Reliability Prediction of HIC and MCM

Anna Vladova Andonova and Rumen Stoyanov Yordanov

Abstract - **Although many models are available for performing reliability prediction analyses, each of these models was originally created with a particular application in mind. This paper describes the most widely used reliability prediction models in terms of their intended applications, noting both their advantages and disadvantages. The purpose of this work is to automate the process of calculating component failure rates for the Hybrid integrated circuits or Multichip modules reliability assessment using the Part count and Part stress analysis**

Keywords –**Reliability Prediction, Multichip module, Hybrid integrated circuits**

I. Introduction

Multichip modules (MCM) and hybrid integrated circuits (HIC) include several elements and their connections. MCM usually consist of bare dies, various die-to-die connections on a routable substrate and connections to the second level package. A HIC often consists of passive elements (capacitors and resistors), bare dies, and interconnections between the active and passive elements, one or more substrates, and interconnections to the second-level package [1].

The reliability prediction is understood as the assessing of a numeric value of a selected reliability indicator, the most frequently a failure rate (λ) or Mean Time Between Failures (*MTBF*), in the initial stages of product life.

The fact is, however, that reliability engineering is based on known information and characteristics. It could be logically argued that there is more supporting data available for the reliability engineering pursuit than that for marketing, project management, business finance, or even functional assessment of designs.

The reliability prediction can be carried out with various techniques based on the experience with similar items, expert's estimates, etc. However, the most credible approach to the reliability prediction is utilizing of internationally accepted reliability data-bases and reliability prediction methods.

Reliability databases provide numeric values of reliability indicators for specific type of items. Reliability prediction methods provide, for separate groups of items (e.g. resistors), models that enable to take into account a specific real situation by choosing various factors, and they allow to calculate a value of a reliability indicator.

Realizing these facts, how does an organization rationalize a reliability program and still remain competitive in the commercial environment? The solution may be found by formulating an optimum program that recognizes the need to supply a quality product, without including high design and development costs in the form of extraneous engineering resources.

II. Reliability Databases and Prediction Methods in the Field of HIC and MCM

When used in reliability prediction analyses, the terms component, or part, typically are used to refer to the lowest level electronic device level – an electronic part such as a resistor, capacitor, transistor or integrated circuit This usage is based on the fact that prediction standards provide failure rates equations for parts. For example, the equation for a prediction standard for a resistor (defined in MIL-HDBK-217) looks like this:

$$\lambda_p = \lambda_b \pi_T \pi_A \pi_P \pi_S \pi_Q \pi_E \text{ Failures}/10^6 \quad (1)$$

where λ_p = predicted failure rate; λ_b = base failure rate; π_T = temperature factor; π_A = application factor; π_S = power stress factor; π_Q = quality factor; and π_E = environment factor.

When performing prediction analyses, the lowest level of a system is the "part" level.

A. Reliability Databasis

The database *EPRD-97 – Electronic Parts Reliability Data* was also developed by The System Reliability Centre (SRC). The EPRD-97 database contains failure rate data on electronic components, namely capacitors, diodes, integrated circuits, optoelectronic devices, resistors, thyristors, transformers and transistors. The data included in the database was obtained by longterm monitoring of the components in the field. Collecting the data was carried out from the early 1970's up to 1996. The data collection was focused on obtaining data on relatively new component types, data on many different sources, application environments and quality levels.

The purpose of the database is to provide failure rate data on commercial quality components, to provide failure rates on state-of-the-art components in case data or analyses are not feasible or required, and to complete the MIL-HDBK-217F or other prediction methods by providing data on the component types not addressed by them.

The database *SPIDR™ – System and Part Integrated Data Resource* is the most recent product in the field of reliability databases. The SPIDR™ was released at the beginning of 2006 by SRC.

The SPIDR™ is a complex product that replaces EPRD-97 database. It contains more than a double amount of data contained in the previous databases. To be specific, it contains data on more than 6000 electronic, electric, electro-mechanical and mechanical component types. The database is based on nearly 40 years of experience and on

A. Andonova is with the Department of Microelectronics, Faculty of Electronic Engineering and Technologies, Technical University - Sofia, 8 Kliment Ohridski blvd., 1000 Sofia, Bulgaria, e-mail: ava@ecad.tu-sofia.bg

R. Yordanov is with the Department of Microelectronics, Faculty of Electronic Engineering and Technologies, Technical University - Sofia, 8 Kliment Ohridski blvd., 1000 Sofia, Bulgaria, e-mail: ryordanov@ecad.tu-sofia.bg

the data collection completed by the Reliability Analysis Center (RAC) and the SRC.

B. Reliability Prediction Models

Parts Count (PC) analysis is used to obtain a very early indication of overall HIC/MCM reliability. Typically performed early on, before detailed HIC/MCM and component information is available, parts count analysis relies on some basic HIC/MCM information for determining HIC/MCM failure rate: the number of total parts (i.e., the parts count), a general failure rate of the components based on average operating stresses, and the operating environment. Parts count analyses also enable us to determine the Mean Time Between Failures (MTBF) of a HIC/MCM. Not all prediction standards support a parts count analysis.

As HIC/MCM design moves further along and more details are available, the parts count analysis is often used as a basis to move into a Part Stress (PS) analysis.

PS analysis involves a detailed assessment of a HIC/MCM with all operational, environmental, and device information taken into account. Parts stress analyses involve many steps: defining the HIC/MCM, breaking down the HIC/MCM into component parts, researching data parameters for all component parts, determining operational and other design-specific parameters, and then performing the mathematical analysis. The amount of information needed for a parts stress analysis varies across prediction standards, but typically involves much more than required for a PC analysis.

Parts stress analysis is normally used later in the development stage when most of the components and operating conditions have been identified. Parts stress analysis can also support "what-if?" analyses by allowing an analyst to make changes to the prediction model.

In many cases, organizations just introducing MTBF analysis into their process start with manually performing MTBF calculations. There are several widely accepted standards for MTBF analyses. These standards can be obtained by various means, depending on which standard is used. No matter which MTBF standard is selected, at the core, they encompass a set of equations and formulas for analyzing the failure rates of the components of your HIC/MCM.

C. Reliability Prediction Standards

A prediction standard is an established and accepted methodology for computing reliability metrics. Over the years, many prediction analysis standards have been developed by the military and commercial companies across the world for many types of electronic and mechanical components. Prediction standards use mathematical reliability models derived from the statistical analysis of accumulated test or field failure data.

The selection of a prediction standard to use for analysis is a critical one, and there is not a single “best” standard for every situation. Many factors must be taken into account when determining which standard is best for your specific needs. An effective way to decide which prediction standard to employ is to understand the underlying similarities and differences between the standards.

On the Table1 are compared advantages and disadvantages of the most widely reliability prediction standards.

TABLE 1. THE MOST WIDELY USED RELIABILITY PREDICTION STANDARDS AND THEIR ADVANTAGES AND DISADVANTAGES

Standards	Advantages	Disadvantages
MIL-HDBK-217	PS and PC analysis /easily move from preliminary to complete design stage.	based on pessimistic failure rate assumptions/does not consider other factors that can contribute to failure rate
Telcordia (Bellcore)	analysis ranging from PC to full P S through the use of Calculation Methods/considers burn-in data, lab testing data, and field test data.	only for limited number of Ground Environments/does not account for other factors/ well-known and accepted
CNET 93	Fairly broad range of part types modeled.	only for electronic parts.
RDF 2000 **IEC-62380**	a new approach to failure rate modeling/considers cycling profiles and their applicable phases	only for electronic parts/cannot be mixed with other models/very new, still gaining acceptance.
HRD5	Similar to Telcordia/fairly broad range of part types	only for electronic parts/not widely used.
PRISM	use of process grading factors, predecessor data, and test/field data.	small, limited set of part types modeled/newer standard
China GJB/z 299	provides for both parts stress and parts count analysis.	based on an older version of MIL-HDBK-217/cannot model hybrids
217Plus	use of process grading factors, predecessor data, and test or field data.	newer standard,/only electronic parts/cannot model hybrids.

There are various factors to consider when selecting a prediction standard to employ.

III. RELIABILITY PREDICTION OF HIC AND MCM BY PC/PS SOFTWARE

The main function of our PC/PS software is the reliability prediction as the assessing of a numeric value of a selected reliability indicator, the most frequently a failure rate or *MTBF*, in the initial stages of HIC or MCM life. The prediction according to the MIL-HDBK-217F is supported by the two basic prediction methods: PC and PS analysis.

On the fig.1 environment describes the conditions of field operation are shown.

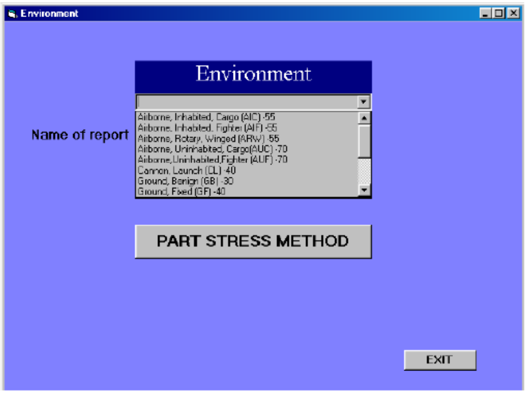

Fig.1. Environments

The next step is to choose the components of the HIC or MCM as well as the type of component connections (see fig.2)

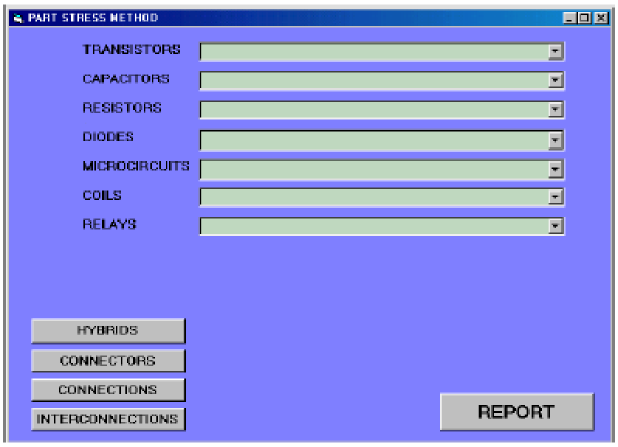

Fig.2. Parts in PS analysis

For example on fig.3 is shown the spreadsheet for the model of a low frequency diode.

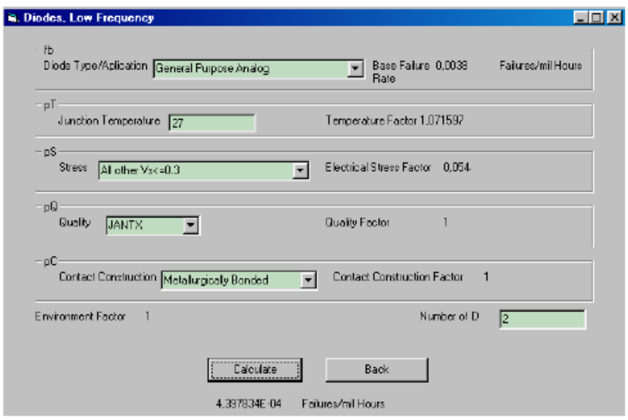

Fig.3. Data for a low frequency diode

A failure rate or *MTBF* assessing of the available connections is done by the models shown on Fig. 4, 5 and 6.

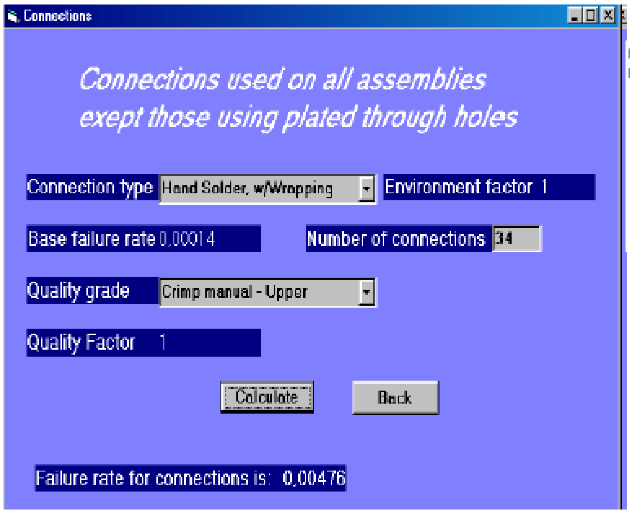

Fig.4. Data for connections

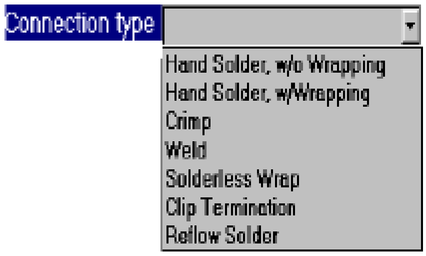

Fig.5. Types of connections

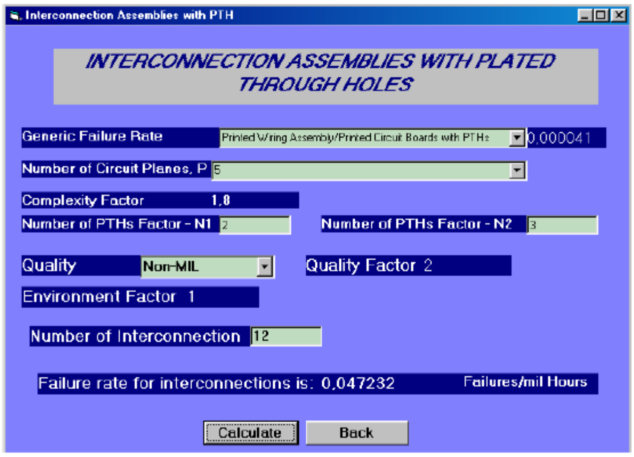

Fig.6. Data for interconnections

By this software a report of all parts of HIS or MCM is prepared. One example of such report is shown on fig.7.

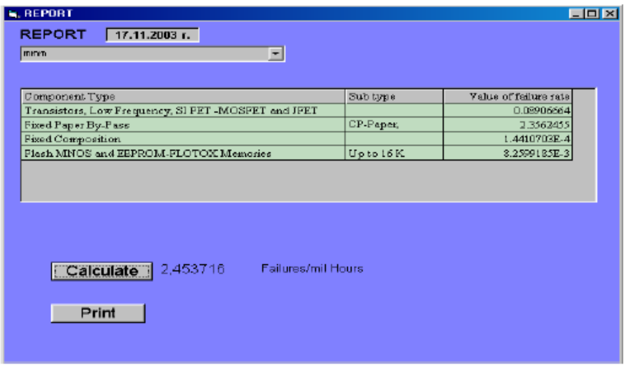

Fig.7. A report of a part

The HIC or MCM reliability assessment is the final goal. The model for HIC/MCM failure rate with parts count method is as follows:

$$\lambda_{HIC/MCM} = \sum_{i=1}^{n} N_i \left(\lambda_g \pi_Q\right) \text{ Failures}/10^6 \qquad (2)$$

where $\lambda_{HIC/MCM}$ = total HIC/MCM failure rate; λ_g = generic failure rate for the i-th generic part; π_Q = quality factor for the i-th generic part; N_i = quantity of the i-th generic part; and n = number of different generic part categories in the equipment. On fig. 8 is shown the spreadsheet for a HIC failure rate calculation.

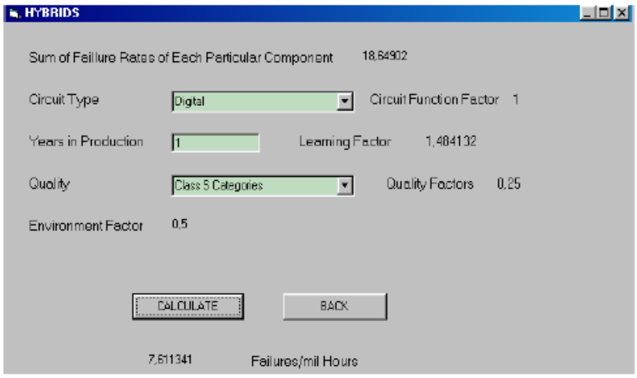

Fig.8. Data for HIC reliability

To illustrate the disparity, consider the following: A circuit board containing 338 components with six component types is used in a mobile radio system.[4] The failure rate of the MIL-HDBK-217 prediction is 1.934 failures per million hours, as shown in Table 2. The field behavior of the board, however, shows 19 failures in a total operating time of 4,444,696 hours, resulting in a field failure rate of 4.274 failures per million hours. The deviation 4.274 - 1.934 = 2.34 failures per million hours was not covered by the MIL-HDBK-217 prediction.

Actually, many field failures are caused by unpredictable factors, often the main reasons for reliability problems in today's electronic systems. But those unpredictable reasons can be successfully precipitated, detected, and eliminated during a HALT/HASS process.

TABLE 2. CONTRIBUTION TO FAILURE RATE OF EACH COMPONENT IN MIL-HDBK-217 PREDICTION

Component	**Ceramic Capacitor**	**Diode**	**Bipolar IC**
Calculated Failures	0.004	0.009	0.05
Component	**Resistor**	**Bipolar Transistor**	**Tantalum Capacitor**
Calculated Failures	0.052	1.225	0.594
FAILURE RATE	**1.934**		

The prediction techniques described in MIL-HDBK-217 for estimating HIC/MCM reliability are based on the Arrhenius equation, an exponentially temperature-dependent expression. More importantly, the reliability of components in many HIC/MCM is improving. Consequently, component failure no longer constitutes a major reason for HIC/MCM failure. But, the MIL-HDBK-217 model still tells us how to predict HIC/MCM reliability based on part failure data.

IV. CONCLUSION

Oftentimes, the reliability analyst may employ several tools depending on requirements. For example, if you were required to forecast the rate at which the HIC/MCM will fail, you would have to perform a reliability prediction.

The basic principle of reliability prediction is to define a rate of failure for all key components in a HIC/MCM and then add them together to obtain an overall HIC/MCM failure rate. This process explicitly considers all components to be in series, which means that if one component fails, the entire HIC/MCM goes down. The result gives a conservative estimate of when a HIC/MCM will most likely fail.

The purpose of this work is to automate the process of calculating component failure rates for the HIS or MCM reliability assessment using the PC and PS analysis contained in MIL-HDBK-217 Reliability Prediction Models.

These computations are done using MIL-HDBK-217 because of Telcordia (Bellcore) calculations are more optimistic than the MIL-HDBK-217 calculations. The primary source of the failure rate data for the electrical components in the HIC systems was a MIL-HDBK-217 reliability prediction.

On the other hand PS analysis of the PC/PS software can also support "what-if?" analyses by allowing an analyst to make changes to the prediction model and view the resulting effects of system reliability.

REFERENCES

[1] MIL-HDBK-217, *Reliability Prediction of Electronic Equipment*, U.S. Department of Defense.

[2] Bellcore TR-332, Issue 6, *Reliability Prediction Procedure for Electronic Equipment*, Telcordia Technologies.

[3] M. Pecht, *Integrated Circuit, Hybrid, and Multichip Module Package Design Guidelines: A Focus on Reliability*, Wiley-Interscience, 1994.