Annual Conference of the Prognostics and Health Management Society, 2011

# Electronic Prognostics and Health Management of Aircraft Avionics Using Digital Power Converters

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## 1. Problem Addressed

Reliability of avionics is essential for safe and efficient operation of an aircraft. Typically, aircraft avionics consists of electronic systems for communications, navigation, flight control (including stability augmentation), engine control and fuel management, environmental control, and collision avoidance. Each of these electronic systems consists of a line replaceable unit incorporating a power supply unit (PSU) and a user electronics unit. The power supply unit contains electronic circuits for power generation, conversion and, conditioning while the user electronics unit contains integrated circuits such as programmable logic devices (PLD), memory, input/output units, and, CPU, etc., as a load for the power supply unit.

The miniaturization of electronic integrated circuits (IC) during the past few years has exceptionally challenged reliability professionals to assess the degradation of electronics from the very beginning of the design process. Although the shrinking of integrated circuits down to nanometre scale has also led to the development of accurate and precise techniques for reliability estimation, limited information is available for predicting the entire health over a wide range of environmental and operational life cycle conditions. On the other hand, methodology of prognostics and health management assures the reliability of a product under its actual application conditions (Pecht, 2008).

Prognostics and health management is the process of predicting the health of a system by assessing the extent of deviation or degradation from its normal operational conditions.



Moreover, the method provides numerous advantages such as i) advance time-to-failure; ii) minimized unscheduled maintenance, extended maintenance cycles, effectiveness through timely repair actions; iii) reduced life-cycle costs by decreasing downtime, inventory and storage and; iv) improved qualification and assistance in the design and logistical support of fielded and future systems (Pecht, 2008).

This research work reflects the development of electronic PHM techniques for aircraft avionics; the main emphasis being on predicting the failure pre-cursors of user electronics using digital power converters.

The rationale behind the use of power converters in particular point-of-load (POL) converters is their ability to provide low-voltage DC power to the proximity loads (user electronics). The location of POL converters in proximity to the concerned load provides efficient voltage regulation and resolve the challenge of high peak current demands and low noise margins required by the high-performance semiconductors such as microcontrollers and ASICs (Application Specific Integrated Circuits) (Davis, 2005). Moreover, the application of POL DC-DC converters in complex electronic circuits, with high current loads such as DSPs and a couple of FPGAs, controls power supply tracking, soft-start, sequencing, margining, and dynamic adjustment of the output voltage.

The motivation behind the use of digital power converters instead of analog counterparts is their capability to analyse in-system frequency response and health monitoring characteristics. Moreover, with the increased use, capability and availability of switching power converters with digital PWM controllers at their core, the system can interact directly with the embedded digital controllers for sharing high-level critical information (Maksimovic et al., 2004). Morroni et al (Morroni et al., 2007) investigated a similar approach for monitoring the health of a system using digitally-controlled power converters. A similar

concept will be exploited in this research where health management of aircraft avionic systems will be demonstrated using the sensing points already available in the digital POL converter.

## 2. Expected Contribution

The project will develop a sophisticated hybrid prognostic capability for aircraft electronic systems by identifying failure precursors, trending them and then estimating remaining useful life (RUL).
Prognostics and health management technologies employ the concept of physics-of-failure (PoF), life consumption monitoring (LCM), and data-driven techniques for predicting the RUL of a product.
Implementing effective LCM and PoF-based prognostic strategies for the entire electronic system is not only difficult but represents certain limitations which bound the applicability of these techniques to semiconductor and component-level electronics. On the other hand, implementation of data-driven methodologies for electronic PHM has been limited due to the complex nature of electronic components and systems. Data-driven algorithms have limited capability in modelling all the environmental and operational load profiles. A hybrid methodology involving PoF and data-driven techniques could provide better estimation of the remaining useful life of a product.

This project will involve the development of a hybrid approach for estimating RUL of the aircraft avionics. This will include:

i. investigation of failure modes and mechanisms of POL and user electronics in an aerospace environment;
ii. survey of prognostic and health management techniques;
iii. identification of useful features for health monitoring using circuit modelling and simulation;
iv. Extraction of useful features for trending and assessing the RUL using a prognostic model

## 3. Proposed Plan

This research project is conducted in pursuit of a PhD degree at the IVHM (Integrated Vehicle Health Management) Centre, Cranfield University in close-collaboration with Thales Avionics, France.

### 3.1 Research Up-to Date

A comprehensive review of failure modes/mechanisms of aircraft avionics including POL converters and user electronics has been conducted. Thereafter, investigation of prognostics and health management techniques for aircraft avionics was undertaken: firstly, traditional developmental techniques such as built-in self test (BIST) used for fault detection and diagnostics were studied; secondly, the concept of PoF-based prognostics and LCM were reviewed for estimating remaining useful life; and lastly, the theory of data-driven prognostics involving the use of machine learning and statistical techniques was analyzed as a suitable technique for and health management of aircraft avionic systems. Subsequently, operational theory of POL converters including design development and implementation techniques has been studied. A comparative study of analog and digital controllers was undertaken for understanding the advantages of digital power converters and their utilization for PHM.

### 3.2 Future Research Work

i. Identification of useful health indicators of point-of-load converters and user electronics will be examined by circuit modelling and simulation.
ii. Development of a sophisticated hybrid prognostic capability for aircraft electronic systems by trending the useful health indicators and then estimating remaining useful life (RUL).
iii. Design of experiments for prognostics validation in the laboratory.

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