Design of Monitoring and Data Acquisition System for Environmental Sensors

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Abstract—In this paper description of monitoring and data acquisition system for environmental sensors is described. Device can be used as standalone device but it also can be connected to the PC through serial communication. Color display is used for local graphical presentation of sensors readings while for online PC analysis specialized application was developed. Application provides alarm occurrence log with e-mail notifications. System is scalable and easily can be expanded with new sensors. System verification was done with SHT11 measurement device and system worked stable and reliable.

Keywords-data acquisition, environmental sensors, monitoring systems, relative humidity and temperature measurement.

I. INTRODUCTION

Real time monitoring and data acquisition have important role in industry but also in everyday life. For example, in literature can be found description of systems used in pollutant detection [1], storing and transportation of medicinal products [2], clothes and books storing [3], food transportation [4] and greenhouses air quality monitoring [5].

In last few decades attention is especially focused on environment (air, soil and water) pollutant monitoring. These systems require sensing elements with high accuracy, selectivity and sensitivity. Data acquisition in these systems is also very important and systems have to be able to store data in long time period (in some applications even more than decade) for analysis and predictions what can be expected in future. Collecting of measurement results must be done with appropriate sampling time and reliable alarm system.

Sensors developed within SENSEIVER project [6] are characterized and mostly tested in laboratory [7]-[12]. Sensors showed excellent characteristics so they can be implemented in the field in real time pollutant monitoring systems. That means that specific equipment needs to be developed for in the field data acquisition [13]-[20] and material characterization [21]-[23].

Therefore in this paper is presented study on such data acquisition system with real time monitoring and online analysis capabilities. System presents improved design of systems reported earlier [18]-[24].

In the first version of the system [18], only local monitoring and offline analysis on PC were possible but that system made core for further upgrades. System was powered by rechargeable batteries with it's own monitoring system and charger unit. Device had two modes for data collecting: continuous and manual. In continuous mode, the device collected data from sensor automatically with defined sampling time and stored it on micro SD card. In manual mode, the user had an option to manually choose the moment of recording the results. Created report of measured values with date and time stamp was stored in format which is compatible with MS Excel. Device had keypad with two navigation and two confirmation keys so full hand-held configuration and operation capabilities were possible. Connection between PC and device was available through serial communication interface: RS-232 or USB cable. Device also had alphanumeric LCD for displaying results and configuration in the field. System verification was done with SHT11 measurement device.

All good features of system presented in [18] are kept and implemented with optimization regarding dimensions and power consumption in new redesigns of the system. In every new design additional option was implemented. For example, in [19] real time analysis was added with PC application developed in LabVIEW. System was later improved also with embedding a PC based web server into the microcontroller [20].

Main contribution of work presented in this paper is adding local real time monitoring with color display and new PC application developed in Microsoft Visual Studio. Microsoft Visual Studio was chosen because it is now free for usage even in systems with commercial purposes [24].

II. DEVICE STRUCTURE

Proposed structure of redesigned system for monitoring and data acquisition of environmental sensors is presented in Fig. 1. Main hardware improvement is replacement of LCD display used before [18]-[20] with TFT color display [25] which allows realization of local system for real-time monitoring and data acquisition with graphical analysis of obtained results. New system also can be USB powered and has smaller dimensions.

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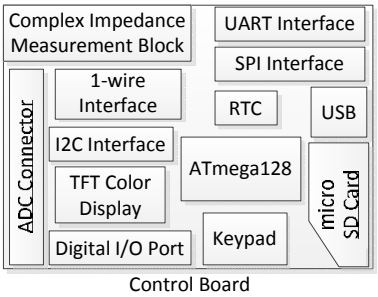


Figure 1. Block-scheme of proposed device

The main part of the Control board is microcontroller AVR ATmega128 [26] that interfaces with user via display and keypad. Other peripherals on the board are micro SD card, real time clock DS1307 [27] and TFT color display.

Measured values of relative humidity and temperature are stored on 2 GB micro SD card. FAT16 file system is used to allow manipulation of file with results on PC and off-line processing. The main advantage for using a micro SD card as data storage system is the ease of transferring data directly to other electronic devices which support the FAT format as a file system.

Real time clock DS1307 is used to provide time measuring. Time and date values are used for presentation on display and for additional information for every result in report stored on micro SD card.

A thin-film-transistor liquid-crystal display (TFT LCD) is a variant of a liquid-crystal display (LCD) that uses thin-film transistor (TFT) technology to improve image qualities such as addressability and contrast. A TFT LCD is an active-matrix LCD, in contrast to passive-matrix LCDs or simple, direct-driven LCDs with a few segments. TFT LCDs are used in appliances including television sets, computer monitors, mobile phones, handheld video game systems, personal digital assistants, navigation systems and projectors [28].

Keypad with two navigation and two confirmation keys is connected to the Control board to ensure easy manipulation through menu system for configuration and measurements. Menu system is based on finite state machine and it can be accessed by external keyboard with two navigation keys (Up and Down) and two confirmation keys (OK and Esc).

The Control board also has connectors for:

- analog to digital conversion (8 inputs),
- 8 digital general input/output pins,
- one-wire devices interface,
- complex impedance measurement,
- UART interface,
- I2C interface and
- SPI interface.

Connector with 8 digital input/outputs ensures that sensor device SHT11 [29] can be attached directly to the microcontroller. The sensors integrate sensor elements plus signal processing and provides a digital output so no additional calibration is needed. SHT11 is a Sensirion's family of surface mountable temperature and relative humidity sensors. Relative humidity is measured by capacitive sensor element while band-gap sensor is used for temperature measurement. The SHT11 has operating range of temperature between -40 and +123.8 °C and range for relative humidity between 0 and 100 %RH.

A hardware outcome of Control board with attached SHT11 sensor is shown in Fig. 2.

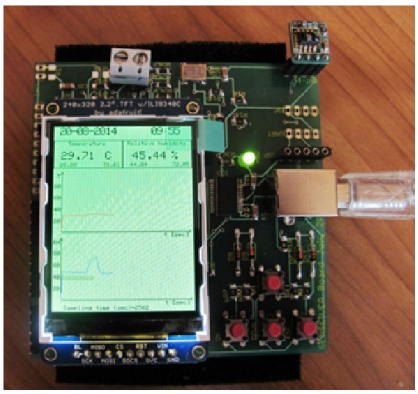


Figure 2. A prototype hardware outcome of Control board with connected SHT11 sensor

Main purpose of developed system presented in the Fig. 2 is to be used as a standalone device for real time monitoring and graphical presentation of obtained results in the field. But USB power supply option can also be used to provide real time connection of the board with PC and more detailed analysis of obtained results. For example, as was reported earlier in [25], LabVIEW can be used for PC data acquisition. In this work PC application was developed in Microsoft Visual Studio.

In Fig. 3 main screen of PC application for temperature and relative humidity monitoring is presented.

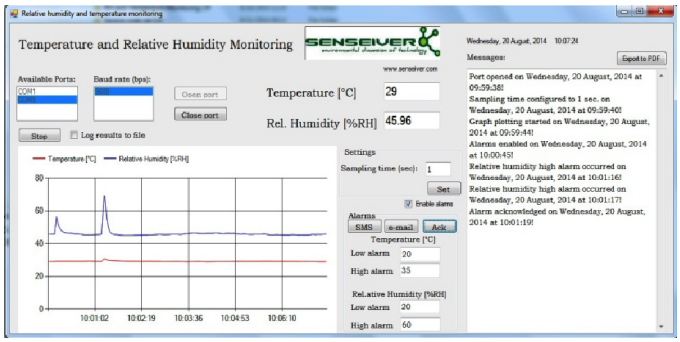


Figure 3. Main screen of the PC application

As can be seen from Fig. 3, PC application consists of few main blocks:

- Communication
- Sampling time configuration
- Alarms
- Graphs
- Logging to file

- Messages log

Communication. User can choose communication PC port which is connected to Control board. Baud rate is fixed and can not be changed because it is set to 9600 bps in the microcontroller program.

Sampling time configuration. After the Control board is connected with PC, user has to define sampling time between measurements. This value can be changed during operation.

Alarms. User can set alarm values for temperature and relative humidity. These values can be easily changed during operation and when any alarm occurs in message log that information is added. User has to acknowledge alarm with "ACK" button. If alarm is acknowledged but actual value is still above defined limit, appropriate filed will remain to be red but no new messages will be added in message log. There are also two buttons for alarm notifications: SMS and e-mail. SMS notification is not yet implemented because SMS gateways were not available in Serbia but with additional hardware (GSM modem) this can be done easily. E-mail notification is implemented and user can choose if e-mail should be sent by clicking to button "E-mail". Example of created e-mail message is presented in Fig. 4.

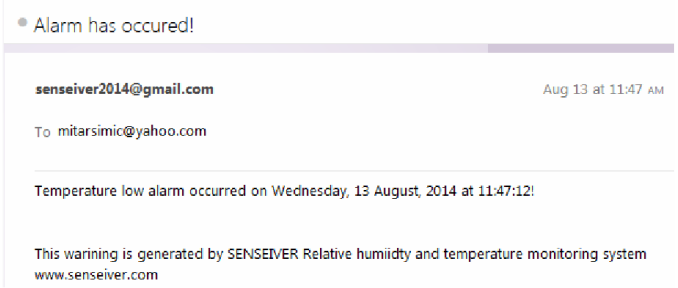


Figure 4. Example of generated e-mail alarm notification

Graphs. User has option to start and stop real time plotting of obtained results in any moment. Time stamp is added on x-axis.

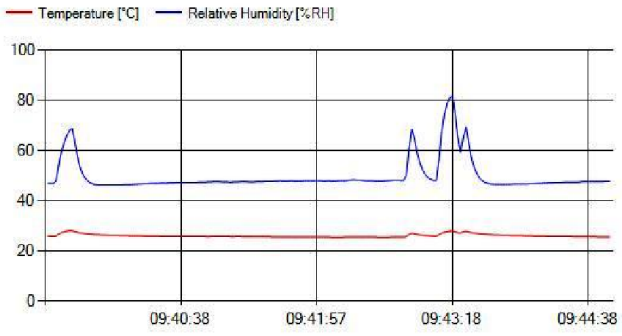
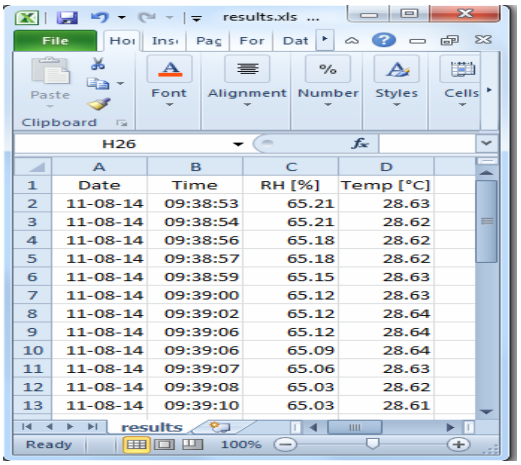


Figure 5. Examples of created graphs

Logging to file. The Control board performs storing of measurement results on the micro SD card, as noted before, but sometimes option for logging on PC hard drive can be useful and because of that it is implemented. In every moment user can disable logging to file and later enable it again. Example of created report is presented in the Fig. 6.



	A	B	C	D
1	Date	Time	RH [%]	Temp [°C]
2	11-08-14	09:38:53	65.21	28.63
3	11-08-14	09:38:54	65.21	28.62
4	11-08-14	09:38:56	65.18	28.62
5	11-08-14	09:38:57	65.18	28.62
6	11-08-14	09:38:59	65.15	28.63
7	11-08-14	09:39:00	65.12	28.63
8	11-08-14	09:39:02	65.12	28.64
9	11-08-14	09:39:06	65.12	28.64
10	11-08-14	09:39:06	65.09	28.64
11	11-08-14	09:39:07	65.06	28.63
12	11-08-14	09:39:08	65.03	28.62
13	11-08-14	09:39:10	65.03	28.61

Figure 6. Example of created report

Messages log. All operations such as connecting/disconnecting from device, enabling/disabling of alarms or graph plotting, changing of sampling time value are logged and presented in right corner of PC application. There is button "Export to PDF" which generates report of logged activities in PDF file format. Example of created report is presented in Fig. 7.

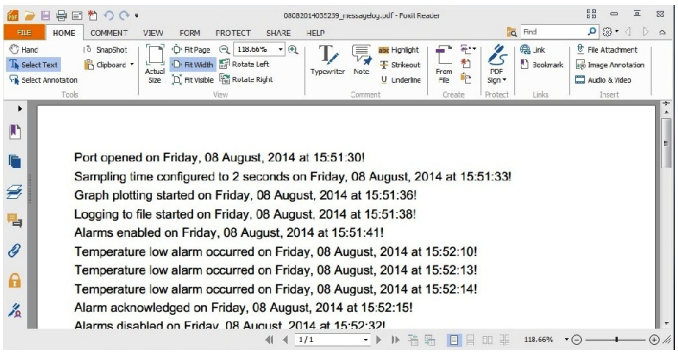


Figure 7. Example of message log

A hardware outcome of complete system is shown in Fig. 8.

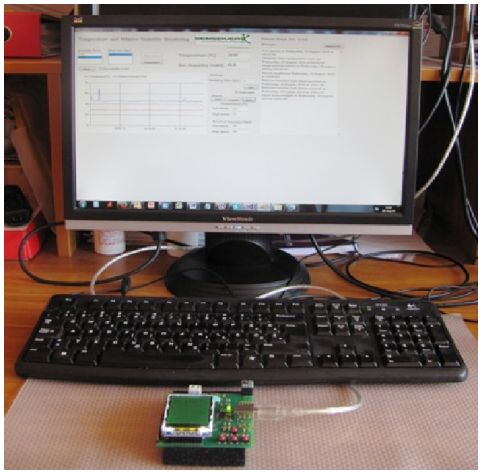


Figure 8. Hardware outcome of device for temperature and relative humidity monitoring

III. CONCLUSION

The main task in this study was to provide direct access to the sensor readings in real time. Device can be used as standalone or with PC connection. Local presentation of results is performed on color display with graphs and information about minimum and maximum measured values. If device is connected to the PC, more detailed analysis is possible with PC application.

The designed system was tested with SHT11 as measurement device under different conditions and in all tests the system worked stable and accurately. Main application of developed system is to be used for monitoring and data acquisition with environmental sensors developed within SENSEIVER project.

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