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Reliability predictions in electronic industrial applications

G. Cassanelli[a,*], G.Mura[b], F.Cesaretti[c], M.Vanzi[b], F.Fantini[a]

[a] DII, *University of Modena and Reggio Emilia , Via Vignolese 905,41100 Modena, ITALY*
[b] *Department of Electronic Engineering, University of Cagliari-INFM Piazza D'Armi, 09123Cagliari,ITALY*
[c] *Quality Department, Thermowatt S.p.A, Zona Artigianale Conce, 60011 Arcevia , Ancona, ITALY*

Abstract

The paper describes a reliability prediction methodology that may be used to evaluate the reliability of electronics systems for industrial applications. The proposed methodology takes advantage of the potentiality of different reliability approaches. The aim of this new methodology is to minimize the deficiencies of the traditional reliability prediction methods calculating a corrective factor using the available field return data. In this way is possible to realize more realistic reliability assessment also in the case of new products or products without historic data. Applications of this prediction methodology on real electronic industrial systems are presented.

1. Introduction

Small and medium industries are more and more interested in assessing the reliability of electronics boards in embedded applications.

Traditionally, these companies have little experience in the field of reliability and little or null specific competences and, since the beginning, they seem to be more interested in obtaining a reliability figure than in improving reliability itself. This phenomenon has his roots in the fact that the original reason for this interest stays frequently in requirements by customers, asking for MTBF figures and, more rarely, for specific tests.

Unfortunately, many companies show too much confidence in easy and rapid solutions and are attracted by "miraculous" techniques, following the promises of some books [1], that are frequently misunderstood. On the other hand, the estimation of product reliability requires knowledge about the components, the design, the manufacturing processes and the expected operating conditions, and it certainly costs money, but only apparently could be cheaper for a supplier to substitute failed equipment and ignore why and how this equipment failed. This paper presents a methodology that attempts to minimize the deficiencies of the traditional reliability prediction methods using different approaches for assessing reliability of electronics during design.

Section 2 reviews the different approaches to the reliability prediction; in the following section, the proposed methodology is described. Section 4 presents the application to two boards. A brief discussion is reported in paragraph 5 and some conclusions are drawn in 6.

* Corresponding author. cassanelli.giulia@unimore.it
Tel: +39 059 2056165; Fax: +39 059 2056129

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2. Reliability prediction methodology

The method used for reliability prediction is often a matter of contention. It is understood that the benefits of a reliability prediction are dependent on the accuracy and completeness of the information used to perform the prediction and on the methods used to conduct the prediction.[2]

While it is generally believed that reliability assessment methods should be used to aid in product design and development, the integrity and auditability of the reliability prediction methods have been found to be questionable; in that, the models do not predict field failures, cannot be used for comparative purposes, and present misleading trends and relations. [3]

The correct way to know the reliability of a product is the collection of field returns, the analysis of the data and then failure analysis of the failed parts. In particular starting from the *failure modes*, the failure analysis is designed to: identify the *failure site*, the *failure mechanism* in order to determine the *root cause* and recommend failure prevention methods. Sometimes on a complex electronic system different concomitant failure mechanisms can be identified that can interact generating questionable statistics. An accurate analysis is strongly necessary to classify different failure mechanisms and to rule out extrinsic damages (no pertinent failure) from the interpretation of reliability result. It is required to study the failure propagation into the structure under test and to focus on the failure signature in order to identify mechanism without a complete analysis of numerous parts/components with the same signature.

However, this approach needs relevant resources and a large amount of field hours. It also requires to early asses reliability of electronic systems already during the design phase, well before the field implementation. The economic constraints allow this approach to be used only by large companies. Small companies usually want to obtain a reliability figure, that can be obtained with limited effort; therefore, the use of the use of "reliability handbook" is necessary. Based on the MIL-HDBK-217 [4] many methods have been developed in the past whose effectiveness, upon comparison with field data, remains questionable [5].

3. The proposed methodology

The proposed methodology tries to combine the evaluation made by means of a prediction model with the collection of results from the field and, when possible, with failure analysis.

The analysis flow concerning the proposed reliability methodology is represented in Fig 1.

This flow involves different approaches:

- **Empirical model** prediction techniques,
- Graphical and numerical analysis of **field return data** about similar product,
- Graphical and numerical analysis of data about test and accelerated test and **physics of failure,**

to asses the reliability of a new product.

3.1. Methodology's steps

The sequence of steps necessary to put in practise the proposed reliability prediction methodology is the following:

1. The methodology starts with the collection of past experience data on product with a similar and comparable technology. The data are evaluated for form, fit and function compatibility with the new product. If the new product is an item that is undergoing an enhancement, the collected data will provide a good basis for comparison to the new product. If the product does not have a direct similar item, then lower level similar circuits can be employed.
2. In the case of a largely new product, data for components or circuits is collected and a similar product reliability value (λ_{hs}) is calculated using an electronic-reliability prediction model. Various prediction methods exist:
   - MIL-HDBK-217 [4]
   - RDF 93 [6]
   - IRPH [7], etc.

   they are based on empirical failure rate models, developed from curve fits and failure data. These data are limited in terms of number of failures in a given environment and in the determination of the actual cause of failure [8].
3. The methodology continues with the calculation of λ_{fs}, that is the failure rate of the chosen similar product obtained through graphical and numerical analysis of the field return data.
4. At this point, the value of the corrective factor **K** is calculated from the comparison of λ_{fs} and λ_{hs}.
5. The new product reliability value is calculated used for the similar product (λ_{hn}).through the electronic-reliability prediction models
6. To the end, the corrective factor **K** is applied to λ_{hn} .

Following these steps, a specific and more accurate new product reliability value λ_c is obtained; if

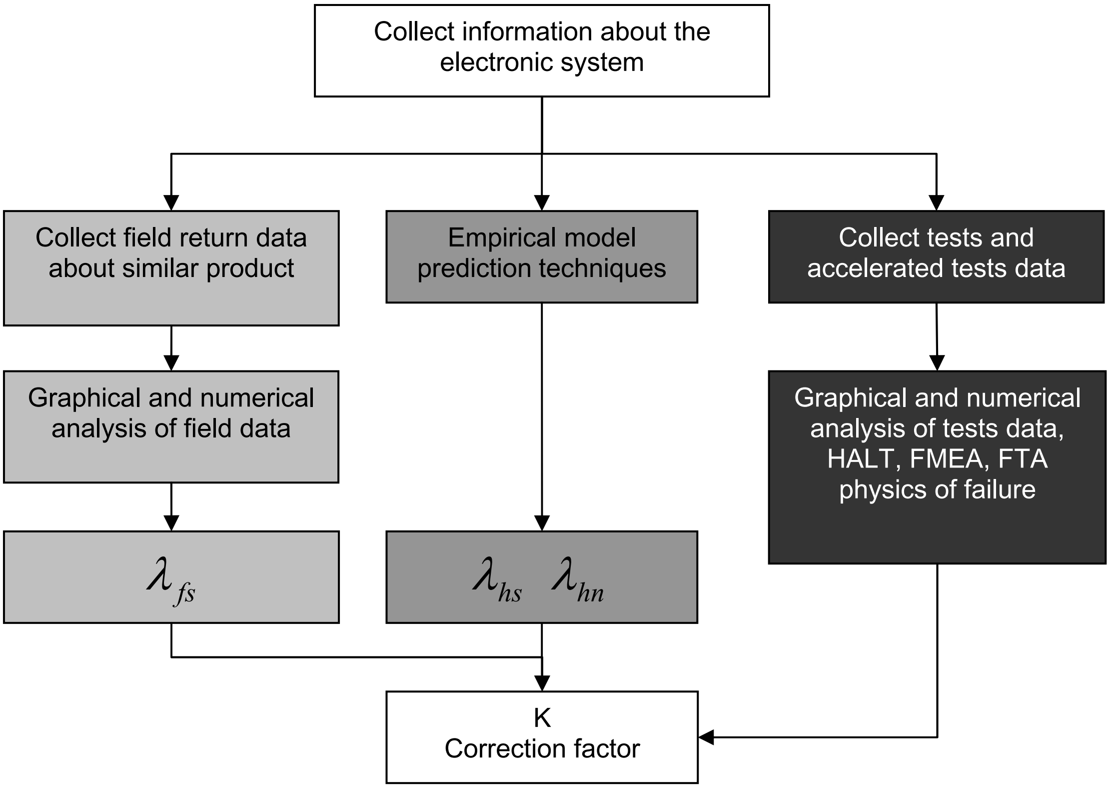

Fig. 1. Analysis flow.

possible, also data about accelerated or HALT tests can be used to improve the evaluation.
Further improvements may be developed by taking into account the overall experience of the company in the field of the experienced quality during design and manufacturing.

4. Applications

The methodology has been tested in two industrial electronic applications:

- System 1: a functional printed circuit unit installed in a ground vehicle.
- System 2: a functional printed circuit unit used in weather-protected locations.

4.1. System 1

System 1 is a functional printed circuit unit, with five hundred components, installed in off -highway vehicles. In Fig. 2 the distribution of the components is shown.

System 1 is a consolidate product, field returns are available, so it is used for the calculation of the corrective factor K with respect to the reliability prediction.

First of all the failure rates of the component and then of the system (λ_{hs}) are calculated with the reliability prediction handbook IRPH2003. This model has turned out to be the most realistic by the comparison to field data.

Then two different approaches for calculating a more realistic failure rate of the system are experimented:

- the revision of λ_{hs} calculation applying the FTA to identify the critical component.
- the graphical and numerical analysis of field data to calculated λ_{fs}.

Failure analysis is applied to depurate field data from systematic failures [9] (see Fig. 3-4).

The values of the failure rates calculated in the three different ways are represented in Table 1. The

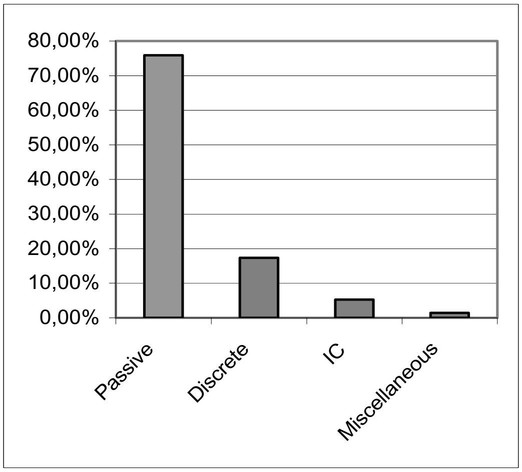

Fig. 2. Automotive electronic system.

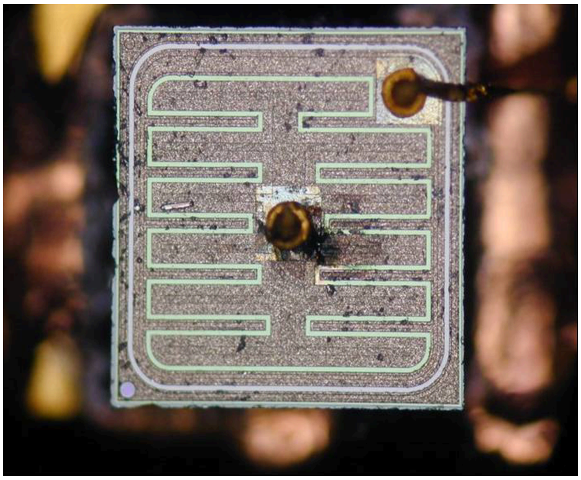

Fig. 3. Optical image of a degraded transistor in system 2.

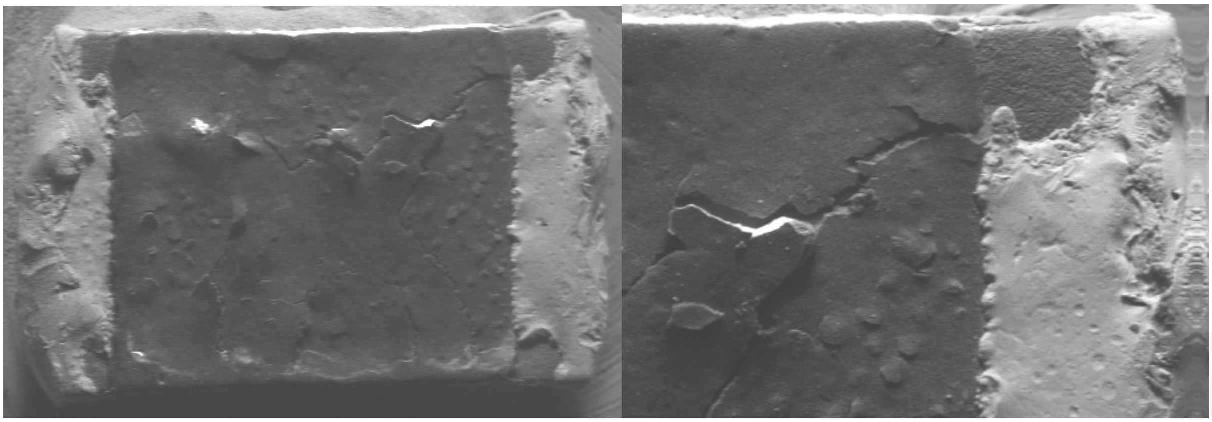

Fig. 4: SEM Image of a degraded resistor (left) and a detail of a contact (right) in system 1 [9]

Table 1
Failure rates values

λ_{hs}	32000 FIT
λ_{hsrew}	5000 FIT
λ_{fs}	600 FIT

corrective factor is estimated by the comparison of the three failure rates. The corrective factor for this kind of automotive systems is approximately 60.

4.1. System 2

The methodology is applied also on an electronic system used for domestic applications; it is composed by 300 components (see Fig.5). System 2 is a new electronic system, there are not any field returns, and it is still a prototype. In this case, a product with a similar and comparable technology has been found.

The IRPH2003 handbook is used to calculate the failure rate of the new system λ_{hs} and of the similar system λ_{hn}.

The field returns of the similar system are analysed graphically and numerically to calculated λ_{fs}.The values of the failure rates calculated in the three different ways are represented in Table 2. The

Table 2
Failure rates values

λ_{hs}	16000 FIT
λ_{hn}	1000 FIT
λ_{fs}	200 FIT

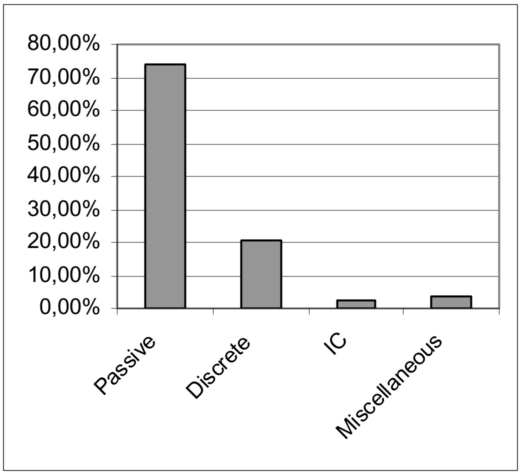

Fig. 5. Domestic electronic system.

Table 3
Reliability Matrix[a]

IC	Descr.	AF	PD	F(t) ref	F(t) h	F(t) lf	F(t)lr	F(t)fr	IC	KC	KR

corrective factor is estimated by the comparison of the three failure rates. The corrective factor for this kind of domestic systems is approximately 80.

5. Discussion

From these examples, we can conclude that specific studies are necessary to apply the prediction model to a given circuit. The study of the circuit by means of techniques (like FTA) and the failure analysis to exclude the systematic failures from the field results are effective in improving the prediction.

However, what industries really want is a risk factor and not a reliability prediction: they want to know the risk of a new product compared to a consolidate product.

A specific system of data collecting to satisfy this kind of request has been designed. This system resumes all the information about components in a table called reliability matrix. This matrix is used to calculated meaningful coefficients to esteem the risk factors of new products.

The basic structure of the reliability matrix is represented in Table 3. The acronyms in Table 3 stand for:

IC: identity code
Descr.: component description
AF: assembly failure
PD: process defectivity
F(t) ref: F(t) calculated by parts count
F(t) h: F(t) calculated by IRPH2003
F(t)lf: F(t) calculated by life test data analysis
F(t)lr: F(t) calculated by line return data analysis
F(t)fr: F(t) calculated by field return data analysis
IC: criticality index takes into consideration F(t)lf, F(t)rl and F(t)fr.
KC: criticality corrective factor takes into consideration F(t)lf, F(t)rl, F(t)fr and F(t)h
KR: reliability corrective factor takes into consideration F(t)fr and F(t)h.

6. Conclusions

Reliability prediction models are widely accepted throughout the industry and the confidence on these methods varies from unconditioned acceptance and null credit. The methodology presented in this paper suggests a road that can be followed also by medium and small size industries in order to obtain more realistic reliability figures.

The importance of supporting the reliability evaluation with the field data collection and with the failure analysis of failed parts is strongly stressed.

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