Development of Software Environment for Adaptive Weather Station with Reduced Power Consumption

Dian Iliev*, Vassil Gourev, Mityo Mitev***

* Technical University of Sofia, Department of Electronics and Electronics Technologies, Faculty of Electronic Engineering and Technologies, 1000 Sofia, Bulgaria,
8 Kl. Ohridski Blvd., e-mail: d.m.iliev@gmail.com

** Sofia University "St. Kliment Ohridski", Faculty of Physics, 5 J. Bouchier Blvd, 1164 Sofia, Bulgaria,
e-mail: gourev@phys.uni-sofia.bg

***Abstract**. This paper describes the design of the bundled software packages within adaptive weather station. The device is based on an ultra-low power micro architecture and adaptive power distribution mechanism. The embedded firmware allows the device to be 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.*

***Разработване на Програмно Осигуряване за Адаптивна Метеорологична Станция с Понижена Консумация (Диан Илиев, Васил Гурев, Митьо Митев).** Настоящият документ представя дизайна на програмното осигуряване за работа с адаптивна метеорологична станция. Устройството е основано на свръх-ниско консумираща микроархитектура и адаптивен механизам за електроразпределение. Вграденият фърмуеър позволява на устройството динамично да се пренастройва за работа във високо производителен режим на работа в реално време и под директен операторски контрол; и в ниско-консумиращ, напълно автономен, саморегулиращ, режим на дълговременно измерване. За удобство събраните данни за параметрите на околната среда първоначално могат да се анализират и визуализират от специализиран потребителски софтуер.*

Introduction

Weather stations are facilities with instruments and equipment for measuring atmospheric conditions to provide information for weather forecasts and to study the weather and the climate.

For studying the climate changes is necessary to analyse data from long-term measurements of the environment parameters (like temperature, barometric pressure, humidity, etc.). In correspondence with the requirements of the World Meteorological Organization [1], those measurements are done three times a day, with respect of the Sun position per each whether station. The data from the daily measurements are then logged in sets of different time frames (3 months, 6 months, year, etc.) and analysed to define the tendencies in the climate changes.

The weather stations are often conveniently located in easily accessible locations, and the data could be collected daily. However sometimes scientific interests are remote regions without sustainable access (unattended areas). In such cases, it is necessary to use a sophisticated apparatus capable of self-configuring, data logging and performance control, taking into account their power distribution and working conditions of the respective area.

For a number of activities (aviation, shipping, scientific researches, etc.) measurements are 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. 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.

With records since latest 50s of last century showing rise in average temperature of the atmosphere and ocean on Earth, and the predictions for the possible consequences if these trends in climate change preserve, more attention is paid to strict measurement of environmental parameters, globally and continuously. But the ground control stations designed for this purpose are often too expensive and highly power consuming to be installed permanently in remote areas. Therefore reporting of climate changes on these sites often rely on satellite measurements – primary temperatures. However these measurements are not directly comparable to the quoted above, since it is a skin temperature deduced from a satellite-measured upwelling radiance, rather than a thermometer-measured temperature of the air 1.5 m above the ground surface.

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 and able to autonomously provide series long-term measurements, by dynamically reconfiguring its working rate.

System 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.

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, an additional external watch-dog subsystem, 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 and the additional watch-dog subsystem, though defined as control devices, in fact belong to the PRCM, as they ensure the continuous operation of the station. RTC also 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 3 main groups.

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 third group of sensors is a low-priority and high consuming additional and synchronizing systems - GPS, wind sensor and sensor for thickness of the snow cover.

The GPS subsystem is provided as synchronization module for time adjustment. GPS as well as Anemometric module are intended to operate primary in serviceable period with available power supply, as their power consumption is very high.

Sensor module for reporting the snow cover thickness is designed to work during unattended period of the system. Therefore, it is planned to provide data once a day and to work in very short interval of time. If a shortage of energy resources appears - use can be further reduced by the system.

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.

Software Environment Design

Based on the above requirements and characteristics, the weather station software is developed on the basis of two main levels:

- *Firmware*
- *PC Application*

Firmware

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.

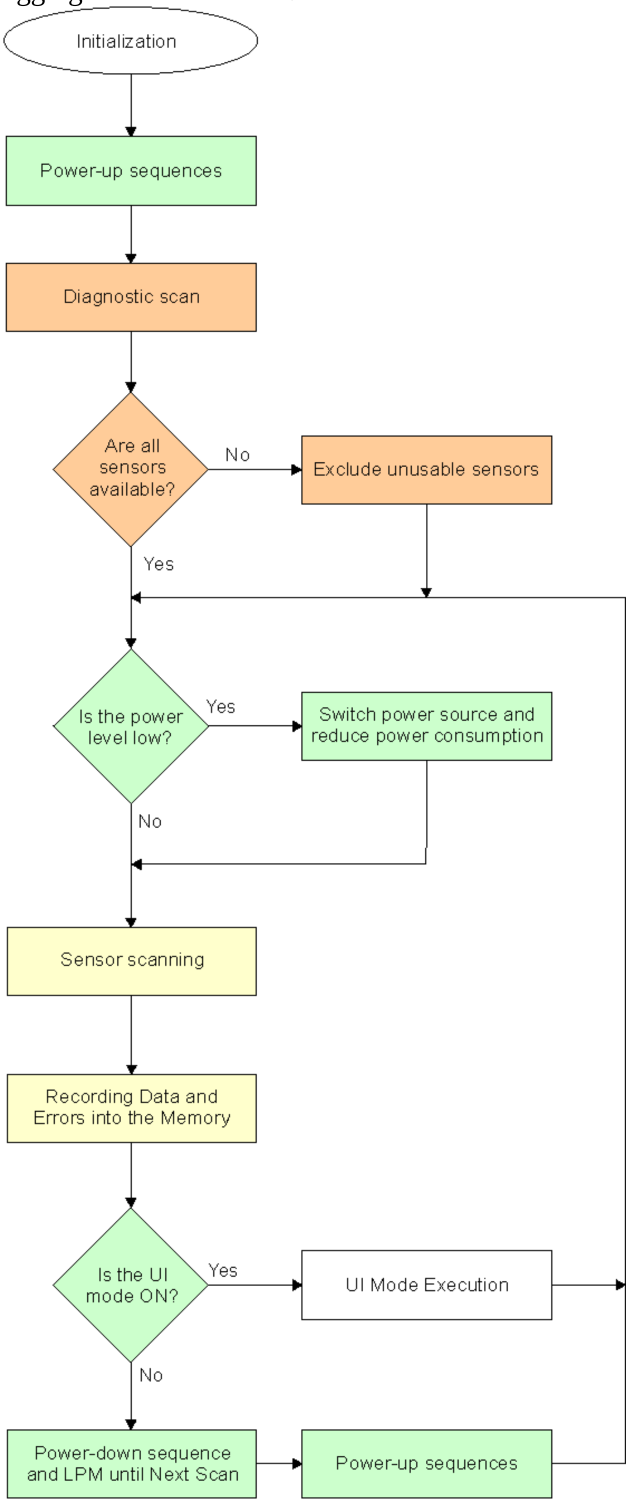

Figure 1. Block Algorithm

Figure 1 presents the simplified block algorithm of the firmware. 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.

Figure 2 presents the generic block diagram of the sub-algorithm that serves PC application's requests during UI mode.

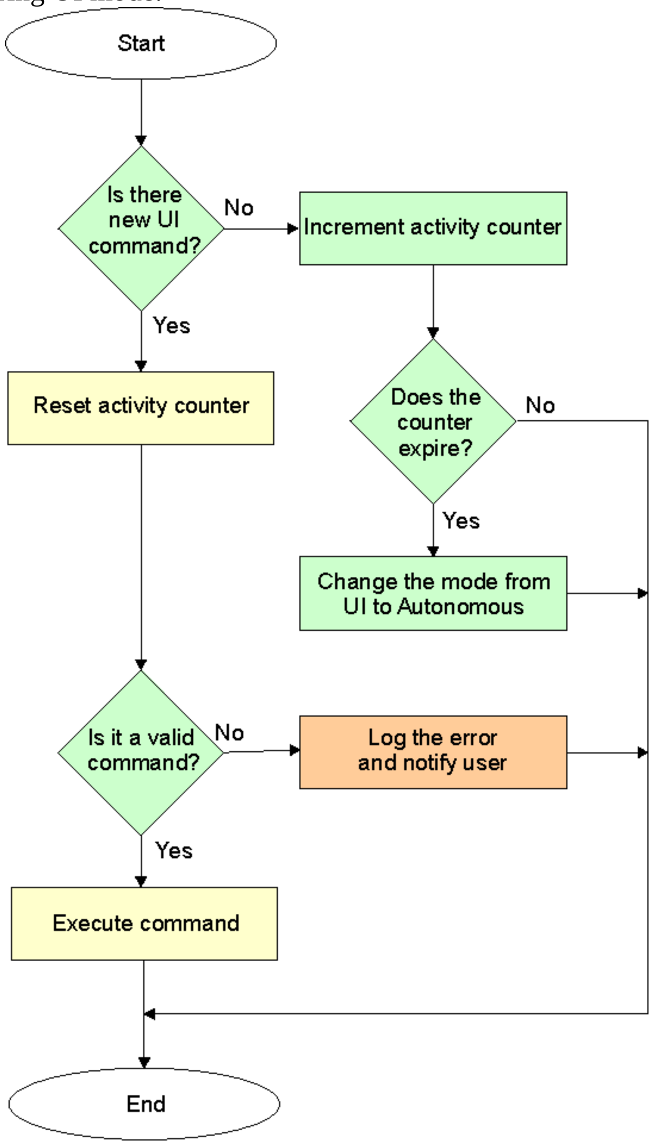

Figure 2. UI Sub-algorithm Block Diagram

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.

Figure 3 presents the summary diagram of computer application for work with the station.

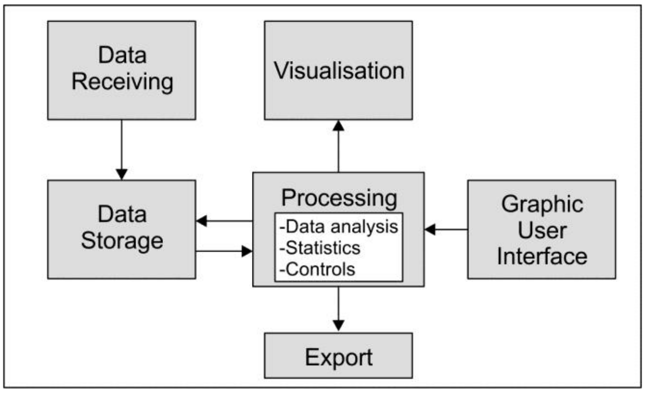

Figure 3. Block Diagram of the PC Application

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.

UI has three components – Control panel, Data window, and Status bar.

The control panel allows easily setting of various parameters – configuring the communication port settings, export file type, data type (Row or converted), refresh rate, and mode. It also has a quick command option for inserting reference data, RTCC synchronization, and clearing embedded memory.

Data window allows the measured data to be presented run-time, and analyzed by the operator in the moment of the measurement. Depending on the required control type, the data can be presented in list as values, or graphically in diagrams.

Status bar provide system information that affect system performance – battery voltage levels, available memory, refresh rate, and error codes in case such appear.

The user interface (UI) is presented on Figure 4.

Conclusion

Ground-based weather stations are among the most important tools for monitoring climate changes and the impact that these changes have on the environment. Of great importance is the collection of as larger as possible amounts of data from all over the world. The main problems in the construction of such a network of ground-based instruments are the size and the cost of the stations, and their use is additionally limited by the specific functions they are initially designed for.

Building cheap and adaptive compact stations could significantly ease the process of collecting data in remote areas, and at the same time offers the

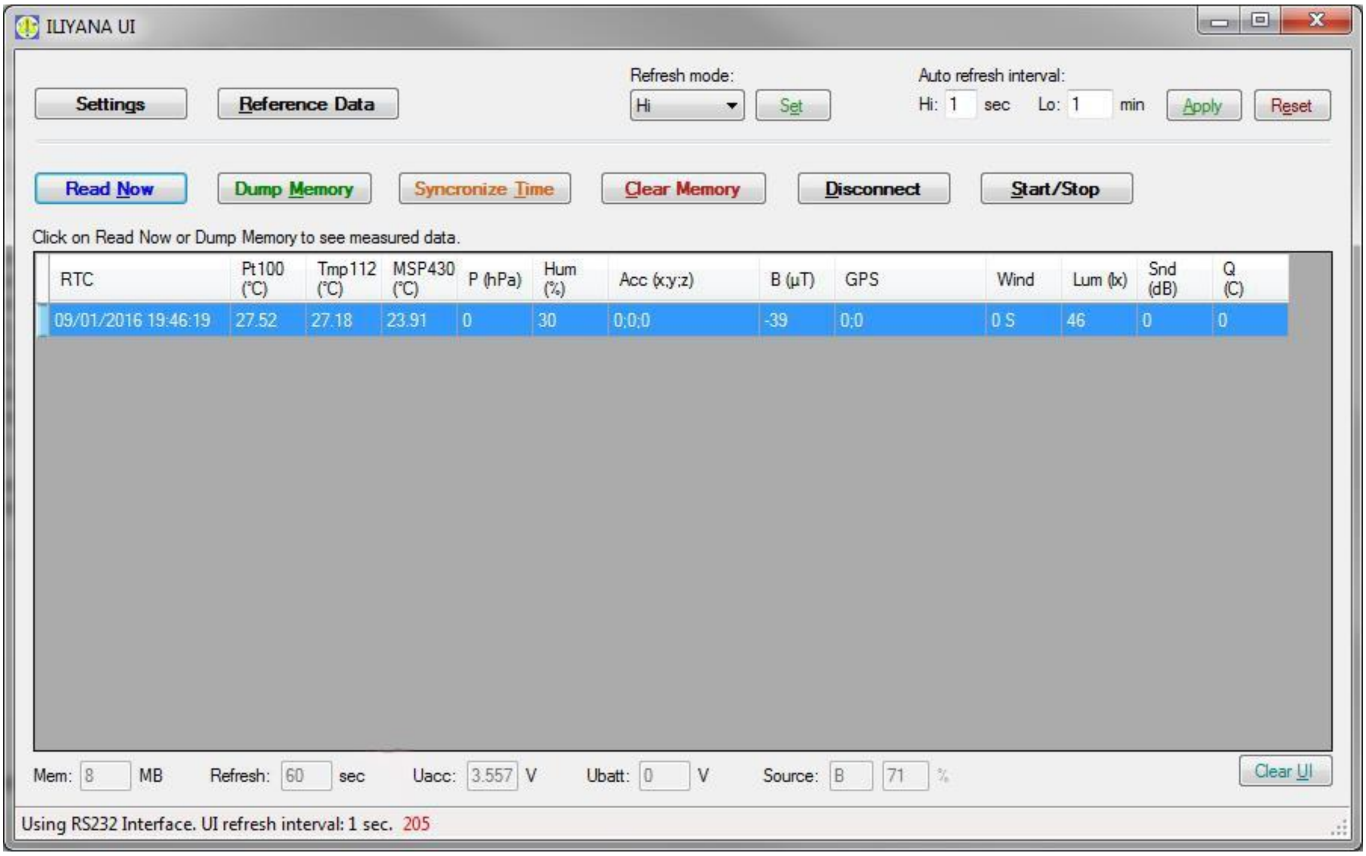

Figure 4. User Interface of the PC Application

possibility to use them as reference tools in other studies.

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 environment.

Acknowledgements

The present research is supported by the Bulgarian National Science Fund under Contract И02/11/2014.

The authors would like to express highest gratitude to S. Chakalov, V. Popov, and Ts. Popova for their invaluable input.

REFERENCES

[1] Guide to Meteorological Instruments and Methods of Observation - WMO-No. 8 - 7th edition 2008 - www.wmo.int