



SURFACE VEHICLE RECOMMENDED PRACTICE

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Reliability Prediction for Automotive Electronics Based on Field Return Data

RATIONALE

In early design activities (typically before the hardware is built), a reliability prediction is often required for the electronic components and systems in order to assess their future reliability and in many cases to meet customer specifications. Those specifications may include the allocated reliability for a particular electronic unit and in the cases of functional safety products to meet the ASIL (Automotive Safety and Integrity Level) requirement specified by the international functional safety standard ISO 26262.

This Recommended Practice (RP) document will provide guidance on performing reliability predictions for automotive electronic products utilizing field return data or any other types of failure data available to an automotive electronics supplier. This document will cover the possible sources of data, types of the data required, ways to collect it, and the methodology of how to process these data to calculate the failure rates and the expected reliability. This document will also include a case study based on the data obtained by Delphi Electronics & Safety, a Tier 1 automotive supplier to illustrate the process of reliability prediction based on field return data.

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FOREWORD

Reliability prediction is a frequently conducted activity preceding the start of a design and hardware build process. This activity is often done very early in the design process or sometimes as early as the business quoting phase. After the development of the functional safety standards such as IEC 61508 [1] or ISO 26262 [2] and other references, the reliability prediction became an integral part of the functional safety analysis required to meet the system ASIL requirements. However, reliability prediction is not limited to the ASIL calculations. It is also used for warranty cost estimation, design evaluation, design comparison, and a number of other applications, therefore the methodology described in this document can be applied to those activities as well.

1. SCOPE

This document should be used as guidance for non-handbook based reliability predictions conducted on automotive electronics products. It presents a method that utilizes warranty and field repair data to calculate the failure rates of individual electronic components and predict the reliability of the entire electronic system. It assumes that the user has access to a database containing field return data with classification of components, times to failure, and a total number of components operating in the field.

1.1 General Perspective and Why this Document Is Needed

Reliability prediction is a common engineering activity, generally conducted early in the design process before the hardware build, often during the business quoting phase, and with the limited information about the product design specifics. Despite the difference of opinions regarding the value of reliability prediction, it is often required by the automotive customers as a part of their engineering specifications. The purposes of reliability prediction activity include an assessment of whether or not a system will meet customer specifications, forecast the expected failure rates and the warranty cost, and an assessment of a system reliability performance in the field.

Reliability predictions and failure rate calculations became even more widespread after the release of the functional safety standards, such as IEC 61508 (core functional safety) [1] and ISO 26262 [2] Road Vehicles Functional Safety. ISO 26262 requires ASIL (Automotive Safety Integrity Level) assessment of all safety related products intended for the European market and beyond (started with the EU ISO 26262 and later became partially accepted by the North American and Asian markets). The methods of reliability prediction are described in various sources including IEEE standard [3], but not specifically for the automotive industry with the focus on the processing of field return data that can provide higher fidelity to guide management actions.

The standard ISO 26262 [2] addresses the automotive development cycle and guidelines for achieving functional safety in Electrical and Electronic (E/E) systems installed on passenger cars and light trucks intended for the EU market. In order to meet the ASIL specifications, it requires a certain value of the failure rate λ , which is calculated by applying one of the available reliability prediction methods described in [4] Chapter 6, which mentions the use of handbook based methods, including SN29500 [21], FIDES [14] and IEC 62380 [19]. ISO 26262 does not dictate a specific reliability prediction method thereby allowing the use of in house databases, which is the main focus of this document.

In the past, there have been significant variations in the reliability prediction methods various suppliers and OEMs were allowed to use for these calculations, including handbook-based methods (see the references [14], [17], [18], [19]) and also 'statistics based on field returns or tests'. Since few automotive suppliers have developed their own reliability prediction methods and field return databases, handbook-based methods became much more prevalent. Therefore, many OEMs prefer handbook-based methods despite their generic nature, low accuracy, and high variability of failure rate estimates among the different sources (see for example [12], Chapter 7, [27] or [28]).

The purpose of this document is to establish an industry accepted practice for reliability prediction activities that rely on sources other than handbook standards. Those sources may include a company's own database of field and warranty data, FRACAS, repair records, bench test data, etc. This document also offers an example of FIT-rate calculations based on the data obtained from a database named WARF (Warranty And Reliability Forecasting) and developed by Delphi Electronics & Safety, a Tier 1 automotive supplier.

2. REFERENCES

1. IEC 61508: Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems <http://www.iec.ch/>
2. ISO 26262 - Road Vehicles Functional Safety. November 2011 <http://www.iso.org>
3. IEEE Standard 1413.1-2002 (2003) IEEE Guide for Selecting and Using Reliability Predictions, published by IEEE
4. O'Connor, P. and Kleyner, A. "Practical Reliability Engineering" Ed.5, John Wiley & Sons, 2012
5. Lawless, J "Statistical Models and Methods for Lifetime Data" John Wiley & Sons 2002
6. IEC EN 61508 Parts 1 to 3 is a core functional safety standard, applied widely to all types of safety critical E/E/PS and to systems with a safety function incorporating E/E/PS. (Safety Integrity Level - SIL) <http://www.iec.ch/>
7. IEC 61511-1, Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements, based on EN 61508 <http://www.iec.ch/>
8. IEC 61511-2, Functional safety – Safety instrumented systems for the process industry sector – Part 2: Guidelines for the application of IEC 61511-1, based on EN 61508 <http://www.iec.ch/>
9. IEC 61511-3, Functional safety – Safety instrumented systems for the process industry sector – Part 3: Guidance for the determination of the required safety integrity levels, based on EN 61508 <http://www.iec.ch/>
10. IEC 62061, Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems, based on EN 61508 <http://www.iec.ch/>
11. ISO 13849-1, -2 Safety of machinery - Safety-related parts of control systems. Non-technology dependent standard for control system safety of machinery. (Performance Levels - PL) <http://www.iso.org>
12. EPSMA, "Reliability. Guidelines to Understanding Reliability prediction", European Power Supply Manufacturers Association, June 2005. http://www.epsma.org/MTBF%20Report_24%20June%202005.pdf
13. IEEE EMC Symposium 2005, Comparison of ISO 7637 Transient Waveforms to Real World Automotive Transient Phenomena
14. FIDES (2009). FIDES Guide 2009 Issue A. Available at <http://fides-reliability.org/> [Accessed 22 March 2011]
15. SAE International Surface Vehicle Information Report, "Product Development Process and Checklist for Vehicle Electronic Systems," SAE Standard J1938, Rev. Jul. 2015
16. ZVEI: First-Mate-Last-Break Grounding Contacts in the Automotive Industry. A Chance to Reduce the Number of Failures in Electronics. White Paper published by ZVEI, July 2011: <http://www.zvei.org/first-mate-last-break> [Accessed 22 June 2016]
17. Telcordia Special Report SR-332 (2001) Reliability Prediction Procedure for Electronic Equipment (RPP). Issue 1, Telcordia Customer Service, Piscataway, NJ
18. UTEC80810, 2000. Modele universel pour le calcul de la fiabilite previsionnelle des composants, cartes et equipememts electroniques.
19. IEC TR 62380 Reliability data handbook – Universal model for reliability prediction of electronics components, PCBs and equipment. 2004. <http://www.iec.ch>
20. ISO 16750-3E (Dec 15, 2012), International Standard – Road Vehicles – Environmental conditions and Testing of Electrical and Electronic Equipment – Part 3: Mechanical Loads

21. SN 29500 Failure Rate, Component, Expected Value, Reliability, Dependability. Siemens Norm, published by Siemens 2004.
22. Steinberg, D. "Vibration Analysis for Electronic Equipment" 3rd Edition, John Wiley & Sons, 2000
23. JEDEC "Failure Mechanisms and Models for Semiconductor Devices", JEP122F, JEDEC Solid State Technology Association, November 2010
24. ISO 25119 - Tractors and Machinery for Agriculture and Forestry -- Safety-Related Parts of Control Systems <http://www.iso.org>
25. EN 50126, Railway Industry Specific - RAMS review of Operations, System and Maintenance conditions for project equipment
26. Def Stan 00-56 Defense Standard "Safety Management Requirements for Defense Systems" UK Ministry of Defense 2007
27. Economou, M. "The Merits and Limitations of Reliability Predictions". Proceedings of Reliability and Maintainability Symposium (RAMS), IEEE 2004
28. Jais, C., Werner, B., Das, D. "Reliability Predictions – Continued Reliance on a Misleading Approach" Proceedings of Reliability and Maintainability Symposium (RAMS), IEEE 2013
29. Aldridge, D. "Do You Know that Your Accelerated Vibration Test Requirement is Correct?" Journal of the IEST, v.55, No. 1 pp. 68-79
30. JESD 94 Standard "Application Specific Qualification Using Knowledge Based Test Methodology". JEDEC Revision A, July 1, 2008

3. NOTATIONS

3.1 Abbreviations and Acronyms

AF	Acceleration Factor
ASIC	Application Specific Integrated Circuit
ASIL	Automotive Safety and Integrity Level (per ISO 26262)
BOM	Bill of Materials
DOF	Date of Failure
E/E	Electrical/Electronic
EU	European Union
FITs	Failure in Time (typically stands for failures per billion (10 ⁹) hours)
FRACAS	Failure Reporting and Corrective Action System
MOB	Month of Build
MTBF	Mean Time between Failures (repairable system)
MTTF	Mean Time to Failure (non-repairable system)
NFF	No Fault Found

NTF	No Trouble Found
NTI	No Trouble Indicated
OEM	Original Equipment Manufacturer (in this document mostly vehicle makers)
PCB	Printed Circuit Board
PoF	Physics of Failure
PSD	Power Spectral Density
RMS	Root Mean Square
RP	Recommended Practice
ROI	Return on Investment
SIL	Safety and Integrity Level (per IEC 61508)

3.2 Definitions

FUNCTIONAL SAFETY is freedom from unacceptable risk of physical injury or of damage to the health of people, either directly or indirectly as a result of damage to property or to the environment.

FAILURE RATE is the frequency with which an engineered system or component fails, expressed in failures per unit of time or unit of usage.

HAZARD RATE is the instantaneous failure rate.

RELIABILITY is the probability that an item will perform its intended functions without failure in specified environments for a specified mission life.

SUSPENSION is a right censored life data representing the time in the field for the part or component, which have not failed and are still operating in the field.

TODAY() is the Excel function of today's date, which will be used in this document as the reference date for data collection and FIT rate calculations.

4. MODELING SYSTEM RELIABILITY

4.1 Failure Rate and Distribution Assumptions

Failure rates of an electronic system are generally assumed to follow the bathtub curve pattern, which has been covered extensively in the literature (see for example [4]). For the purposes of this document, we will focus specifically on the middle portion, often referred as useful life, where the failure rate remains constant. Reliability of a system with a constant failure rate is typically modeled by the exponential distribution.

The Exponential distribution is one of the most commonly used reliability models. It assumes that product failures follow a homogeneous Poisson process (see for example [4] Chapter 2), where the reliability, $R(t)$ can be expressed as a function of time as:

$$R(t) = e^{-\lambda t} \quad (\text{Eq. 1})$$

where:

λ = failure rate (or hazard rate if λ = constant)

t = time in the field

More detail on failure rate calculations can be found in Section 5 of this document.

As mentioned before, the exponential distribution assumes a constant failure rate λ throughout the life of a part/system. Despite the fact that most systems (mechanical or electrical/electronic) follow the bathtub curve pattern (see [4], Chapter 2) by experiencing decreasing failure rates in the early life and increasing failure rates towards the end of life (wear-out), this model has been considered acceptable for complex electronic systems and is utilized by all reliability prediction handbooks, including MIL-HDBK-217, IEC 62380, SN29500 (Siemens), FIDES and others (see references [14] through [21]).

Failure rates are measured by the number of failures per unit of time or unit of usage. One of the most commonly used units for λ is FIT, which stands for Failure In Time and represents the number of failures per billion (10^9) hours. Under the assumption of the exponential distribution, the mean time between failures is the inverse of the failure rate: $MTBF = 1/\lambda$

When λ is measured in FIT (λ_{FIT}) and time t in hours of operation, Equation 1 takes the form of:

$$R(t) = e^{-\frac{\lambda_{FIT}t}{10^9}} \quad (\text{Eq. 2})$$

4.2 Series System

The diagram in Figure 1 shows an example of a series connected system having three parts with reliabilities and failure rates of R_i and λ_i , $i = 1, 2, 3$.

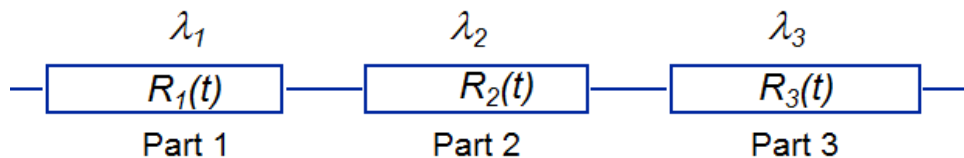


Figure 1 - Series reliability system (single point of failure)

Note that series reliability system is not the same as series electrical/electronic system, since it does not require a physical connection, but only functional dependency. Series reliability connection means that a failure of one component in the system will cause failure of the entire system similar to the 'logical OR' function in digital computation. Therefore, the reliability of the system in Figure 1 can be calculated by Equation 3.

$$R_{sys} = R_1(t) \times R_2(t) \times R_3(t) = e^{-\lambda_1 t} \times e^{-\lambda_2 t} \times e^{-\lambda_3 t} = e^{-(\lambda_1 + \lambda_2 + \lambda_3)t} \quad (\text{Eq. 3})$$

Therefore, a series system where each component has a constant failure rate, the failure rate for the system in Figure 1 will be:

$$\lambda_{sys} = \lambda_1 + \lambda_2 + \lambda_3$$