# Condition Monitoring of High Reliability Electronics using Resistance Based Methods

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## ABSTRACT

The ubiquitous use of electronics in engineering systems today has catalyzed the need of prognostic health management (PHM) for electronics. The utmost goal of PHM for electronics is safety. After ensuring the safety of a system, PHM for electronics can also facilitate reliability, maintainability and supportability goals.

This work aims to use a physics of failure approach to develop a PHM system for second level interconnects in electronic devices. In this context second level interconnects are the solder alloys used to attach individual electrical components, such as a CPU, to a larger circuit board. Second level interconnects are commonly referred to as solder joints. A typical PC mother board contains approximately ten thousand solder interconnects. A failure of a single interconnect will result in the failure of the entire system. Solder alloys used as electrical interconnects are formulated mainly to facilitate the manufacturing of electrical components. Compared to the relatively common steel and aluminum alloys, solder alloys are a soft, compliant material. It is hypothesized that because of this unique material behavior a change in geometry of a solder interconnect under stress will be measurable prior to failure of the joint. Real time resistance measurements are used to monitor the interconnect geometry and determine the remaining useful life of the system.*

## 1. INTRODUCTION

Improvements in sensor technology and failure analysis has increased the scope of prognostic systems to include large electromechanical systems such as aircraft, helicopters, ships, power plants and many industrial applications.

Avionic systems are a typical candidate for prognostics systems due to the need for ultra high reliability to fulfill tasks such as autonomous aircraft control and navigation, flight path prediction and tracking, and self separation. Additionally the cost of maintaining and supporting such a system can be demanding. Complex electrical power systems (EPS) which broadly comprise of energy generation, energy storage, power distribution, and power management have a major impact on avionic systems availability. Advanced health management techniques for electrical power systems and avionics systems are required to meet the safety, maintainability, and supportability requirements for these ultra high reliability systems. Current health management techniques in EPS and Avionic Systems provide very-limited or no-visibility into health of power electronics, and packaging to predict impending failures. [McCann 2005].

## 2. EXPECTED CONTRIBUTIONS

The end result of this work is expected to be a functional prototype that can demonstrate the accuracy and repeatability of resistance based techniques for a PHM for electronics system. A functional prototype is required for two reasons. The instrumentation required to measure the changes in resistance of the interconnects is not trivial and a

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viable solution that could be integrated into an existing system needs to be demonstrated. Secondly the types of materials and the varying size scales found in electrical systems makes modeling the systems with finite element analysis difficult and error prone.

Therefore the contributions to the PHM community would be a fully fielded system that can generate data sets and be benchmarked against other prognostic systems.

The contributions to the electronic packaging community would be a understanding and demonstration of the physics of failure involved with second level interconnects subjected to drop, shock, and thermal loadings. Since the resistance based technique is analogous to transducing the strain in the interconnect based on resistance (like a strain gage), FEA models could be improved and verified based on experimental measurements of individual solder joints that are currently impossible to obtain in generic test specimens and geometries.

## 3. CURRENT PROGRESS

The applicability of the resistance based techniques used to determine the remaining useful life of individual electrical components has been demonstrated in drop, shock and vibration environments (Lall, Lowe, et al. 2009[a,b]). The specifics of the test involve connecting all 400 of the interconnects on an advanced electronic package that would traditionally house the chip for a CPU into a series circuit. Then according to industry standard test procedures the electrical assembly is stressed until failure while the resistance of the circuit is measured. The resulting data from the experiment is a trend line that can be extrapolated to determine a remaining useful life prediction. Using this method the prognostic distance has been shown to always be positive. The first prototype for this technique was delivered to our sponsors in April of 2009. The only necessary equipment to run the prototype are a bread board with the test circuitry, a signal generator and an oscilloscope.

## 3. FUTURE WORK

While the initial work has helped validate the that the physics of failure are correct and that the technique is applicable to develop a PHM for electronics system, a number of underlying issues must be addressed before fielding more advanced prototypes. The testing methods used to stress the electrical components to failure was a repeatable laboratory test. Real stress histories are not repeatable and incremental. Therefore the damage per drop can not be used to determine the remaining useful life accurately. Furthermore connecting all of the interconnects of a package in a series circuit is an industry standard practice for testing. In functional products only the interconnects at the corners of the components will be available for resistance monitoring. From a reliability standpoint the corner interconnects will be the first to fail so the technique is still applicable. But from a measurement standpoint the resistances needing to be measured will be at least an order of magnitude smaller that the values measured to date. The information obtained from current results have allowed us to re-define the goals of the project into a more meaning full scope of work whose challenges can be more easily addressed.

The goal of the future work is to develop a PHM for electronics system that provides accurate and repeatable remaining useful life predictions that are not dependent on knowledge of the past stress history, but still are available to users in real time.

Currently an effort to develop an improved resistance measurement is underway based on previous researchers work (Constable 1995). Furthermore tensile pull tests are being used to characterize electrical characteristics during mechanical testing for the various types of solder alloys commonly available on the market. These tensile tests are then being used to fine tune finite element models. The end result will be a more accurate remaining useful life prediction based on the physics of failure instead of historical failure data obtained in controlled laboratory experiments.

A new low volume electronic assembly prototype line has been brought on line at Auburn University to facilitate testing specimens with non-standard product arrangements. This line will enable the rapid development and testing of experimental setups that would otherwise be costly and time consuming to manufacture at an outside vendor.

## REFERENCES

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