A Prognostic and Diagnostic Environment for High Reliability Electronic Systems

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Increasing reliance on electronics in high reliability applications, such as the transport and medical sectors, is raising concerns about the reliability, safety and maintenance of manufactured electronic products. As a consequence Prognostics and Health Management (PHM) of electronics is emerging as one of the key enablers for achieving efficient system level maintenance and lower life cycle costs.

In an ideal design environment, the designer would have access to reliability models for each element of the manufactured product, together with a means for integrating the reliability models and associated data into a design tool which could then be used to assess a large number of potential design solutions over a broad range of prospective in-service conditions. Once a final design choice had been determined, the designer would be able to export the complete reliability model for the system to a real-time environment which could then be used to establish a health monitoring function on the in-service hardware. Such an approach has a number of key advantages over traditional design approaches:

- Design for Reliability: consideration of through-life reliability is used as a driver from the outset of design process. A reliability model of the system is generated as part of the design process.
- Prognostics: reliability wear-out models can be used as part of a real-time health monitoring system for in-service hardware to provide life consumption monitoring and scheduling of maintenance tasks.
- Diagnostics: inverse models can be used to assess key product parameters and identify when and where overstress failures have occurred.

The aim of the research is to develop a methodology for real-time prognosis and diagnosis of high reliability electronic products through the application of reduced order system models that are generated automatically in an integrated design environment. This is being achieved through the following measurable objectives:

1. Establish electrical, physical and projected in-service operational definitions for representative electronic systems.
2. Investigate techniques for establishing Reduced Order Models (or Compact Models) for Fast Analysis of Electronic Modules. Employ a chosen methodology to develop Electro-Thermal and Thermo-Mechanical Models for selected electronic components and systems.
3. Demonstrate the integration of the Reduced Order Models with relevant failure models from the IeMRC flagship project and those within the public domain. Evaluate the performance of the integrated models under predicted in-service conditions.
4. Design and construct a power electronic converter test bed and employ this to validate the developed reduced order models. Establish acceptable ranges for the model parameters that capture typical variations arising from manufacturing and assembly processes.
5. Investigate techniques for producing inverse models that use measured temperature data to estimate model parameters. Evaluate the diagnostic capability of selected inverse models through simulation studies and a real-time power electronic converter test bed.
6. Implement a real-time prognostic and diagnostic environment using reduced order electro-thermal-mechanical models and inverse models for parameter estimation. Validate the approach using a power electronic converter test bed.

This project brings together multi-physics modelling, optimisation, compact model generation, and inverse analysis. These mathematical and computation techniques will be used with the Physics-of-Failure models from the IeMRC Power Electronics Flagship project to form the foundations for a prognostic/diagnostic tool. The work complements and builds upon the IeMRC-funded work in the SiP design project and the work underway in the 3D-Mintegration project on developing and using reduced-order-models for fast physics-based analysis of electronic modules. The novelty lies in the use of these validated techniques to characterise power electronic systems and to then extend this methodology to inverse analysis, by producing compact inverse models, which will be employed within an on-line diagnostic and prognostic tool. Although the emphasis of the project is on electrical-thermal-mechanical driven wear-out mechanisms, the developed methodology is expected to be sufficiently flexible to be able to accommodate other environmental effects such as vibration and altitude.