Micro-multi-sensor platform for industrial processes monitoring

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1 Abstract

Till now there is no standard or common platform to design and manufacture monitoring systems for industrial processes. In response to that, Taipro Engineering with the support of the Microsys lab of the University of Liege are designing and developing a micro-multi-sensor-platform. The platform is a development tool for a rapid integration of different existing sensors in a miniaturized ($1cm^3$) autonomous device. The sensors can be processed by different technology and can have different package format, including non-packaged sensors in a form of a bare die. The system, without external power supply is able to acquire, process and transmit data to a receiver.

2 Key-words

Micro-multi-sensor-platform, industrial processes monitoring, smart microsystem, full autonomous device, smart sensor, health monitoring, predictive maintenance.

3 Introduction

Because of a recent progress in microelectronics towards functionally, miniaturization and cost reduction, many industrial processes can be monitored in an accurate and cost effective way. The information acquired can be processed, transmitted and stored. The monitoring can be performed by smart systems. Up to now there is no standard or common platform to design such systems. The common platform must response to the market requirements. The developers and the designers of the monitoring systems pursue different objectives; however the most common challenges they are facing, are a total cost of ownership, a time to market, combined with the device's user friendly features. The platform must be an open construction tool box, and to serve as a smart virtual house to accommodate different functional features for wide variety and ranges of industrial processes monitoring. In contrast to multi-functionality, the compatibility issue of the different components must be addressed.

4 The micro-multi-sensor-platform for smart systems design

In response to industrial needs, TAIPRO Engineering with the support of the Microsys lab (University Liege) is designing and developing the micro-multi-sensor-platform. The platform is a development tool for a rapid integration of different (in terms of functionality) existing, off-the-shelf sensors and components in one miniaturized (less than $1cm^3$) autonomous device. The system is able to acquire, to process, to store and to transmit the data's to the receiver. The receiver is usually a standard wireless system and can be installed at any factory. The receiver can be a standard PC (desk top or laptop) or a commercially available wireless receiver.

The platform comprises a processing unit to drive and control each sensor individually. It also includes features to monitor an interaction if there is any between sensors. The platform possesses all necessary features for a simple signal processing obtained from each individual sensor on board, to store and to transmit the information in a wireless way to the receiver where they can be analyzed. The platform allows to adjust, according to specific customer requirements, the sensing speed, the sensing accuracy and the processing speed of the information. The embedded software can be modified via the wireless connection.

The miniaturized device developed with the help of the micro-multi-sensor-platform is a fully autonomous system. The autonomy is provided by the power supply on board. The designer can choose the most suitable to the required specification, source of energy among following options available: a compact battery, a photovoltaic element or energy scavenging system. Important, that the high level of autonomy is achieved by smart auto-power management system. The smart power management system is the part of the global self-management system of the microsystem. The global self-management system comprises following features: built-in test (auto-diagnostic), smart auto-power management, self-calibration, synchronization and reconfiguration. The built-in test feature is responsible for detecting a measurement problem and provides the information to the commercial transceiver. The smart auto-power management is to detect a low battery level and provide the information to the commercial transceiver. The self-calibration feature ensures that the system detects itself the calibration periodicity and more importantly calibrates the system without intervention of maintenance personal. The system is to synchronize the clock at each communication with the transceiver. The smart system can be easily configurated and re-configurated via the receiver. That allows easy and quickly to upgrade and adapt the embedded software of the smart system to specific needs.

Microsys lab performed extensive research on packaging and assembly issues to assure the compatibility between different sensors, between the sensors and the processing unit, and the transmitters. The result of the research is translated into the platform architecture. Thus the platform is designed and constructed in such way, that it already resolves compatibility issues of components and all system features on board.

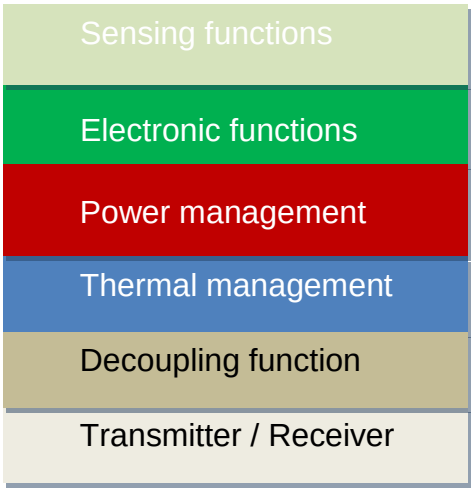

Figure 1: Conceptual model of autonomous smart microsystem designed using TAIPRO Engineering and Microsys lab (University Liege) micro-multi-sensor-platform.

The example of a product designed and assembled using micro-multi-sensor-platform is a fully functional prototype of the miniaturized (less as 1cm3) autonomous device. The device comprises a temperature, pressure and vibration sensors on board, a logic element to control the sensors, data's processing unit, a wireless transmitter to send the information to the receiver and a power block to provide the autonomous for the miniaturized device. The receiver is a standard PC that processes and stores the acquired information.
The 3-D model view of the smart microsystem of 1cm3 is depicted on figure 1.

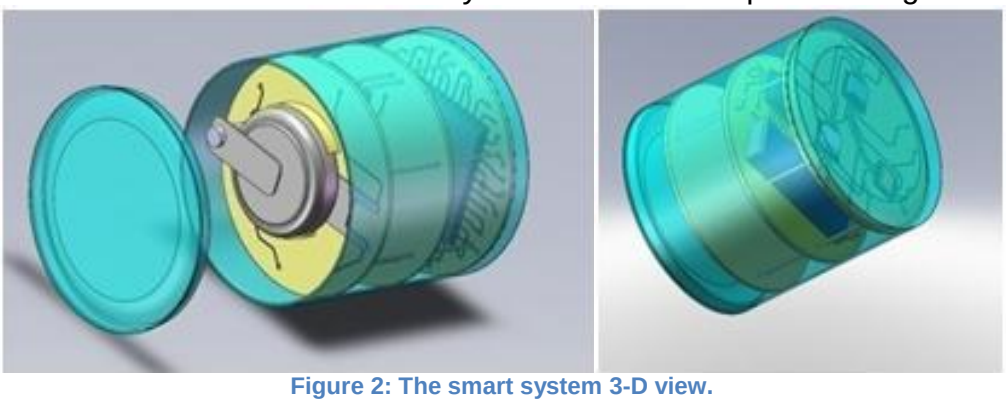

Figure 2: The smart system 3-D view.

The housing of the smart system is robust enough to meet standard industrial operational condition specifications. The working temperature range of the smart system is from -10 up to +85°C. The pressure range is from 1 bar up to 6 bar (absolute pressure values). The system can withstand a vibration up to 5g acceleration in the frequency range of from 0 up to 100 kHz.

5 Industrial processes monitoring

The most industrial processes require monitoring. The industrial equipment and tools usually experience overheating, excessive vibration of different frequency. During equipment operation the pressure and the level of lubrication and cooling agents must meet strictly defined specifications.
The preventive maintenance is a widely common type of service to ensure that entire equipment and on each module and sub-module level operates correctly and to therefore avoid any unscheduled breakdown and downtime. Usually it is performed by conducting a systematic inspection, detection before a real failure occurs or before they develop into major defects. Thus, the preventive maintenance includes monitoring of the most critical parameters of the equipment. The equipment is subject to preventive maintenance through the total life span. Furthermore, the preventive maintenance can be turn into a predictive maintenance by using the micro-multi-sensor-platform. Another parameter, the pressure of cooling and lubricating oil is usually not measured, and the condition is observed indirectly by measuring the oil level. The read-out of both parameters, the temperature and the oil level, requires a maintenance personal, in another words a human presence.
The most difficult parameter to monitor is vibration. The vibration, in general and for the specific case of the gear reducer is undesirable, wasting energy and creating unwanted noise. The vibrations can be caused by imbalances the rotating parts or critical wearing-off, uneven friction, etc. The vibration can indicate beginning of major failure development. Thus the vibration on any frequency must be detected and

measured. We, together with our industrial partners have identified the vibration frequency that may have an effect on the gear reducer operation. The critical frequency range starts from infra-sound (from 0.25 to 20 Hz), to acoustic range (20Hz to 20 kHz) and extends to ultra-sounds (from 20 to 100 kHz). The vibration is generated in the body of the equipment and can propagate in air surrounded the equipment, generating a noise. Currently the monitoring is performed mainly in-directly. The maintenance personal based on the experience detects un-usual vibration directly on the tool or un-usual sound generated by the equipment. Such observations are often subjective, not accurate enough and perform at a discrete moment of time. A fundamental problem is to monitor the noise in infra- and ultra-sound range because it is un-detectable by humans.

As we see on the example of the gear reducer, the industrial equipment requires in-situ accurate monitoring. The data's must be accurate, objective, easy and unambiguous to interpret. The response to the describe challenge is a microsystem, designed using TAIPRO Engineering and Microsys (University of Liege) micro-multi-sensor-platform that can constantly (24 hours a day) measure the temperature of the tool at specified location, can measure the oil pressure and can measure the vibration in wide frequency range. The data acquired are transferred to the base station where they can be analyzed.

The smart microsystem has a broad monitoring range. The system can monitor the temperature locally in the range of: -10C up to 150°C, a pressure range is from 1 bar up to 10 bar (absolute pressure values). The system detects and measure vibration in range of from 0 up to 100 kHz, up to 5g acceleration.

The monitoring system can be incorporated permanently or temporary at the body of the equipment. For specific application the life cycle of the monitoring system is designed equal to life cycle of the equipment.

6 Conclusion

The micro-multi-sensor-platform developed by TAIPRO Engineering with support of Microsys (University of Liege) is unique open construction tool box to design a smart microsystem for broad variety industrial process monitoring. Use the micro-multi-sensor-platform helps your company to concentrate on your core business competence and results in lower cost of ownership and shorter time to market smart microsystems.

7 Reference

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