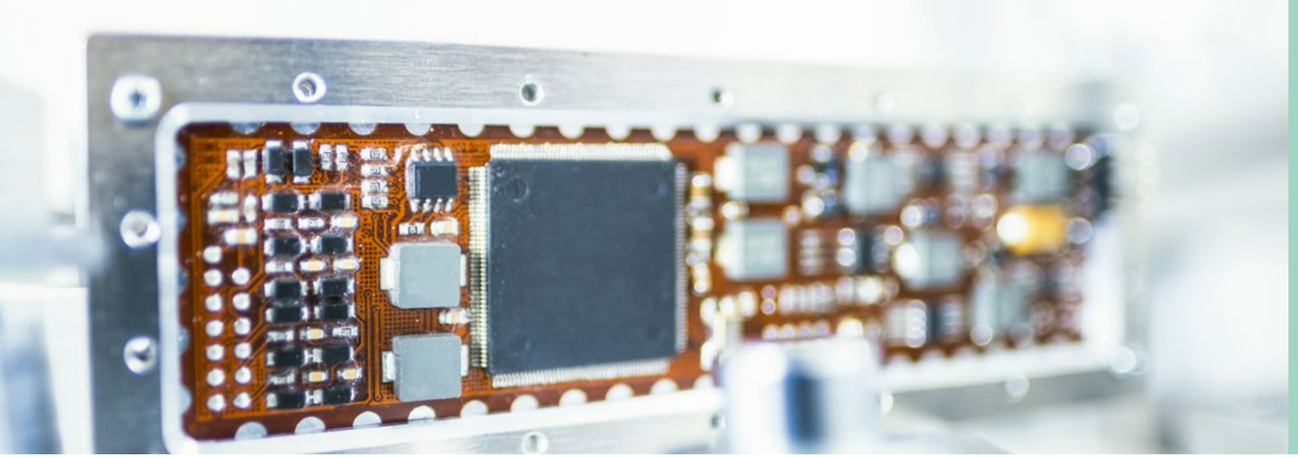

< Highly integrated sensor systems for industry must be able to withstand extremely harsh environmental conditions.

GROUP **THERMAL MEASUREMENT TECHNIQUES AND SYSTEMS**

HE Lab: Exposing sensors to thermal and compressive stress

In many areas of life, Highly Integrated Sensor Systems are state of the art technology. However, this is not the case in industrial environments. Here, extreme temperatures and pressures, chemically aggressive or wet media, and mechanical stress often cause sensitive sensors and electronic components to malfunction. Fraunhofer IPM is using specially developed measurement technology that mimics these extreme conditions in order to develop particularly robust sensors.

Geothermal drilling is well underway, the turbine is spinning at full speed and: A measurement platform assumes central control of various sensors to collect digital measurement data which are then processed and "reported" to external systems. These systems utilize the data for monitoring and intelligent process control, for example by triggering an actuator. This is the vision of scientists working on the eHarsh Fraunhofer lighthouse project involving Fraunhofer IPM and other Fraunhofer institutes. Taking engine or turbine monitoring and geothermal drilling as examples of use, they are developing a model sensor platform intended to withstand extremely harsh environmental conditions. The centrally installed high-temperature and high-pressure electronics have enough processing power to read and pre-evaluate signals directly in the sensor and transferred them to a control station. Consequently, cabling for the sensors is minimized. Given the harsh operating environments, cables often prove to be a weak point – partly owing to the prevailing high temperatures and also due to poor signal transmission and the sheer quantity of cables that would be necessary to operate a sensor network.

HE Lab — customized materials testing

High-performance sensors and electronics components that can withstand temperatures of up to 300 °C and pressures of up to 1000 bar are the building blocks of these systems. Since such sensors and components are not yet commercially available, specialized measurement technology is needed to develop and characterize them. The team therefore constructed a measurement laboratory that can replicate the actual environmental conditions as closely as possible. The HE Lab (Harsh Environment Laboratory) is used to test components and systems exposed to high temperatures and pressures. The first test rig for electronic components was put into operation in early 2019; customized measuring stations for small electronic components and for systems with volumes of up to several liters will likely be available in the new institute building from 2020 onward. The measuring range covers temperatures of up to 200 °C and pressures of up to 2000 bar. Installations for pressure shock and vibration testing are also being planned.

In addition to stress testing in the HE Lab, a high-temperature measurement platform for controlling sensors is also being constructed inside the measurement chamber.

IMPEDANCE ANALYSIS In electrical engineering, impedance is the frequency-dependent, complex resistance of a component. It is made up of ohmic, capacitive and inductive parts. Impedance measurements provide a wide range of information: Conventional conductivity can be measured at low frequencies while high-frequency measurements provide additional insights into dielectric properties — in other words, the capacitance of the measured object. When supplemented by frequency-dependent measurements of thermal properties, further information can be gained as to the object's thermal conductivity and capacitance.

It contains a control unit and various interfaces for connection to integrated and external sensor components. The components employed are all commercially available, though the permitted operating temperatures only range from 150 °C to 210 °C. Initial temperature tests on these electronics at 210 °C were successful. Many of the components used have already withstood pressure testing at up to 2000 bar, though a pressure-resistant, hermetically sealed housing is still needed for continuous operation in the field.

Impedance analysis yields wide-ranging information

Alongside the central control unit, the team is also developing sensors which operate in these harsh conditions and supply important information, for example on surrounding media. In the case of geothermal drilling, such media may be the lubricating fluid or the wall being drilled into, though they can also be sensitive layers that provide additional information on the type of mineralization or hydrocarbon concentrations, for instance. A combination of electrical, thermal and mechanical impedance analysis represents a key technology here. Electrical impedance analysis provides insights into the conductivity of the environment; thermal impedance analysis aids in the metrological separation of different media, such as water, oil and gas. Mechanical impedance analysis, on the other hand, measures pressure, vibrations and the solidity of materials or objects in the vicinity of the sensor. This combination allows the integrated measurement system to register a wide range of information that can make the construction and operation of systems cheaper and safer.

The "Harsh Environment Laboratory" measuring range covers temperatures of up to 200 °C and pressures of up to 2000 bar.

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