# RESEARCH NEWS

**Increasing system reliability**

## Self-validation of complex electronic systems using grey box models

**When you mix together black and white, you get gray — and with it, a new method that should allow complex electronic systems to monitor themselves. Using so-called grey box models, on which researchers at the Fraunhofer Institute for Reliability and Microintegration IZM are working, it will be possible to detect signs of wear or manipulation in electronic systems at an early stage, before an actual failure occurs. The new process is being initially developed and tested for safety-critical applications in the automotive and rail sectors. The basic principle can, however, be transferred to many more application areas.**

A car is expected to run reliably for many years, through hot summers, frosty winters, rain and storms. Today, however, our vehicles are equipped with more and more electronic devices that must be able to withstand these extreme conditions. Until now, this problem for safety-critical systems has often been solved in practice with overdesign and redundant features. One such example is electronic systems or parts thereof that are installed in duplicate, so that when a fault occurs, the backup system can take over until the problem is fixed.

A research project at Fraunhofer IZM is contributing to a future of more elegant, sustainable and energy-efficient solutions in this area. As part of the SesiM project, which began last summer under the leadership of Siemens AG, Fraunhofer researchers are working together with other partners from the fields of mobility and artificial intelligence to find self-validation solutions for complex electronic systems. Focusing on automotive and rail applications, the researchers are investigating how these systems could assess themselves and report on their condition, for example via an integrated light system.

“We are more interested in the state before the electronics are broken than when they are actually broken,” explains Dr. Johannes Jaeschke, electrical engineer and the Fraunhofer IZM project lead for the joint project. “Long before a system fails, certain functions can be compromised, for example when materials become brittle. The mechanical stability of the component often does not provide early enough detection of signs of aging. This makes it a struggle to monitor electronic systems.”

**Contact**
**Roman Möhlmann** | Fraunhofer-Gesellschaft, Munich, Germany | Science Communications | Phone +49 89 1205-1333 | presse@zv.fraunhofer.de
**Georg Weigelt** | Fraunhofer Institute for Reliability and Microintegration IZM | Phone +49 3046403-279 | Gustav-Meyer-Allee 25 | 13355 Berlin, Germany | www.izm.fraunhofer.de | georg.weigelt@izm.fraunhofer.de

**Making gray from black and white**

The project's researchers see the grey box model as the key to effective self-validation of electronic systems. It has acquired this name as it is based on both white box and black box approaches.

For many years, Fraunhofer IZM has been working intensively on electronic systems at a physical level. With their expertise in measurement technology and design, the researchers can develop models for condition monitoring and forecasting based on physical processes and modeled around, for example, boundary conditions such as temperature or humidity. Because it is clear how this type of model functions, it is called a white box model. However, the more complex an electronic system is, the harder it is to map and monitor it on a purely physical level in a holistic manner. For data-driven models that use artificial intelligence, complex structures and large amounts of data are no problem. However, what happens inside these systems remains unclear - hence the name black box model.

"We can combine the best of both worlds in grey box models," summarizes Jaeschke. "This is why we are also referring to it as hybrid modeling. We can process a vast amount of data while, at the same time, understanding the physical reasons behind changes in the signal. This way, we can increase trust in our data."

**From test printed circuit boards (PCBs) to prototypes**

To date, practical applications of grey box models are largely unchartered territory. So, after an initial design phase, the SesiM researchers are now also working on describing simple circuits that will increase in complexity as the research project progresses. The test PCBs are precisely measured and tested during production and then in their operating state. "By doing this, we are generating a digital fingerprint for our test wiring," explains Jaeschke. This means that data will be collected even under extreme boundary conditions.

The next step is to identify the parameters within the large amount of data that are relevant for mapping the system and then, taking into account the physical knowledge, to create a model that detects deviations from a predefined ideal state. External manipulations should thereby be recognized as quickly as possible, and wear can be forecast early on. At a later point in the project, the test PCBs will then be transferred to prototypes for automotive and rail applications, which will be used to extensively analyze the models created.

**Potential for a range of applications**

In the future, it may therefore be possible for an integrated intelligent system in a car to provide an early warning for a problem with the electronics, offering a self-diagnosis. When servicing a car, mechanics will then be able to view all of the information collected by the vehicle about its condition and make targeted repairs on the basis of this information.

A follow-up project by researchers at Fraunhofer IZM will focus on the topic of aviation. Applications outside of the mobility sector are also possible — for example in medical engineering and offshore windfarms, for which regular external monitoring and preventative maintenance are difficult to carry out.

The overarching aim of SesiM is to initially prove that the basic principle that electronic systems can self-validate using grey box models actually holds true. Jaeschke has faith in the idea: “If we succeed, our approach will make a significant contribution to increasing the reliability of electronic systems. It is hugely important, particularly in the safety-critical mobility sector, and would further strengthen the reputation of automotive and rail technology developed in Germany.”

The SesiM project (FKZ 19|21018), funded by the German Federal Ministry for Economic Affairs and Climate Action, was launched on July 1, 2021. The project partners include Siemens AG, Robert Bosch GmbH, AUCOTEAM GmbH, GÖPEL electronic GmbH, Gestalt Robotics GmbH and the University of Stuttgart.

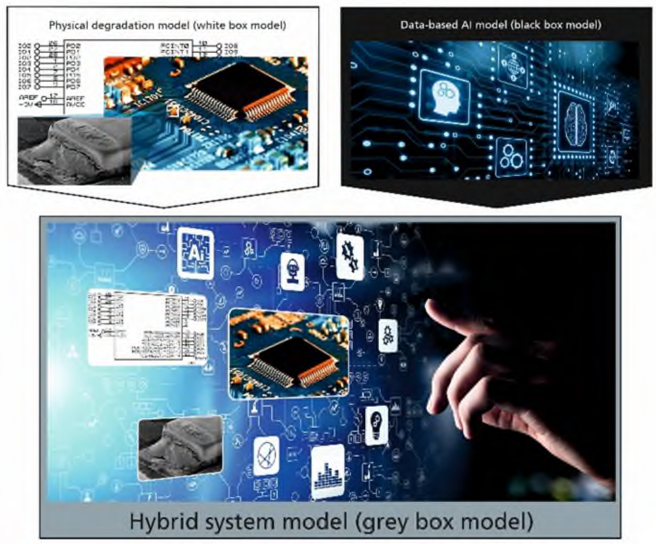


**Fig. 1 Hybrid models combine the advantages of both physical and data-driven models.**

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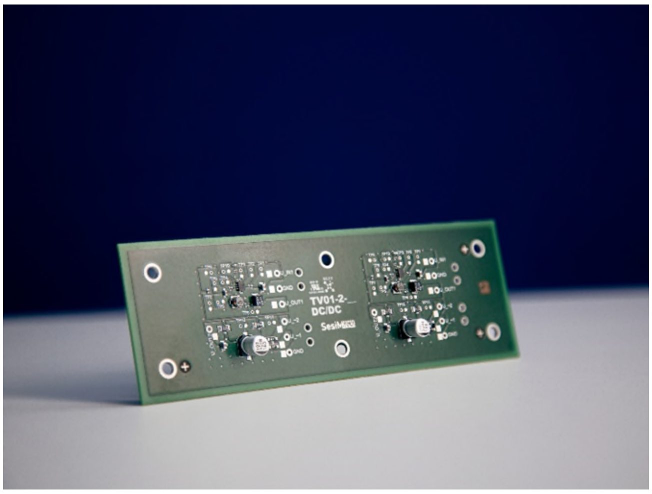


**Fig. 2 Test PCB with functional structures for generating a digital fingerprint**

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