Proceedings of the 33rd European Safety and Reliability Conference (ESREL 2023)
Edited by Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio

doi: 10.3850/978-981-18-8071-1_P640-cd

Stress-test Based Transition Model for Lifetime Drift Estimation and RUL Prediction of Discrete Parameters in Semiconductor Devices

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In recent years, self-driving technologies in cars have become more and more mature. This affects the whole automotive industry. Autonomous cars are expected to have more up-time and more total usage time compared to the current generation of non-autonomous vehicles.

In semiconductor industry for automotive applications, functionality over lifetime is a quality target. With the increasing usage time in self-driving cars, new challenges arise in the prediction of remaining useful life (RUL) in the context of prognostics and health management (PHM). Predictions of remaining useful life are both important for on-line monitoring and product testing before shipping. For this, statistical models for lifetime based on accelerated stress tests are needed.

We propose a semi-parametric transition model for the calculation of the lifetime drift of discrete electrical parameters based on accelerated stress tests. We further discuss methods for extrapolation of projected drift to calculate interval estimators for the remaining useful life.

Keywords: Lifetime Drift Model, Quantile Regression Methods, Remaining Useful Life Prediction, Semiconductor Industry, Transition Model

1. Introduction

Accelerated stress tests are used in the semiconductor industry to simulate the lifetime of devices in a shorter-than-real time frame.

Electrical parameters of devices are first measured, then they are put to harsher-than-usual stress conditions, i.e., heat, cold, or humidity. Then, the parameters are measured again at certain, predefined times, called readout times, and the devices are put back to the stress test and so on.

The electrical parameters of the devices change as the devices age. This drift of parameters is called lifetime drift and is taken as an indication of the level of degradation within the device. A statistical model for the lifetime drift is needed to guarantee customer quality and calculate the RUL.

2. Methodology

A model for continuous lifetime drift has already been proposed previous work of the authors, Lewitschnig (2022), based on Hofer (2017). We now introduce models for discrete parameters in the case of both discretized and truly discrete data. The model for discretized data is based on an adaption of existing methods and the model for truly discrete data uses non-parametric estimations of transition probabilities to obtain a Markov model for the lifetime drift.

3. Outlook

We further discuss extensions of the models to extrapolate future behaviour and compare them with different regression-based methods for the calculation of the RUL. We discuss both quantile and expectile regression methods and also propose a regression method based on calculated model quantiles to obtain interval estimations for the remaining useful lifetime.

Acknowledgement

This work has been performed in the project ArchitectECA2030 under grant agreement No 877539. The project is co-funded by grants from Germany, Netherlands, Czech Republic, Austria, Norway and - Electronic Component Systems for European Leadership Joint Undertaking (ECSEL JU).

All ArchitectECA2030 related communication reflects only the author's view and ECSEL JU and the Commission are not responsible for any use that may be made of the information it contains.

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