaturization of Electronic device, electronic components are required to have a larger capacitance and also to be miniaturized. In the 90's, capacitor technology shifted from Precious Metal Electrode (PME) technology to Base Metal Electrode (BME) technology. BME capacitor technology primarily utilizes nickel in the electrode system whereas PME technology utilizes a palladium-silver alloy electrode system. One of the primary advantages of using BME technology is the increased voltage stress capability over traditional PME dielectrics. Figure 1 illustrates the BME technology that enables to reduce the dielectric thickness, increase the number of active layers and increase the total active area. All of these improving variables significantly contribute to the increased capacitance and volumetric efficiency of ceramic capacitors over time.

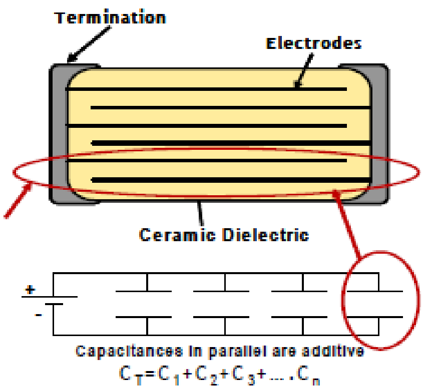


Figure 1: Ceramic Capacitor

This study examines two leading-edge BME C0G and X7R dielectric systems. In X7R type MLCCs, the temperature coefficient of capacitance (TCC) must be within ±15 % for a –55 °C to 125 °C temperature regimes. The temperature stability of capacitance can be created by control of the so-called core shell structure. The specification of C0G dielectric is that the capacitance variation from room temperature (25°C) should be within 0±30 ppm/°C over the temperature range of -55°C to 125°C. Traditional C0G dielectric materials for precious metal electrodes (PME, such as Pd or Ag/Pd) are typically based on the barium neodymium titanate (BNT) [4].The leakage current or insulation resistance of MLCCs is the major failure modes for the capacitors. The above mentioned failure modes are induced in the capacitor by subjecting them to high temperature and high multiples of rated voltages by accelerated life testing.. The performed accelerated life testing is used to characterize the reliability of the capacitor at accelerated conditions.

The Prokopowicz and Vaskas (P-V) [5] empirical equation is employed to correlate the reliability behavior at accelerated test conditions to operating conditions. Equation 1 depicts the P-V formula.

Eq. 1:

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

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

The P-V model has been used extensively in experiments and studies on ceramic capacitor reliability [6]-[8]. Due to the differences in voltage coefficients and activation energies, it is important to characterize each dielectric system across a range of dielectric thickness values and case sizes. This study examines case sizes 0603 and 1206 with voltage ratings of 25V and 50V. These voltage ratings and case sizes are commonly used in the electronics industry. Table 1 depicts a summary of the values studied.

Table 1

Dielectric	Case Size	Voltage Rating	Capacitance
X7R	0603	50V	0.1µF
C0G	1206	25V	0.1µF

II. EXPERIMENTAL METHODOLOGY

The flowchart shown in Figure 2 Illustrates the ccelerated Life Testing of capacitor and its Integration with PLM Solutions.

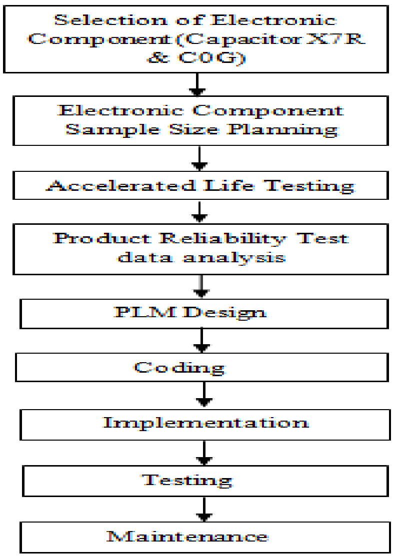


Figure 2: Accelerated Life Testing of Capacitor and its Integration with PLM Solutions.

A. *Sample Size Planning*

Once the reliability objectives are established, the sample sizes are estimated based on the statistical analysis at a percentage confidence level. In this study the single sided the chi-square estimate is used for sample –size planning.

$$N = \frac{\chi^2(\gamma,\ 2Y+2)}{2\bar{\lambda}At}$$

Where
N = the sample size,
λ = the upper-bound or failure-rate objective,
Y = the number of failures (nominally zero),
t = the total test time,
A=the estimated test/failure mode acceleration factor, and
γ = the confidence level (nominally 90%).

B. *Reliability Testing*

The initial values of capacitance of chips were measured with a LCR meter at room temperature. In the HALT the capacitor are subjected to accelerated temperature of 125 ℃, 150 ℃, 175 ℃ and 5 times the rated voltage. The HALT conditions used in this study were temperature condition of and 4 to 5 times of rated voltage. The samples as per the sample size calculation were tested and the leakage current of each component was monitored during the test. MLCC failures are said to be failed when insulation resistance degraded to a value which is less than the actual condition. The time to failure data that were obtain from the test were used to plot Weibull graph. It is assumed that the mechanism for failure is both thermal and voltage activated following the empirical P-V model. This P-V equation can be simplified to a single function of time.

Eq.2

$$\mathbf{t = A}\ v^{-n} \exp\left[Ea/kT^{-1}\right]$$

A = time constant (min)

III. EXPERIMENTAL RESULT

The HALT experiments for (C0G 1206 25V 0.1µF) were conducted in a commercial oven with maximum capabilities of 200V and 175ºC. The capacitors which were subjected to accelerated temperature and voltage in the commercial is monitored for every 40 seconds. The MTTF Data is generated based on the HALT results. It was found that the Weibull distribution is the best fit for the generated product reliability test data of ceramic capacitors. The Weibull distribution is a general distribution which failure times of many components follow. The probability density function of the Weibull distribution is given by

$$f\ (t) = \beta\theta^{-\beta}\ t^{\beta-1}\, e^{-(\frac{t}{\theta})^\wedge\beta}$$

Reliability function is given as

$$R = exp\left[-(\tfrac{t}{\theta})^\wedge\beta\right]$$

Where
β = Shape parameter
θ = Scale parameter

Rearranging the above expression, we get

$$\ln[ln(1/R(t)] = \beta\ \ln t - \beta\ \ln\theta$$

This is of the form of the straight line, y = mx+c. This can be expressed in terms of F(t) as follows.

$$\ln[ln(1/(1-F(t))] = \beta\ \ln t - \beta\ \ln\theta$$

Table 2: The life test data for C0G 1206 25V 0.1µF capacitor

i	ti(hrs)	F(ti)
1	67	0.166
2	120	0.33
3	130	0.5
4	220	0.666
5	290	0.833

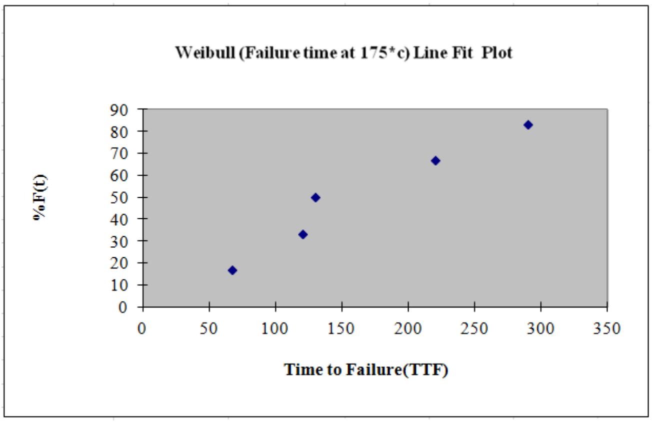


Figure 3: Weibull (Failure time at 175 C) Line Fit Plot

The Weibull probability is developed based on this relationship. The following steps may be followed.

i. Evaluate F(t_i) = i/N+1, where N is the total number of failures and i is the index for failures after arranging in ascending order.

ii. Plot F (t_i) vs t_i, to get a straight line on Weibull chart.

iii. The slope of the line is the shape parameter (β), which can be directly evaluated from graph.

iv. The scale parameter (θ) can be estimated by substituting β and F = 0.632 in the expression. θ can also be derived from the Weibull in figure 3.It corresponds to the time at which F(t) = 0.633.

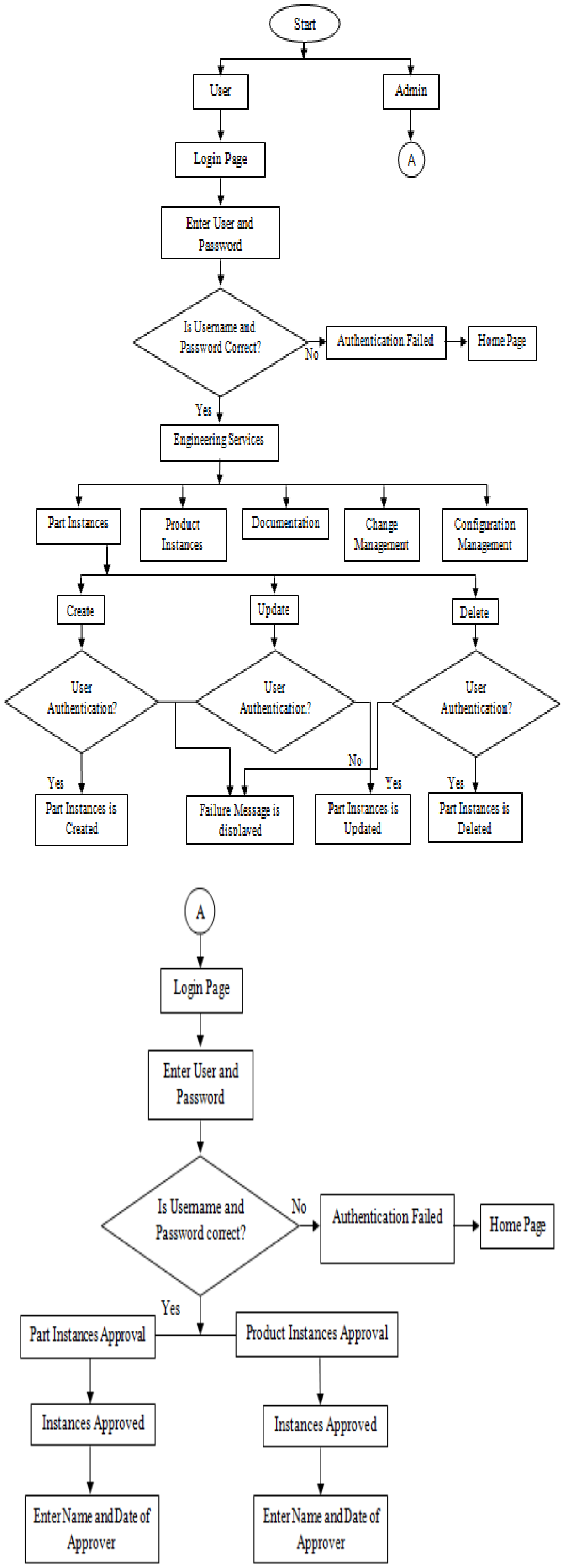
Plotting F (t_i) vs t_i on the Weibull Plot, a straight line is obtained shown. The distribution parameters estimated from the Weibull plot are β=2.25 and θ=190 hours. The MTTF of these devices can be estimated from the distribution parameters. The estimated MTTF is 166 hours.

IV. PRODUCT LIFECYCLE MANAGEMENT

Product Lifecycle Management is an integrated, information-driven approach to all aspects of a product's life, from its design through manufacture, deployment, and maintenance – culminating in the product removal from service and final disposal. PLM software suites enable accessing, updating, manipulating, and reasoning about product information that is being produced in a fragmented and distributed environment.

A. PLM Technology for Reliability Module

PLM systems are used to increase efficiency and productivity, to manage product data and to reduce costs for product development. Instead of covering applications and processes along the product lifecycle, PLM solutions are still focused on product design and prototyping. Implementation problems have been underestimated and project goals have not been fully achieved. Using PLM it is easier to access, to extract and to handle product information in global environments. Although quantification of certain benefits is difficult for users, the reduction of product development times and time-to-market are facts. PLM technology provides high data consistency and transparency, which have tremendously increased process and product quality. Figure 4 illustrates the framework that is used in the study to create, update and delete the part and product instances in PLM.



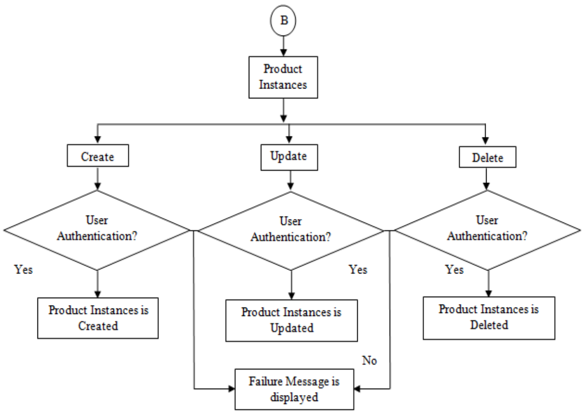


Figure 4: PLM Framework for Reliability Module.

V. PLM INTEGRATION

A. System Architecture

The PLM framework for Reliability module is built on three-tier client-server architecture. The requirements of concurrency and synchronization in a collaborative modeling context necessitate the adoption of client-server architecture. The server provides the communication, co- ordination and data consistency [9]. At the client side, HTML, Java and Oracle are used to develop systems for the Web browsers. The server side system consists of four modules namely Web server, Java virtual machine (JVM), database server and file vault.

B. Software Tools Used

This architecture consists of a front-end Web server as a client, a middle dynamic content processing and generation level application server and a back end database, comprising both data sets and database management system. The front-end of this system is designed using HTML. Apache tomcat serves as the application server. The logic coded in Java and Java server pages (JSPs) are used to communicate from the client to the application server. SQL (Structured query language) serves as the backend database. Java's networking support allows the creation a socket connection between the client and the server.

C. Java

Java is used as the backbone of this system due to its superb networking and multithreading capability. Its multithreading capability enhances the performance of the overall system since each client is handled by its own thread and no individual thread needs to be concerned about the rest of the thread execution at any event in the system. Much of the initial appeal of Java comes from the fact that it can be embedded in Web pages (i.e. Java applets). Thus interactive, user-friendly and context sensitive Web pages can be created, which improves the interaction between the client and the server. Java applets are transferred from the server to the client where they are interpreted. Applets are assigned to a specific area within Web documents where they can interact with the users through a user-friendly graphical interface. Therefore, Java applets can perform interactive System Architecture Animation and other simple tasks without sending a user request back to the server [10]. Furthermore, Java applets can establish network connection from the server to the client, whereas the HTTP (Hypertext transfer protocol) only transfers the applet code.

D. Java server pages

Java Server Pages (JSP) is a technology that helps software developers create dynamically generated web pages based on HTML, XML, or other document types. JSP may be viewed as a high-level abstraction of Java servlets. JSPs are translated into servlets at runtime; each JSP's servlet is cached and re-used until the original JSP is modified. JSP allows Java code and certain pre-defined actions to be interleaved with static web markup content, with the resulting page being compiled and executed on the server to deliver a document. The compiled pages, as well as any dependent Java libraries, use Java byte code rather than a native software format. Like any other Java program, they must be executed within a Java virtual machine (JVM) that integrates with the server's host operating system to provide an abstract platform-neutral environment. In general JSP languages are easier and faster to code in than the structured and compiled languages such as C and C++. However, a JSP takes longer time to run than a compiled program since each instruction is being handled by another program first rather than directly by the basic instruction processor. The JSP processes the data provided by the browser and returns information to the browser through the server.

E. Apache Tomcat

Tomcat is a Web server that supports servelets and JSPs. Tomcat comes with the Jasper compiler that compiles JSPs into servelets. The tomcat servelet engine is often used in combination with an Apache Web server or other Web servers. Tomcat can also function as an independent Web server. Tomcat is being increasingly used as a standalone Web server in high-traffic, high-availability environments. Tomcat runs on any operating system that has a JVM. Figure 5 & 6 shows the login page of the product lifecycle Management software and the created part instances page which includes average time to failure data.

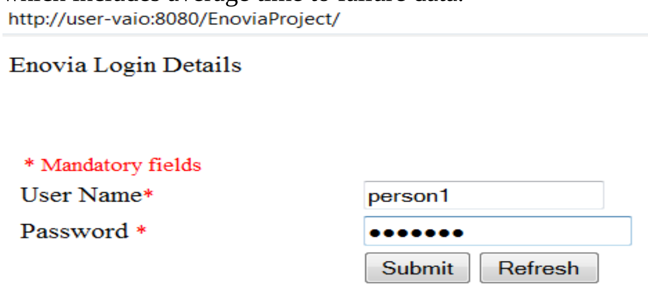


Figure 5: Login page of the PLM Software

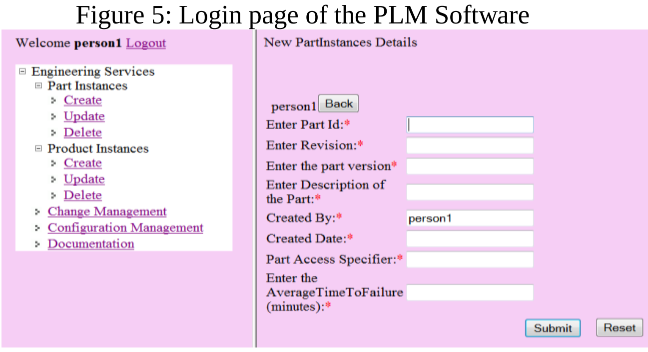


Figure 6: Created Part Instance .JSP Page with Failure detail.

F. JDBC-ODBC Driver

JDBC-ODBC Bridge is a database driver implementation that employs the ODBC (Open Database Connectivity) driver to connectivity to the database. The driver converts JDBC method calls into ODBC function calls. Figure 7 illustrates the structure of database.

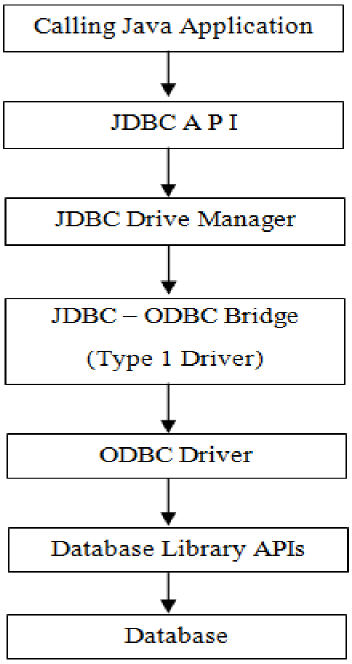


Figure 7: Structure of Database

G. Eclipse IDE (software)

Eclipse is a multi-language software development environment comprising an integrated development environment (IDE) and an extensible plug-in that can be used to develop applications in Java. Eclipse supports development for Tomcat, GlassFish and many other servers and is often capable of installing the required server (for development) directly from the IDE. It supports remote debugging, allowing the user to watch variables and step through the code of an application that is running on the attached server.

VI. CONCLUSION

In this study, using HALT the ceramic capacitor are subjected to highly accelerated temperature and voltage conditions. The time to failure data obtained from the tests are used to fit Weibull graph as it is found to be the best fit for the data. The data obtained at the accelerated conditions are used to find out the life of the capacitor under actual working conditions using P-V Empirical Model. The Reliability test data of capacitors are integrated with PLM solutions using JAVA, HTML and SQL Technologies. The PLM framework for the reliability module thus developed in this work is usedful for electronic component manufacturer, vendors and customers.

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