The sensor network targeted for temperature and humidity monitoring within buildings, based on the BMS architecture

Main goal in scope of this project was to design system – the sensor network, targeted for monitoring isolation efficiency of novel facade panels designed for building thermal isolation. Additional aim was to make measured, by our monitoring network, humidity and temperature also useful in buildings with building management system (BMS) installed. Our system incorporates LonWorks BMS standard which means it can be used in every buildings that utilizes it. Designed devices can measure humidity and temperature inside of the isolation panels and walls as well as inside and outside of the building. Series of tests in realistic experimental conditions were carried out to ensure proper behavior of designed system before its launch in mock-up buildings.

1. Achievement description

System was designed with flexibility in mind, so it can be implemented both as monitoring system for SESBE mock-ups and work within actual BMS in residential, office, or industrial buildings. With that in mind following architecture was established (Fig. 1). It supports communication vis BMS network and enables online access to measured data.

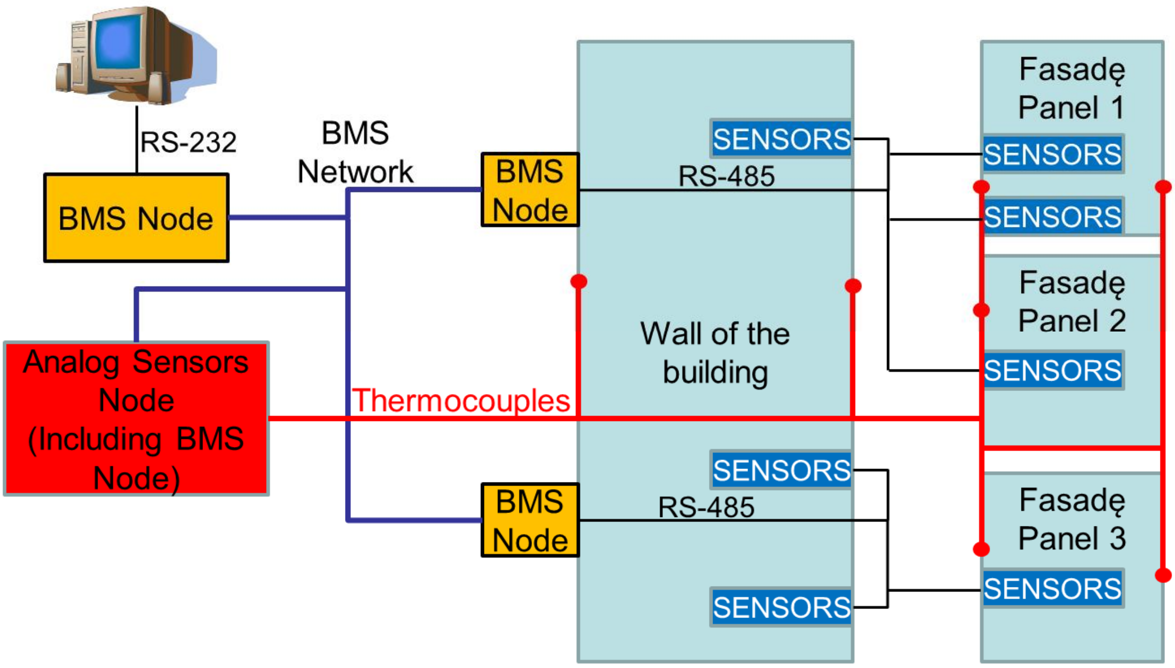

Fig. 1. Monitoring system architecture

Monitoring system presented in Fig. 1 consists of following elements:

- **Sensor Nodes**

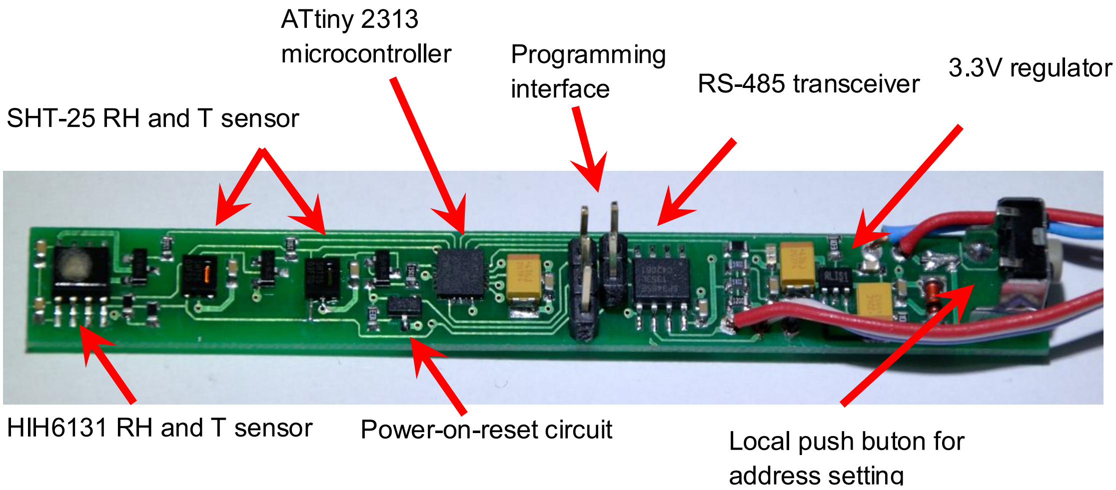

Fig. 2. Sensor node prototype

Sensor node, presented in Fig. 2, is intended for installation inside drilled or prefabricated hole in the wall or facade panel, therefore to avoid thermal bridging radical reduction of sensor node dimensions was necessary. In final design it was possible to reduce size of printed board to 7 mm wide. Prototype utilize two types of humidity and temperature sensors : SHT-25 i HIH6131. In order to provide proper communication of sensor node with other devices the addressing and communication protocol via RS-485 was implemented. After being triggered (by proper data frame) sensor node outputs current humidity and temperature measurement. The ATiny2313 MCU from Atmel was chosen to oversee mentioned above functionalities.

- **BMS Node.**

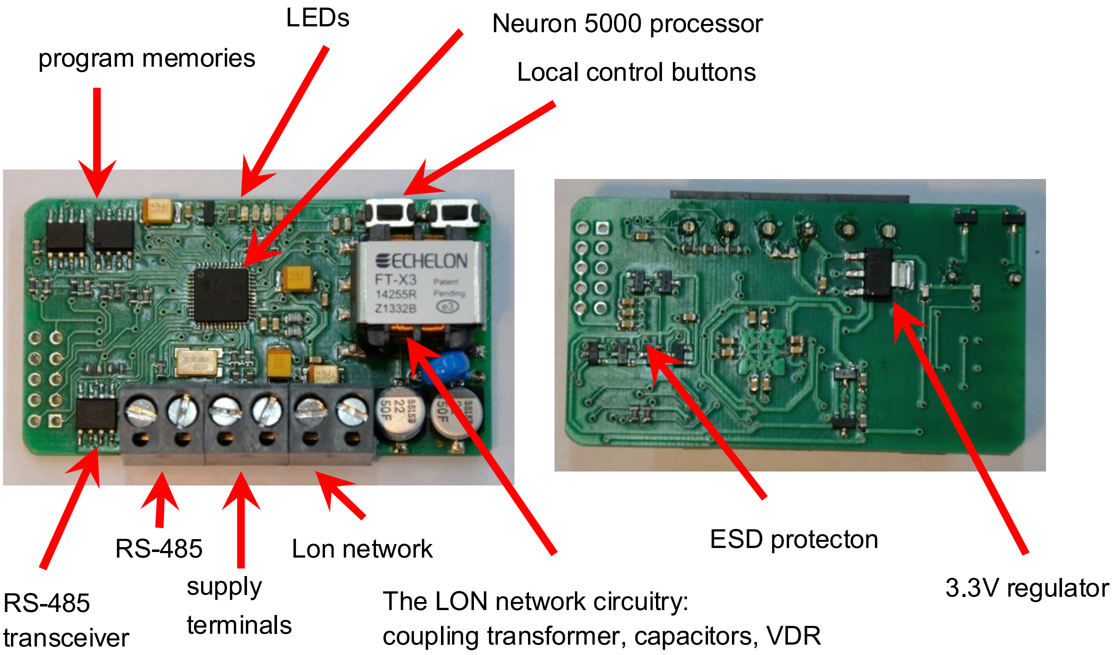

Fig. 3. BMS node, top and bottom view

In order to make sensor node as small as possible it wasn't possible to incorporate LonWorks interface with it. Size of transformer alone were few times to grate. Due to those size considerations designing BMS node was necessary. Its main purpose is converting LonWorks messages to RS-485 and vice versa, between sensor nodes and LonWorks network devices. BMS nodes support addressing procedures, which make cutting off selectively pars of measurement network possible. Device was based on Neuron 5000 microprocessor from Echelon company.

- **Analog sensors node**

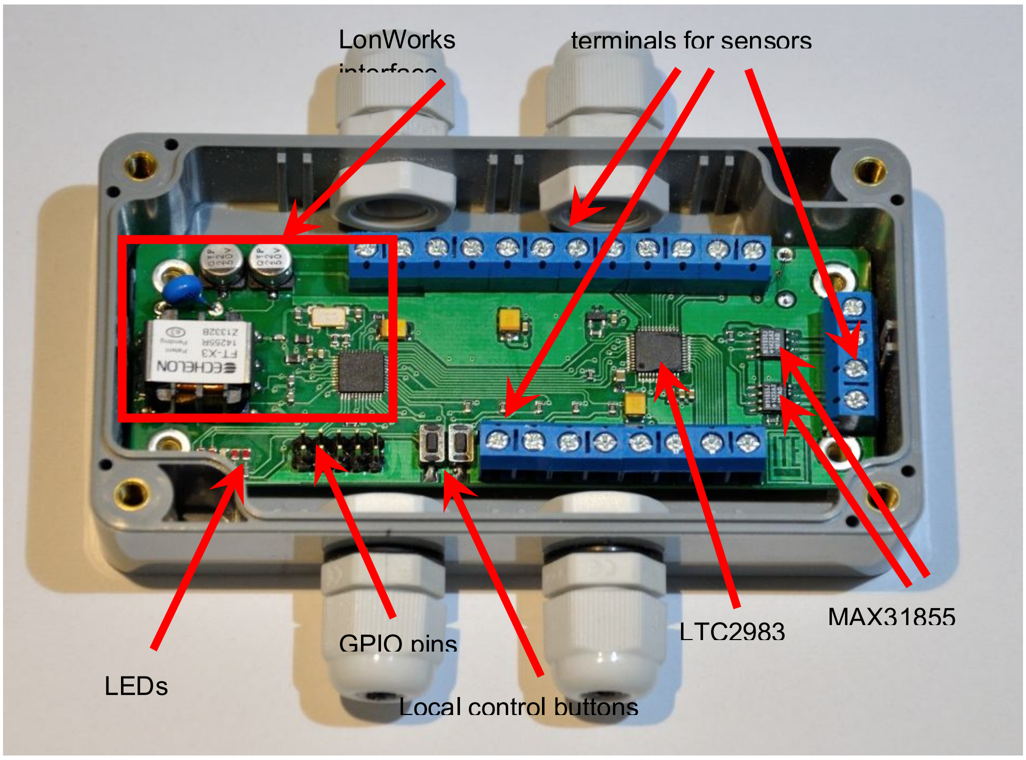

Fig. 4. Analog sensors node

Additional analog sensors node aim is to measure temperature both on the inner and outer wall surface. It was built based on new Linear Technology IC - LTC2983. It supports up to 20 different analog temperature sensors (diodes, RTDs, Thermistors, Thermocouples) at ones and implements thermocouple cold junction compensation procedures. BMS communication and measurements are carried out by Neuron 5000 microprocessor from Echelon company.

- **Monitoring network controller**

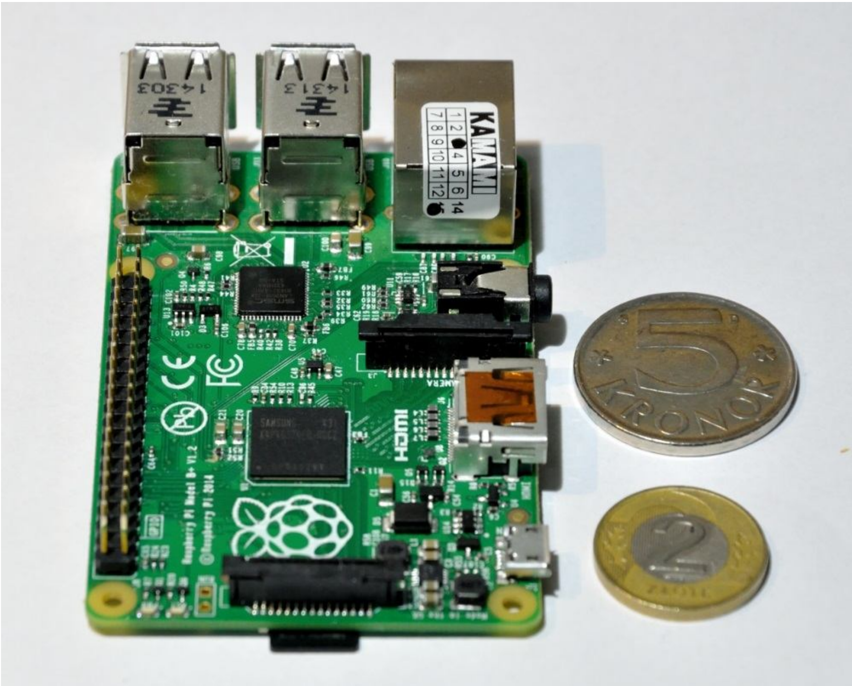

Fig. 5. Raspberry PI 2 B

Scheduling and initiation of measurements in monitoring network is carried out by microcomputer Raspberry PI 2 model B. Additionally its other role is uploading measured data to data base. To be able to do all of that it utilize ARM Cortex – A7 and operating system Raspbian – clone of the Debian GNU Linux. It offers many useful tools that makes interfacing with outside devices and global internet network safe and efficient. Singular unit of Raspberry PI 2 B can manage measurements in whole even relatively big monitoring network.

- **Data base.**

Last key part of monitoring system is data base. Defined in MySQL it will contain two tables and aggregate measurement data from two mock-up sites that monitoring system will be installed on (In Poland and in Spain).

In general, before comprehensive large scale system tests each element of described system should be evaluated separately. It simplifies process of detecting and solving any potential problems that may occur and speeds up whole system launch. Testing process was divided in few separate steps to test following issues:

- transmission reliability,
- sensor data reliability,
- interferences resistance,
- long term and environmental durability of elements.

In order to investigate those issues additional software and dedicated testing environments were designed.

- Sensor nodes accuracy and stability testing

In order to evaluate measured, by sensor nodes, data reliability dedicated LabVIEW application was designed. Its front panel is visible in Fig. 6. Main goals of that program are: measurement triggering, data loggind and visualization.

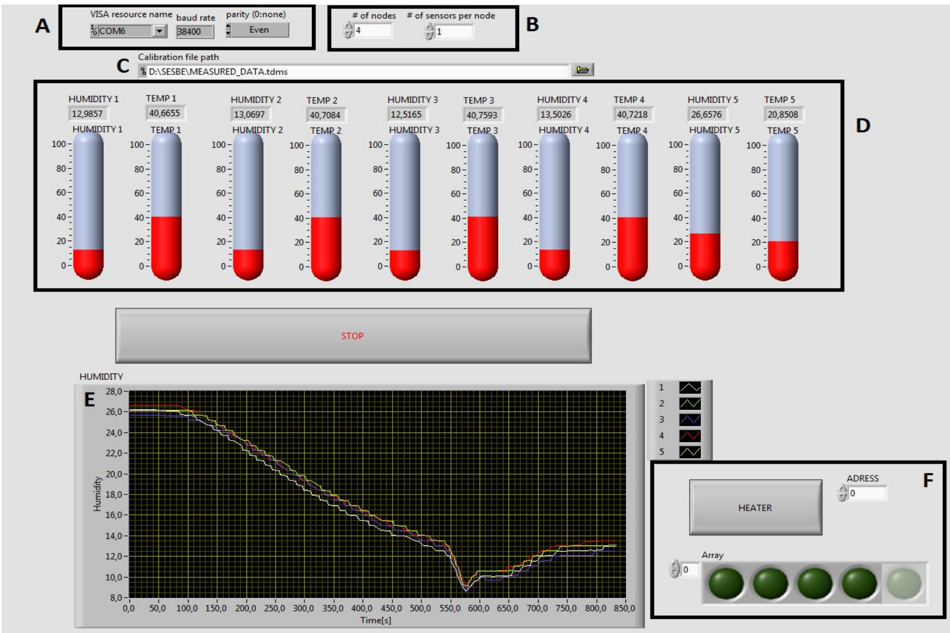

Fig. 6. Front panel of the sensor node test application

After designing such evaluation software following testing scenarios were carried out:

I. Simulation of harsh environmental conditions in climate chamber

In order to validate if sensors behave as specified and if designed hardware is resistant enough to work both in high and low temperatures the climate chamber (visible in Fig. 7) was used to expose sensor nodes to temperature cycles. Proper behavior, of sensor nodes, was confirmed in temperature range from -20 to 50 Celsius degrees.

Fig. 7. the climate chamber

II. Testing of measurements inside solid material

This served as empirical test of measurement method utilized by sensor nodes. Since project requires measuring humidity and temperature inside solid material similar test was prepared. Two sensors were sealed inside holes drilled in Ytong of different depth. Block of Ytong was at first left in container with some amount of water to soak it up (during weekend). After confirming that in fact all readings indicate significant rise of humidity inside both holes, Ytong block was dried first slowly in room temperature, then quickly in 60 Celsius degrees. In both cases drying solid material caused falling humidity readings.

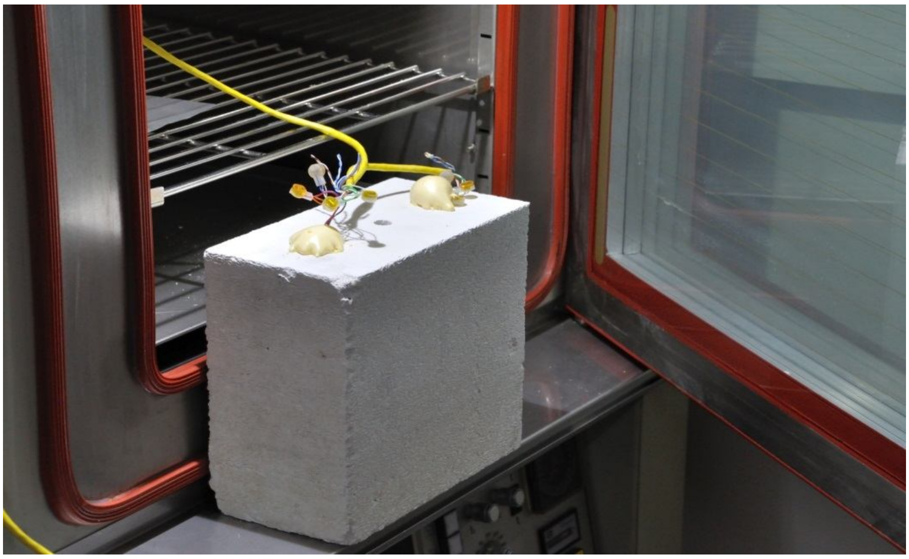

Fig. 8. Ytong block with embedded sensor nodes

III. Resistance to interferences in industrial conditions and long routing tests

In order to evaluate if monitoring system will perform correctly without communication errors, next to other data and power lines, it was decided to install sensor node outside ITE building and route it alongside with phone and power lines that are used daily in the institute. This set-up is operational for few months without any problems, witch confirms both strong immunity to interferences of LonWorks based networks and long term transmission stability of designed system. Fig. 9 illustrates the controller device, based on Raspberry PI microcomputer used for these purposes (top cover removed), while Fig. 10 shows the sensor and BMS nodes installed outside the building.

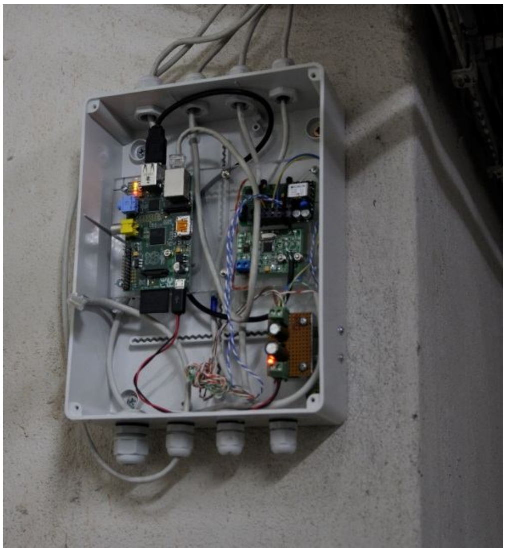

Fig. 9. The network controller box used for testing pruposes - top cover removed

Fig. 10. the sensor and BMS node installed outside the building on ventilation chimney

- The analog temperature sensors node testing

Additional LabVIEW application was develop in order to evaluate proper behavior of analog sensor measurement process. Its main role is to cooperate with analog sensors node, trigger its measurements, log and visualize its measurements. Its front panel is presented in Fig. 11.

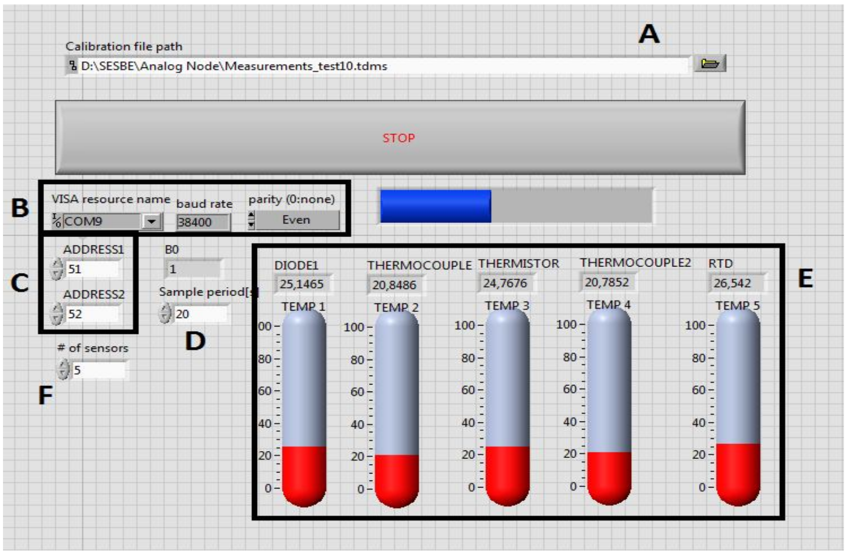

Fig. 11. front panel of Analog Node evaluation program

Series of measurements were carried out (again in climate chamber presented in Fig. 7), sensors were calibrated and proper behavior was verified. Different cold junction compensation sensor types were tested.

2. Application (including the information about moving into production)

Described monitoring system is meant for two kinds of applications. Firstly it will be installed in SESBE mock-ups to evaluate quality of, manufactured within a project scope, façade panels. Secondly end product is ready to be incorporated into any building that utilize LonWorks BMS technology.

3. Scientific, economic and social significance

In general BMS can reduce media consumption (and cost) in buildings they're implemented in. Additionally designed sensor network helps not only to monitor temperature distribution inside building, but also moisture penetration inside walls, therefore monitor structural health of the building.

4. Sources of funding

SESBE (*Smart Elements for Sustainable Building Envelopes*), FP7-2013-NMP-ENV-EeB, grant agreement: 608950

5. Authors of the achievement

Grzegorz Janczyk, Dariusz Obrębski, Michał Zbieć