The 2012 CALCE Spring Technical Review Meeting will be held on March 20-21, 2012, in Room 1202 Martin Hall, at the University of Maryland, College Park. During this meeting, the CALCE PHM Group will present their latest research efforts on innovative PHM methodologies and implementations. The agenda for the PHM sessions include:

1. **SOC and SOH Dependence in Lithium Ion Battery State Estimation**, which presents a generalized approach for combining state of charge (SOC) and state of health (SOH) techniques together to create a self-adaptive battery monitoring system. The proposed method is able to utilize SOH predictions to update the SOC estimator in order to minimize modeling errors due to capacity loss and cell degradation.

2. **State of Charge Estimation for Electric Vehicle Batteries under an Adaptive Filtering Framework**, which presents an Unscented Kalman filtering-based approach to perform SOC estimation under dynamic loading conditions. The proposed approach is able to self-adjust the battery model parameters and provide the SOC estimation with a known level of confidence.

3. **Early Detection of Fan Bearing Faults Using Acoustic Emission Signals**, which presents the use of the sequential probability ratio test for the detection of statistical changes against a null hypothesis/healthy data at the earliest possible time. The proposed method is able to extract features in a statistical way from sensor signals that are indicative of and sensitive to bearing degradation.

4. **Fault Simulation and Diagnostics Using System Level Signals by Dynamic Modeling**, which presents the use of system-level signals to perform component-level diagnosis. The proposed method is able to detect and identify component-level faults in a complex system, such as a wind turbine, with much reduced number of monitoring sensors.

5. **A Novel Warranty Servicing Approach Based on Prognostics**, which presents the use of PHM methods as a proactive means to improve business warranties, in terms of identifying no-fault-found failures, understanding root causes of failures, alleviating problems associated with recalls, enabling optimized warranty service and logistics decisions, and creating new warranty strategies.

6. **PHM Framework for the Real-Time Assessment of Analog Circuits**, which presents a systematic approach to perform online soft-fault diagnosis and prognosis on actual analog circuits subjected to component variations within standard tolerance range. The proposed approach is capable of detecting and isolating faults, and predicting circuit failure in real-time and thus, can be used to evaluate the reliability of electronic systems during field operation.

7. **PHM Software Suite**, which presents a generic, modular, flexible and interoperable software architecture that integrates effectively and efficiently various PHM routines. The proposed software can be implemented on-board and in real-time with easy deployment and maintenance/update.

For more details on the meeting, please contact Prof. Michael Pecht (pecht@calce.umd.edu) or Dr. Chaochao Chen (chaochao@umd.edu).
MODEL PARAMETER SELECTION FOR SEQUENTIAL PROBABILITY RATIO TEST TO DETECT FAULTS

The sequential probability ratio test (SPRT), first developed by Wald, is a powerful technique for testing hypotheses and has been used to detect faults at the earliest possible time in a variety of applications, including computer servers, solder interconnects, and biometric systems. One of the advantages of using SPRT, compared to a classic hypothesis testing method, is that SPRT minimizes the number of sample measurements used to make a decision for testing a hypothesis. Model parameters for SPRT should be determined before conducting an SPRT and are typically selected based on personal experience. However, a random selection of the model parameters may result in the increase of false positive and/or false negative probabilities, and the delay of fault detection time of SPRT due to the non-optimal shift-in-mean parameter.

CALCE developed a systematic method in order to select a proper set of model parameters for SPRT. The novel method is based on the functional relationship between the model parameters of SPRT and the minimization of costs resulting from the occurrence of a false positive or negative and the delay of fault detection time. A case study of fault detection using cooling fans in electronics applications demonstrated that the proposed method can provide a proper set of model parameters without a need for experience. CALCE expects that fault detection of cooling fans based on SPRT is a potential way to identify low reliability fans cost-effectively with reduced testing time, while the testing time of cooling fans is usually more than 6 months due to the high reliability of ball bearings. For more information, please contact Dr. Michael Azarian (mazarian@calce.umd.edu).

| Derive equations that define functional relationship between model parameters |
| Estimate the cost associated with false positive probability |
| Estimate the cost associated with false negative probability |
| Estimate the cost due to the delay of fault detection time associated with shift-in-mean |
| Identify a shift-in-mean that minimizes the sum of the costs |
| Calculate false positive and negative possibilities using the identified shift-in-mean |

IEEE STANDARD ON PHM

In the field of reliability practice, prognostics and health management has been widely recognized as the means to protect the integrity of equipment and avoid unanticipated operational problems leading to mission performance deficiencies, degradation, and adverse effects to mission safety. Researchers have developed a variety of approaches, methods, and tools that are useful for these purposes, but applications to real-world situations may be hindered by the lack of real visibility into these tools, uniformity in application of these tools, as well as consistency in their demonstrated results. There is a need for documented and favorable guidance that will encourage practitioners to invest the resources necessary to put these techniques into practice.

The development of an IEEE standard for PHM will be beneficial to those who wish to implement prognostics for complex systems. The IEEE Reliability Society is sponsoring the development of this standard. The project authorization request has been submitted to the IEEE Standards Committee and is expected to be approved shortly.

We invite all who are interested in developing the standard to join the working group. Interested individuals can contact Mr. Sony Mathew (sonym@umd.edu) for more information.
While PHM technologies continue to mature, PHM users have a lot of choices for PHM algorithms, such as diagnostic algorithms, for their applications. Finding a suitable diagnostic algorithm for a specific application, however, is a very challenging task. Apart from using domain expertise, the trial and error method is commonly used to find a “suitable” diagnostic algorithm, which is always time consuming and even impractical in real-world applications due to the increasing number of existing diagnostic algorithms. Fusion technologies are able to make use of the complementary advantages of each algorithm when an optimal algorithm selection and/or combination is achieved. CALCE is developing a fusion approach that incorporates the best features from multiple machine learning algorithms to improve diagnostic accuracy. This novel methodology utilizes a cost-based model to reduce the probabilities of false positives and false negatives by using a sequential quadratic programming (SQP) based optimization method.

This effort by CALCE expects to provide a robust and systematic approach to combine multiple classifiers/algorithms to achieve the results with higher confidence and lower uncertainty, as compared to any single classifier/algorithm. For more information, please contact Dr. Chaochao Chen (chaochao@umd.edu).


**RECENT CALCE PAPERS ON PHM**

**BATTERY MANAGEMENT SYSTEMS IN ELECTRIC AND HYBRID VEHICLES**

Yinjiao Xing, Eden W. M. Ma, Kwok L. Tsui, and Michael Pecht (*Energies 2011, 4, 1840-1857*)

The battery management system (BMS) is a critical component of electric and hybrid electric vehicles. The purpose of the BMS is to guarantee safe and reliable battery operation. To maintain the safety and reliability of the battery, state monitoring and evaluation, charge control, and cell balancing are functionalities that have been implemented in BMS. As an electrochemical product, a battery acts differently under different operational and environmental conditions. The uncertainty of a battery’s performance poses a challenge to the implementation of these functions. This paper addresses concerns for current BMSs. State evaluation of a battery, including state of charge, state of health, and state of life, is a critical task for a BMS. Through reviewing the latest methodologies for the state evaluation of batteries, the future challenges for BMSs are presented and possible solutions are proposed as well.

**A HEALTH INDICATOR METHOD FOR DEGRADATION DETECTION OF ELECTRONIC PRODUCTS**

Sachin Kumar, Nikhil M. Vichare, Eli Dolev, Michael Pecht (*Microelectronics Reliability 2012, 52 439–445*)

A methodology for detecting the gradual health degradation of electronic products is presented by defining a health indicator to represent a product’s health state in a time interval. A health indicator is defined as the weighted sum of a histogram bin’s fractional contribution in a time interval that is based on the data collection rate, the likelihood of change in a product’s performance, and a user’s readiness to accept risk. The unified distance measure, Mahalanobis distance (MD), is used to create histograms where optimal bin-width is calculated using a kernel estimator. Summarization of a product’s performance in a time interval for health and degradation estimation together with the behavior of the MD values can reduce false alarms regarding the presence of fault and increase the capability of detecting intermittent and ‘no fault found’ events.

A case study performed on computers is presented. A healthy baseline for the computers was created and a threshold for both fault detection and degradation identification was defined. After fault injection into one of the computers, the increase in the MD values detected the initial change in performance parameters. After a short time period, the health indicator detected the degradation whereas the MD values returned to below threshold as the degradation in this case study was an aftereffect of the damaging event.

**A PROGNOSTIC APPROACH FOR NON-PUNCH THROUGH AND FIELD STOP IGBTS**

Nishad Patil, Diganta Das, Michael Pecht (*Microelectronics Reliability 2012, 52, 482–488*)

Development of prognostic approaches for insulated gate bipolar transistors (IGBTs) is of interest in order to improve availability, reduce downtime, and prevent failures of power electronics. In this study, a prognostic approach was developed to identify anomalous behavior in non-punch through (NPT) and field stop (FS) IGBTs and predict their remaining useful life. NPT and FS IGBTs were subjected to electrical–thermal stresses until their failure. X-ray analysis performed before and after the stress tests revealed degradation in the die attach. The gate–emitter voltage \( V_{CE} \), collector–emitter voltage \( V_{CE} \), collector–emitter current \( I_{CE} \), and case temperature were monitored in situ during the experiment. The on-state collector–emitter voltage \( V_{CE(ON)} \) increased and the on-state collector–emitter current \( I_{CE(ON)} \) decreased during the test. A Mahalanobis distance (MD) approach was implemented using the \( V_{CE(ON)} \) and \( I_{CE(ON)} \) parameters for anomaly detection. Upon anomaly detection, the particle filter algorithm was triggered to predict the remaining useful life of the IGBT. The system model for the particle filter was obtained by a least squares regression of the \( V_{CE(ON)} \) at the mean test temperature. The failure threshold was defined as a 20% increase in \( V_{CE(ON)} \). The particle filter approach, developed using the system model based on the \( V_{CE(ON)} \), was demonstrated to provide mean time to failure estimates of IGBT remaining useful life with an error of approximately 20% at the time of anomaly detection.
DR. CHEN TO PRESENT JUNE WEB SEMINAR ON PHM

On June 26th, Dr. Chaochao Chen will be the featured speaker for the CALCE Web Seminar series. In this web seminar, Dr. Chaochao Chen will present the fundamentals of PHM technologies.

Prognostics and Health Management (PHM) is being widely applied in many industrial systems to ensure high system availability over their life cycle. This web seminar will present the five key steps of PHM: data processing, feature extraction, fault diagnostics, failure prognostics, and decision making. The fundamental algorithms, models, and techniques for each step will be discussed. Time domain, frequency domain, and time frequency data analyses are introduced, and the corresponding feature extraction technologies presented. Mode-based and data-driven-based approaches are described in fault diagnostics and failure prognostics. Finally, decision technologies incorporating prognostics results are illustrated to optimize maintenance policies and logistics business practices.

Please click here or contact Dr. Chen (chaochao@umd.edu) for more details.

BATTERY MANAGEMENT SYSTEMS FOR HIGH OPERATIONAL AVAILABILITY AND SAFETY CONFERENCE

Hong Kong Productivity Council and PHM Centre, City University of Hong Kong, is holding the Battery Management Systems (BMSs) for High Operational Availability and Safety conference on May 21st, 2012, at Shenzhen, China. The conference programs reflect the interests in BMSs from both government and industry. Battery experts from different countries, such as USA, Singapore, Korea, and China, will present their innovative ideas to improve the reliability and safety of BMSs. The CALCE battery group will also show their recent efforts in the applications of novel PHM technologies to BMSs.

IEEE PHM CONFERENCE IN CHINA

The 2012 Prognostics and System Health Management Conference (PHM-2012) will be held in Beijing, China, on May 23-25, 2012, following the success of the PHM-2010 Macau and PHM-2011 Shenzhen conferences. The PHM-2012 conference aims to bring together the global community of PHM experts from industry, academia, and government in diverse research and application areas such as aeronautics and astronautics, defense, marine systems, power and electronic systems, process industries, computers and telecommunications, material systems, industrial automation, and healthcare and medical technology. For more information, please visit: http://www.icphm.org

JOIN THE CALCE PHM CONSORTIUM

If you are not a member and would like to join the CALCE Prognostics and Health Management Consortium, please email Prof. Michael Pecht (pecht@calce.umd.edu), and we will provide you with the membership agreement. Upon becoming a member, users can register for a password to gain access to the research website.