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1 *Sensor Unit*

SELF-SUSTAINING WIRELESS SENSOR SYSTEM

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Wireless Process Monitoring

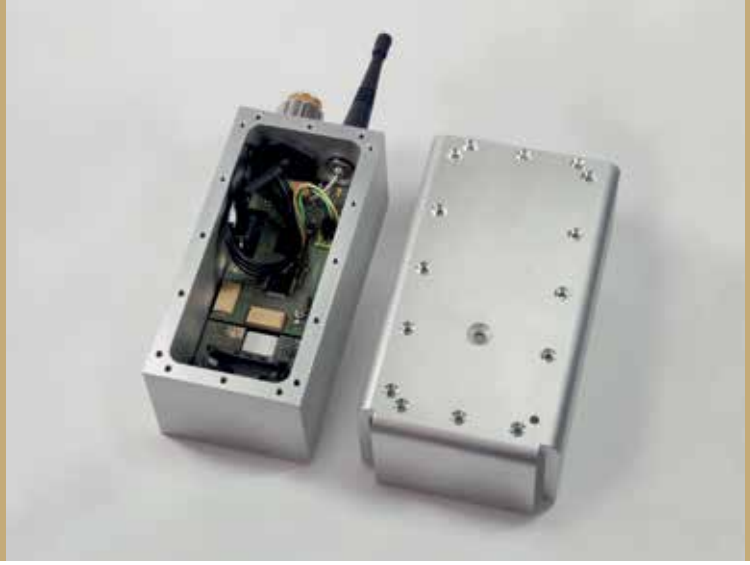
In industrial processes, especially in production processes, monitoring of operating data is essential for the early detection of damages, failures and wearing. This is important to ensure product quality and assembly yield and to keep the costs as low as possible.
In many applications measurement points of interest are difficult to access, for example in case of rotating parts of machines. In these and similar cases the use of wireless transmission of sensor data is an appropriate means. But the power supply of sensors will arise as a new challenge, if there are no wires available. The use of batteries is not very popular because of their limited lifetime and the related maintenance work and costs. Self-sustaining wireless sensor systems supporting process measurement technology have the advantage that they are maintenance free and easy to install in a process environment. Energy harvesting is a promising technique to realize self-sustaining sensors.

Several energy sources are usable for harvesting:

- Ambient light (solar cells)
- Lateral movement of parts (piezo elements, linear induction generators)
- Rotating parts (dynamos)
- Radio waves (antennas with rectifier)
- Process heat (thermoelectric generators)

In numerous industrial facilities process heat is available and can be used for harvesting. Fraunhofer IMS has developed a self-sustaining wireless sensor system for the measurement of pressure and temperature with various essential characteristics:

- Self-sustaining operation supplied by a thermoelectric generator (TEG)
- Battery-free operation from a few Kelvin of temperature difference
- Wireless real-time data transmission with a large number of sensors
- Flexible architecture, also suitable for other applications



System Architecture

The system consists of a PC as control computer, one or more base stations and a large number of self-powered sensors. Each sensor is assigned to a dedicated base station. Limited by the wireless protocol, a base station can manage up to 80 participants. If more sensor nodes are needed for a special application, a second base station for further 80 participants will be added. In that case a new communication cell is created with its own carrier frequency similar to the technique known from mobile phone systems.

RF Link and Protocol

In order to meet the ambitious requirements of the wireless data transmission a special synchronized time slot management (TDMA - Time Division Multiple Access) was realized that results in guaranteed time slots for many participants by collision avoidance methods.

Power Supply by TEG Energy Harvesting

A thermoelectric generator (TEG) converts the temperature difference between the cold environment and the warm process medium directly into electric energy for the supply of the sensor. The output voltage of the TEG has to be transformed to one or more stable DC operating voltages. Depending on the used components, typical values for these voltages are 1.8 V, 3.3 V or 5.0 V. The power management unit supervises the operation voltages and indicates the power status to the processing unit.

Mechanical Design

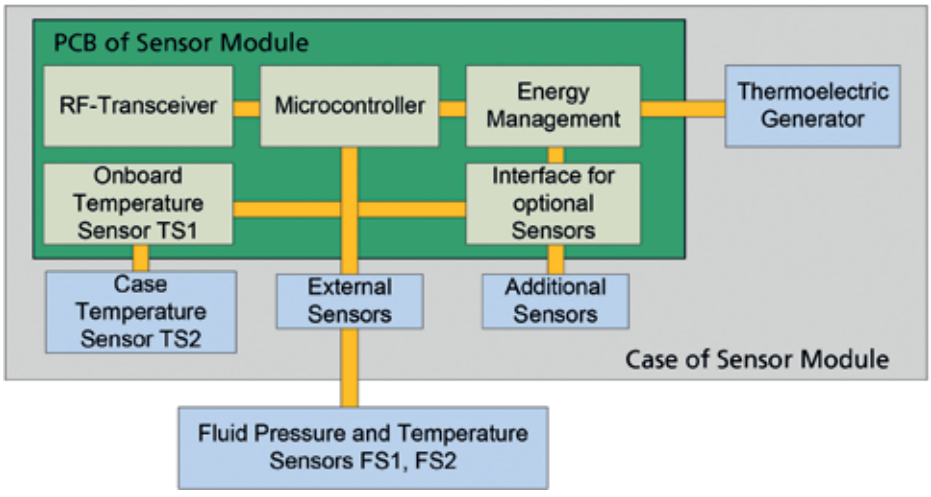
Due to the harsh environment in industrial applications, a housing with a protection class better than IP 65 is designed. The hot-side temperature provided by the process medium is fed from the bottom to the thermal generator; the cooling of the cold side of the generator is realized by the housing itself that keeps the temperature of the environment. The two housing halves are thermally decoupled from each other by means of a thermal insulator, which also ensures the tightness of the housing.

Results of Test Setup

During the verification the system was tested on a specially built test setup using realistic environment parameters. A self-sustaining operation is possible if the temperature difference has an amount of at least 8 Kelvin. This value refers to a measurement and communication interval of 30 s. If the application provides a higher temperature difference, the number of measurements and transmissions can increase up to one measurement per second.

Technical Summary

- Pressure and temperature sensor
- Configurable sample rate: up to 1/s
- Real-time collision-free wireless protocol
- UHF transmission (868 MHz ISM band)
- Powered by thermoelectric generator
- Maintenance-free operation
- 80 sensors per channel



2 *Components of Sensor Unit*

3 *Block Diagram*