Data Analysis and Improvement of Adaptive Weather Station for Work in Antarctic Conditions

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Abstract – **This paper describes the improvement and initial data analysis of adaptive weather station. The device relies on 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 analysed and visualized by specialized end-user software tools.**

Keywords – **Weather Station, Ultra-Low Power Management, Self-Monitoring, Data acquisition.**

I. Introduction

In order to support a research of Bulgarian Antarctic Expedition was requested to create an adaptive compact system that ensures all the necessary measurements to support experiments performed in real-time and able to autonomously provide series long-term measurements, by dynamically reconfiguring its working rate. First prototype was used by 24-th Bulgarian Antarctic Expedition.

Purpose of the current paper is to present improvements in the system used by 25-th Bulgarian Antarctic Expedition, and the data received during the active period.

Design and development of the adaptive weather station, calibration process, and initial experimental data are described in series of papers ([1], [2], [3]), thus here is provided just a brief description.

II. Design and Improvements

A. Hardware Changes

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. The system is equipped with two power sources – rechargeable accumulator to support routine daily and power demanding operations; and back-up battery to be used during long-term measurements, where accumulator capacity may not be enough.

The new version of the device is equipped with enhanced integrated Li-ion linear charger and system power path management device. Initial one was proved to have a design defect. New one allows faster charging of a high-capacity accumulator. In addition to the new charge controller is added companion DC-DC module, allowing battery charging to be done with high-voltage (up to 36V) power source (solar panels, accumulators, generators, etc.).

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 includes sensors and peripherals required for the operation of the station – temperature sensors, pressure sensor, humidity sensor, light sensor, and magnetic field sensor.

Original humidity sensor used by design (HDC1008) is replaced by enhanced version (HDC1080 [5]). New one has high accuracy (±2%) and better power management.

Pressure sensor is also replaced with more enhanced version (BMP180 [6]), for lower altitude noise and fast conversion time.

The sensor subsystem includes interfaces for anemometer [4], GPS module, accelerometer, and four expansion interfaces for adding additional sensor modules.

Fig. 1 shows the updated version of the adaptive weather station.

B. Firmware Updates

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

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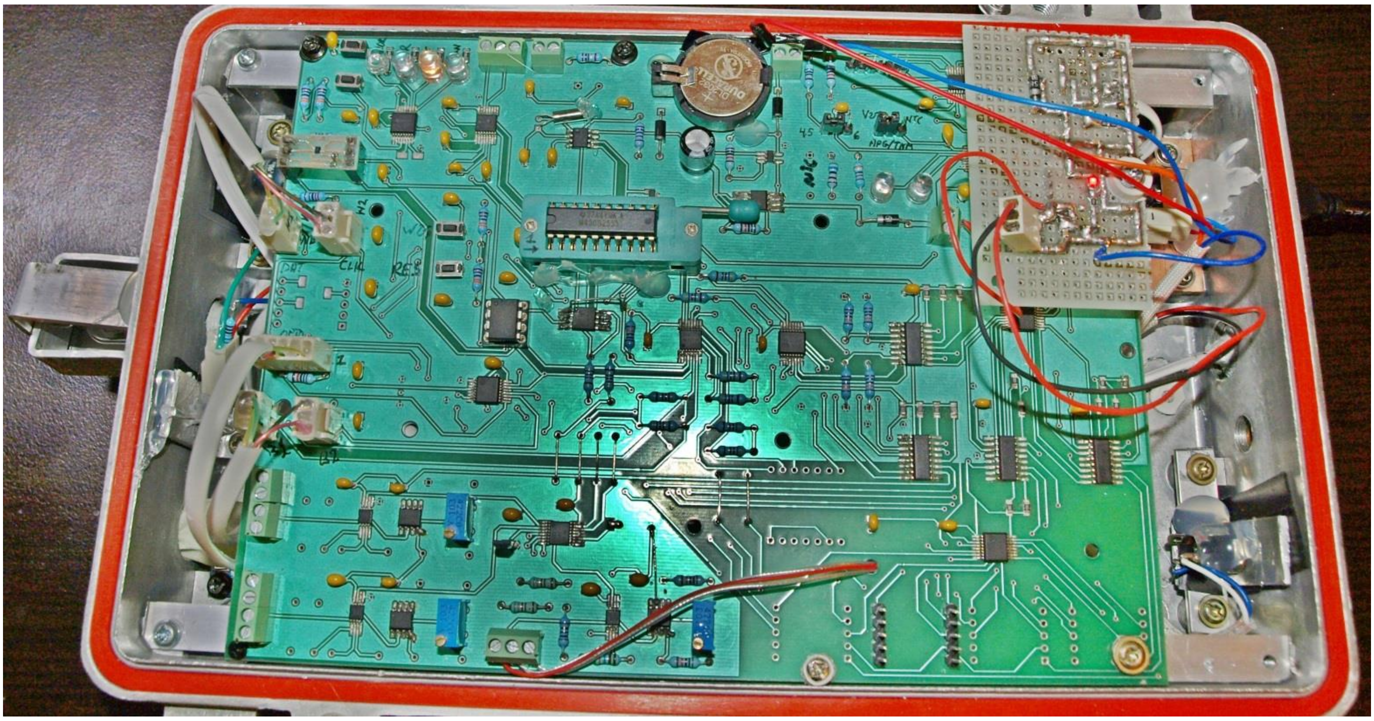

Fig. 1 – Evaluation board of the Adaptive Weather Station

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, watchdog (WDT) is responsible to monitor 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. New firmware version includes extended set of diagnostic codes, which provide more detailed information of diagnostic conditions.

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.

New version of the firmware includes update that allows this algorithm to save one additional scan data on every hour in additional data memory chip connected to sensor bus. This operation provides data and system operation back-up in case of main memory bus operation fail or main memory malfunction.

C. Other Improvements

During the development of this version of the device, several mechanical improvements are done.

Pt100 is now inside the box for protection and thermally connected to the box for better thermal stability.

Optical sensor is now integrated in special glass casing and aluminum shield.

USB connector, LED indication, wake-up button, high-power jack, humidity and barometric sensors are now secured inside the box, accessible through isolated on-box openings.

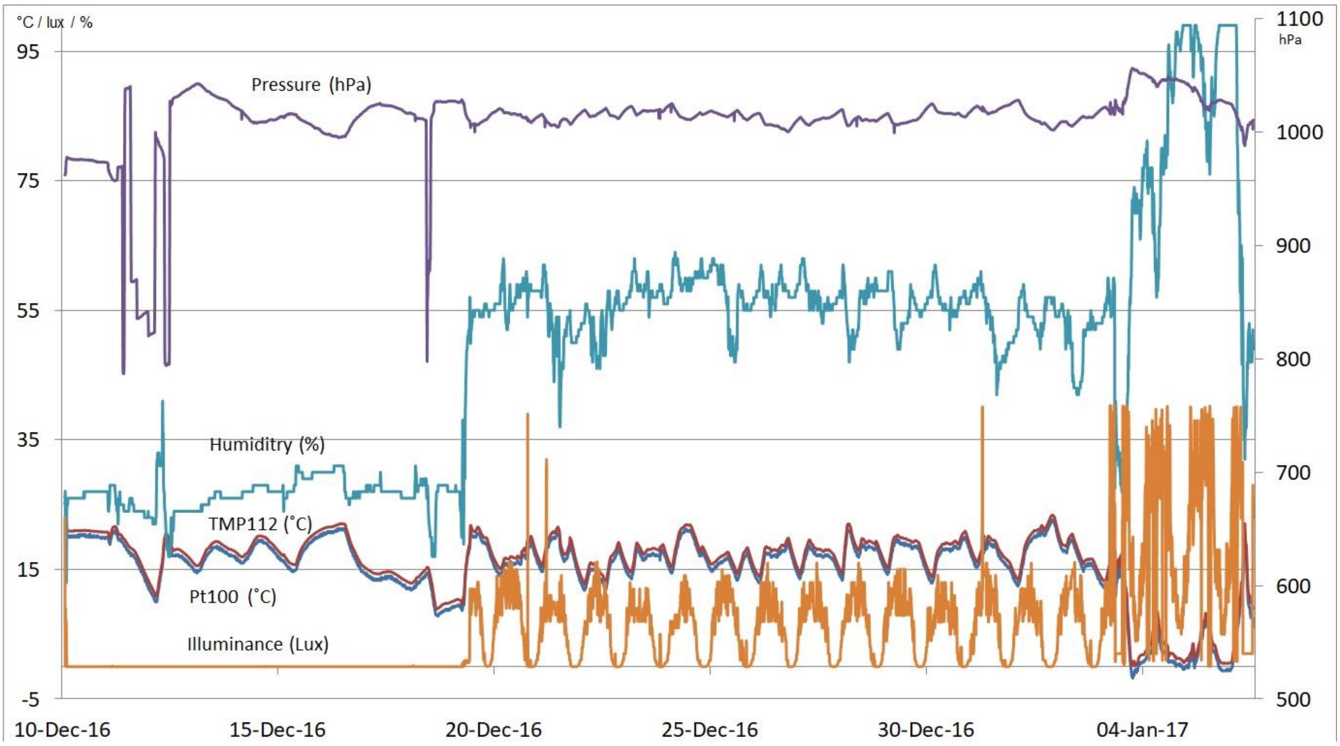

Fig. 2 – Initial Data from 25-th Bulgarian Antarctic Expedition

The computer application, designed to ease the work with the system, is also updated. New version includes several bug-fixes and new automation request mode. 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. Results

Fig. 2 presents the data collected during the active season of 25-th Bulgarian Antarctic Expedition. It contains three clearly defined regions of data.

First part is the transportation data. It is very easy to define this period as illuminance sensor is covered with a protection shell, thus it's data is pointing to zero. Specific drops in the temperature and pressure clearly define plane flights.

Second part is a period of real-time measurement used to support a research work. System is located near the rest of research equipment and provides reference data for it. Period of this time is about two weeks, which is clearly visible from the daylight oscillations of the illuminance 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, [7]. The graph of the platinum RTD is much more stable in comparison with the previous version (see [3]), which is in direct result of the improvements of this version of the system.

Third period corresponds to the preparation of the system for the winter season. It is moved to new location and secured to a wind-turbine mast in order to withstand to the harsh winter conditions. This change is clearly visible from the highest illuminance values. Daily cycles are still good outlined. Fig. **4** provides more detailed view of this period.

This part shows a sudden change of the weather – lower temperature, high humidity, and higher pressure. Data trends of the different parameters show a good correlation, which is expected and confirms data reliability.

There are some disturbances in the illuminance, which are very sharp and presume to be indication of a human interaction with the system. This assumption is also confirmed from the correlation between those disturbances and the intensity of the data log as shown on Fig. 3.

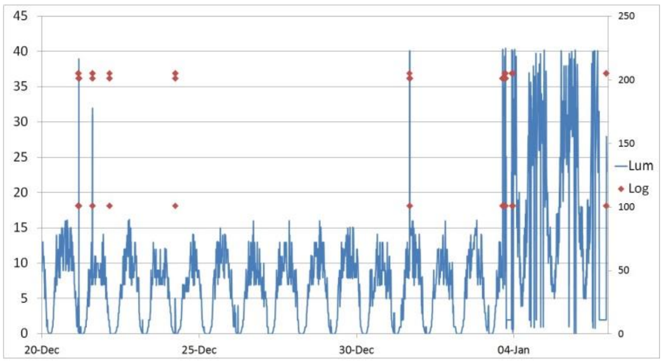

Fig. 3 – Data log vs Illuminance

In addition to the presented data, Fig. 5 presents the data from the magnetic field sensor. This sensor is a chopper-stabilized Hall IC with great sensitivity stability over temperature. Its main purpose is to detect strong magnetic fields that may affect the field tests or measurements.

As the diagram shows, there are no such events appeared in this period, except some small deviations during human interaction as seen from the correlation with data log.

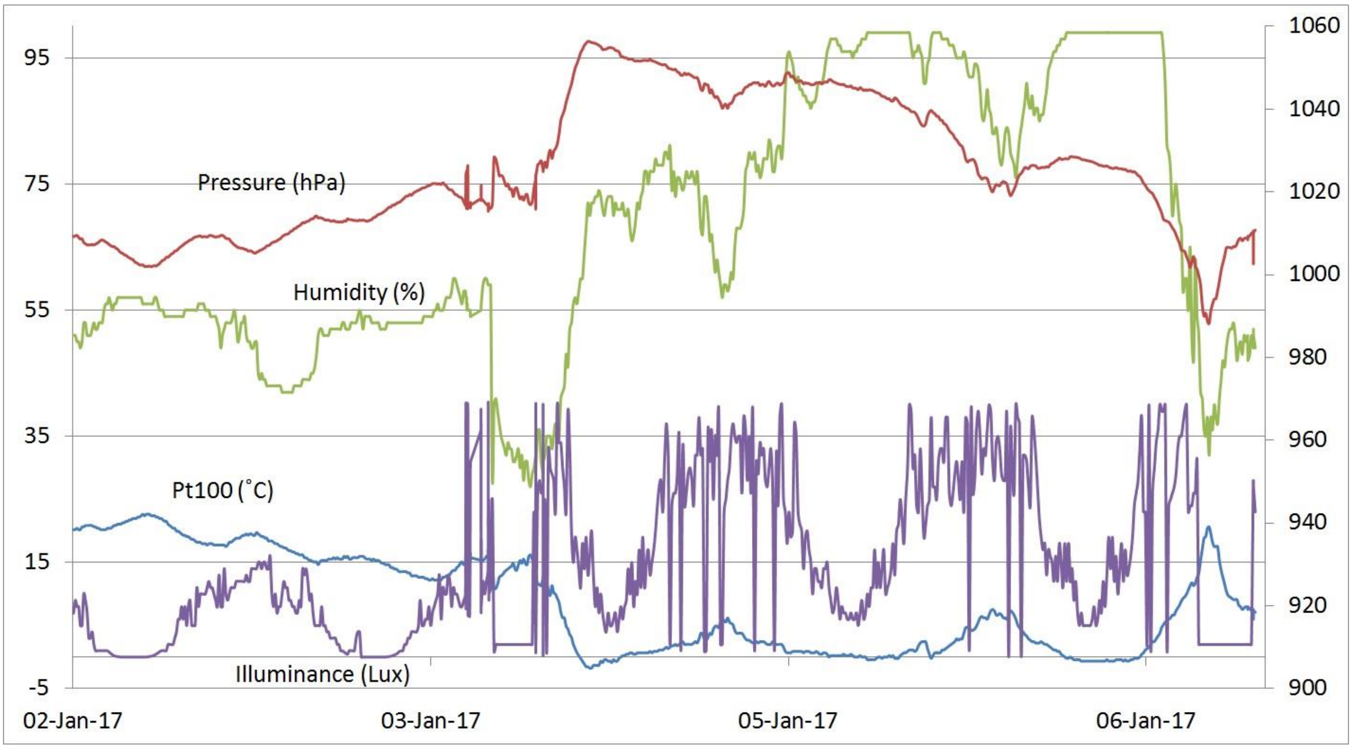

Fig. 4 – Detailed data from the third period

Interesting here is that even thought this sensor is not designed to accurately measure Earth's magnetic field, the data is in good correlation with it, as seen from the trend-line on the diagram.

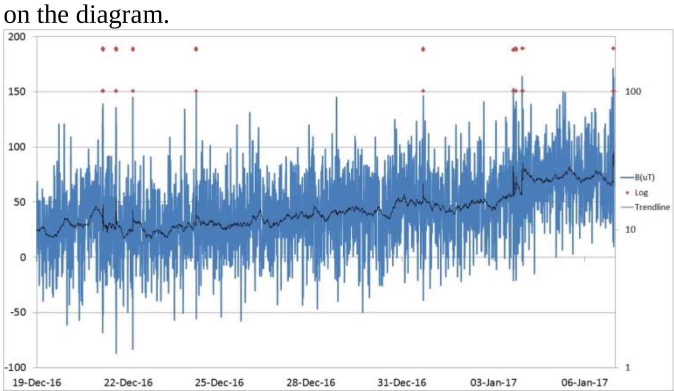

Fig. 5 - Magnetic field data

IV. CONCLUSION

Bulgarian Antarctic Expedition reported there was a massive storm during last winter season, which cause lots of damage to the equipment and buildings, including the Adaptive Weather Station. The remains of the system will be delivered later this year.

Specialized strain gauge anemometric system is under development [4], as an evaluation of the project in aspect of hardware design.

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.

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