Realization of Adaptive Weather Station for Work in Antarctic Conditions

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Abstract – **This paper describes the realization, calibration process and initial experimental data analysis of the prototype version of adaptive weather station. The device relays on an ultra-low power micro architecture and adaptive power distribution mechanism. It is dynamically reconfigurable for working in high performance, real time transfer mode with direct operator control; and ultra-low power, fully autonomous, self-monitoring, long-term measurement mode. For convenience the collected data of the environmental parameters could be initially analyzed and visualized by specialized end-user software tools.**

Keywords – **Weather Station, Ultra-Low Power Management, Self-Monitoring, Dynamically Reconfigurable, Global Warming, Data acquisition**

I. Introduction

Monitoring of the ambient parameters is important task for a number of activities. This includes, but is not limited to, studying the weather and the climate, preparing whether forecasts, collecting reference data for other studies, for aviation and navigation purposes, etc. Each of those tasks requires specific monitoring and/or logging system.

Typically, for studying the climate changes, is necessary to analyze data from long-term measurements of the environment parameters (like temperature, barometric pressure, humidity, etc.). The data from the daily measurements are then logged in sets of different time frames (in conditions defined by World Meteorological Organization [1]) and analyzed to define the tendencies in the climate changes.

At the same time collecting a reference data for other studies requires measurements to be focused on current weather conditions. In this case is used equipment allowing monitoring of environmental parameters in real time – measurements are done continuously, and a suitable interface is provided for communication with the user and/or other systems. Data from these measurements can be then used as a reference in order to take into account possible errors in the further processing of data from other measurements taken in parallel or used as an input for other systems.

In order to support a research of Bulgarian Antarctic Expedition was requested to provide systems for environmental control on two different bases – measuring environmental parameters in real time as an aid to perform parallel measurements; and securing long term environment measurements in order to log statistical information on climate changes during the winter season. These conditions make two contradictory system requirements. The first ensure monitoring of a wide range of parameters, where the high performance of the system is priority; and the second – long-term measurements, where the total power consumption should be as low as possible. The last one requires a great reduction of the parameter count and a data logging rate, which are a priority for the first one.

The optimal solution is to create an adaptive compact system that ensures all the necessary measurements to support experiments performed in real-time (respond within specified time constraints [2]) and able to autonomously provide series long-term measurements, by dynamically reconfiguring its working rate.

II. Design of the Device

A. Hardware Design.

Key factors affecting the development of the system with the specified requirements are the working conditions under which the system operates, power consumption, autonomy and cooperativeness. A special feature is the combination of high power consumption real-time monitoring system of the environmental parameters and minimum power consumption requirements for long-term measurements. For the purpose of which was developed a specialized power control system that could isolate from the power source all unnecessary subsystems, for the duration of their passive states, and switch them on again when necessary. Management is fully electronic, as the specifics of the working conditions do not allow use of mechanical switches or moving parts.

Figure 1. Prototype presents the prototype of the weather station.

The control subsystem is based on a microcontroller and includes user interface for direct work with the system, interfaces for data transfer with other systems, real-time clock, and a data memory.

The Device has USB interface designed for direct transmission of data to the computer systems, so the operator can monitor real-time measurements.

Real-time clock provides a time stamp required for the synchronization of the measured parameters with a global database.

The sensor subsystem contains all the necessary sensors and peripherals required for the operation of the station. Sensors are prioritized and divided into 2 main groups.

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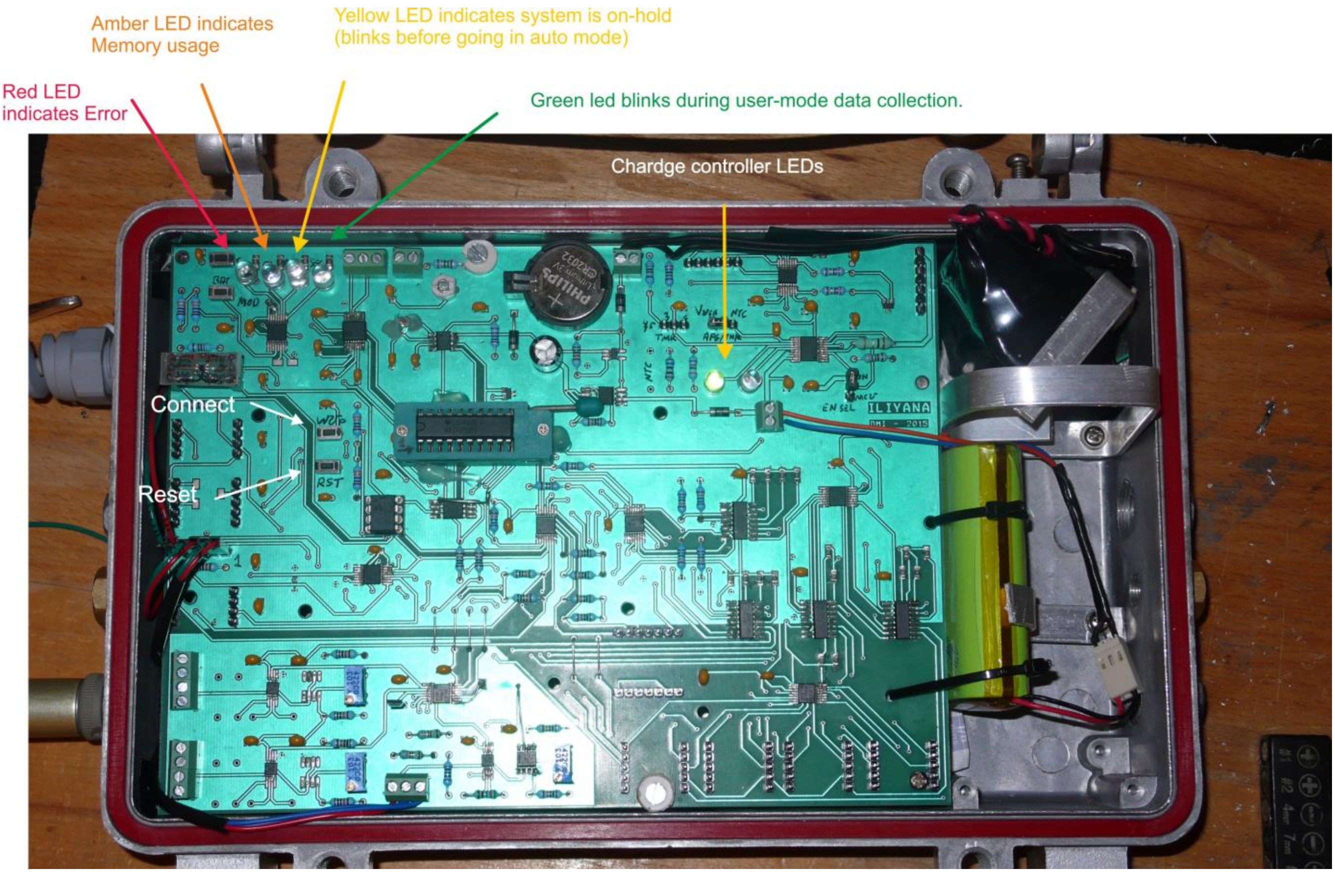

Figure 1. Prototype of the Adaptive Weather Station

The first group contains the basic sensors for the station – temperature sensors, pressure sensor, and temperature compensated humidity sensor.

The second group of sensors is used for the purposes of the research. It includes an accelerometer, a light sensor, and a magnetic field sensor.

The sensor subsystem includes three expansion interfaces for adding additional sensor modules. The interfaces are equipped with controllable power supply, two analog inputs, a digital interface for data transmission, and two digital ports with general purpose.

B. Firmware Design

System management is executed by embedded software, including algorithms for determining the operating modes of the system (autonomous control or subordinate work), powering the sensors, synchronization, error detection, analysis and reconfiguration of the operating modes, the data logging and transmission.

There are three main algorithms that build the firmware:

- Self-diagnostic
- Power Management
- Data collection

Self-diagnostic algorithm is executed during the first (diagnostic) system scan after restart. Its main task is to check the system health status and to configure appropriate working mode. It is executed in two phases.

Component detection - during this phase firmware is scanning all peripherals within the system. Each scan is performed for a predefined period of time (2x sensor's maximum response time); if a response does not appear during this time frame, the program cancels the scanning process, flag the sensor as unusable, and log an error message. Once detection scanning is completed a watchdog (WDT) starts monitoring the system during its normal operation. Component detection is performed only once after restart, as this is high power consuming operation. If sensor fails during normal working mode, WDT will restart the system and the failed sensor will be detected during new diagnostic scan.

Error detection – this phase is active during the normal operation mode of the system. It logs all errors that could appear – mode change, reset, manual scan requests, inappropriate user configurations (invalid input data, syntactic error, invalid command, etc.), data memory overflow, etc.

Power Management algorithm is executed immediately after initial initialization and have the responsibilities to perform power-up and power-down sequences necessary to prepare the peripheral devices for work, and to switch them off to save the power. This program is in direct service of data collection algorithm. Additionally, this program monitors the traffic upon the user interfaces and can change the working mode from user-controlled (UI Mode) to autonomous if a defined time of user inactivity expires, and vice versus if the user request control. In cooperation with Data collection algorithm, Power Management also monitors the battery status, and can switch between primary and secondary source depending on the battery levels. It can also cut down the power exhaustive sensors, if the secondary source drops below predefined thresholds, and keep the system active for longer periods.

Data collection algorithm is the main program that is running during normal operation mode. Its main task is to collect data from the sensors and record them in the embedded memory. It also provides vital data for Power Management and Self-diagnostic algorithms in order to keep them function properly. It is also responsible for user communication and all data exchange including acceptance of control commands and data conversion for real-time user usage.

C. PC Application (Offline tool).

A specialized computer application is designed to provide easy control over the station during the real-time operation, and easily retrieve data collected during long-term measurements.

The application enables direct recording and storing data obtained during real-time operation of the station. It can be processed immediately and visualized on the display for direct monitoring and / or exported as a file for further analysis. It also provide current device status data, and set of options for configuration setup.

III. CALIBRATION

Essential part in realization of data acquisition systems is calibration of its sensors in order to achieve maximum accuracy. Although all sensors could be fine calibrated, this process is intended to the custom designed analog sensing elements like platinum RTD.

On Figure 2 is presented the calibration graph of the platinum RTD (temperature value as function of LSB).

The calibration of the front-end electronics consists of performing multiple measurements over set of calibration resistors and defining the average value and standard deviation per each resistance. For building the calibration function are used 48 different resistors that correspond to exact temperature value, as defined in the RTD's lookup table.

As a result we achieve a linear equation that describes the measured temperature as function of the LSB:

$$y = 0.221811x - 372.615678$$

Where the coefficient of determination is:

$$R^2 = 0.999947$$

This result premises the use of linear equation.

IV. EXPERIMENTAL DATA

Some initial experimental data is shown on Figure 3. It is collected during setup process in the base camp at Bulgarian Antarctic base on Livingston Island. The graph presents the correlation between the humidity (the top line with right axis) and temperature (middle graph is from platinum RTD and lowest is from TMP112 smart sensor).

The two temperature graphs have identical trend lines, where the TMP112 is around 0.5°C lower than platinum RTD, which is matching the specification of the sensor [3]. TMP112 is measuring the temperature inside the device case, and due to this its graph is smoother. The graph of the platinum RTD has some peaks due to its higher sensibility and because it is measuring the temperature outside of the device case, where is affected by sudden airflows and/or radiation. The peak to peak deviation of the platinum RTD is within the range of one LSB, which also match the device specification and does not affect the accuracy.

The shape of humidity graph is similar to the RTD's one, and the reasons are the same – it is outside of the case. Trend line is correlating with the temperature, which is exactly as expected.

The device is equipped with a third temperature sensor, which is measuring the temperature inside the microcontroller.

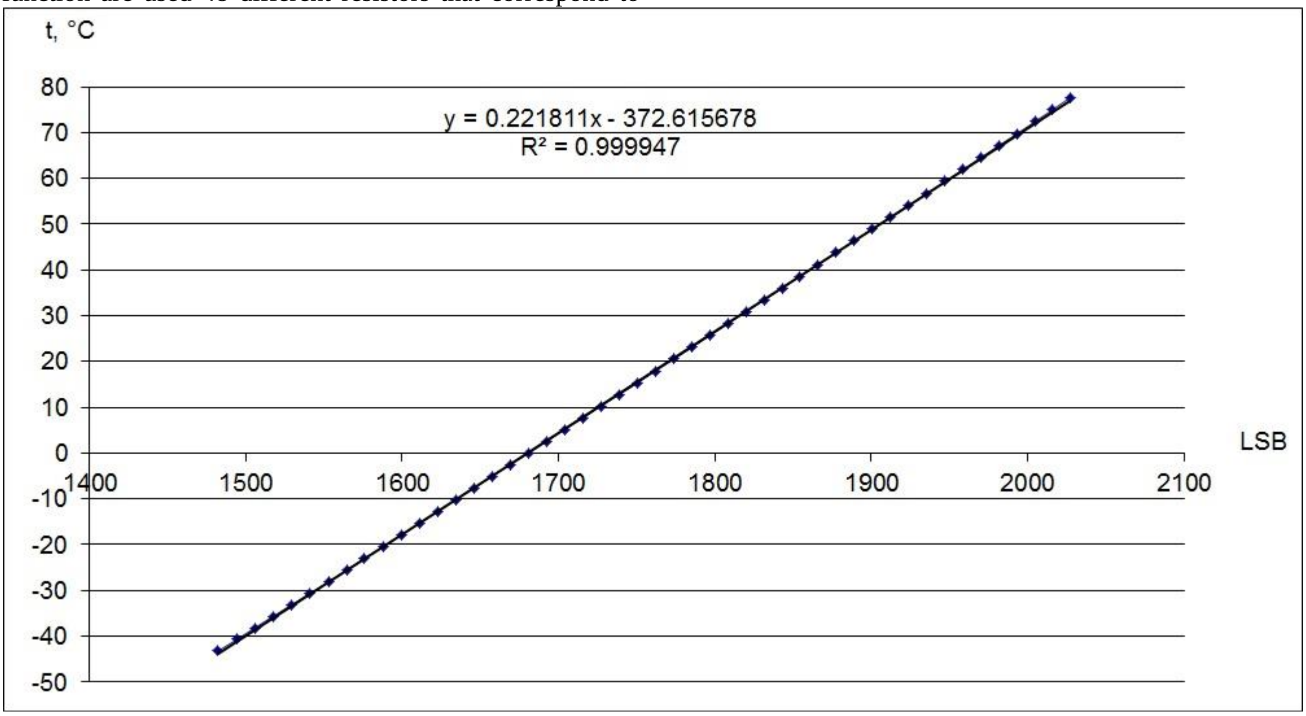

Figure 2. RTD calibration graph

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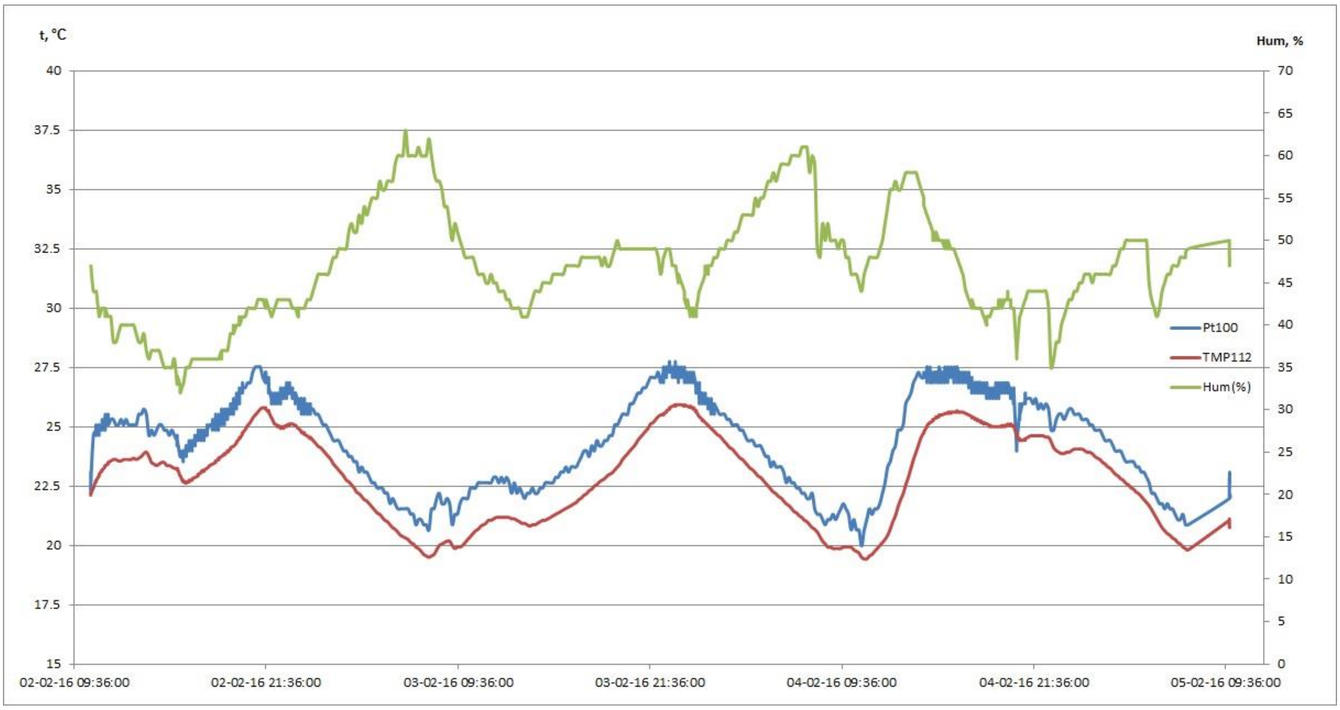

Figure 3. Experimental data

Although this internal sensor is recording temperature, its data is more valuable in term of logging microcontroller activity. As the graph on Figure 4 shows, the internal sensor indeed follows the trend line of the temperature (RTD's line shown here for reference), but the deviation is higher and accuracy is way lower. Interests here are the area of high disturbance, where the internal sensor data have big amplitudes. These periods actually corresponds to the timeframe when the device is under direct user control and works in high performance. The status log messages are shown on top of the graph and actually indicate the events like mode change and manual log requests. This effect on the internal temperature sensor is expected, as the microcontroller is running at full performance during user mode and generates more heat.

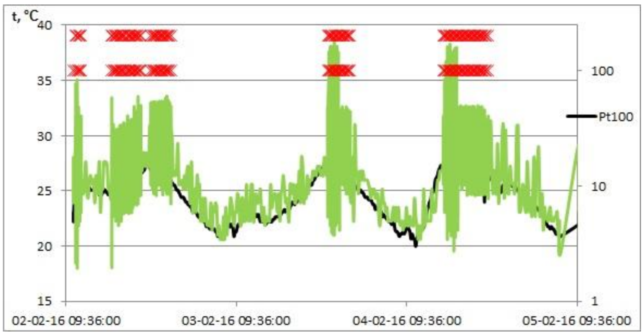

Figure 4. Status data

V. Conclusion

First prototype of the adaptive weather station was built and sent to Bulgarian Antarctic base on Livingston Island, during 24-th Antarctic expedition. The system was set in autonomous mode and left to collect data during winter season. The results are expected to be collected during 25-th expedition in the end of 2016.

For a future evaluation of the project in aspect of software environment is planned development of specialized online tool that will be able to transfer the data from the system through web application.

For the evaluation of the project in aspect of hardware design is planned development of a specialized anemometric system without moving components that will be capable of measuring high-speed winds in harsh arctic environment.

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VII. References.

[1] Guide to Meteorological Instruments and Methods of Observation - *WMO-No. 8* - 7th edition 2008 - www.wmo.int
[2] Ben-Ari, M., "Principles of Concurrent and Distributed Programming", Prentice Hall, 1990.
[3] TMP112 High-Accuracy, Low-Power, Digital Temperature Sensor - *SLOS887* – www.ti.com