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Education set for collecting and visualizing data using sensor system based on AVR microcontroller

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Abstract: *This article presents the issues of the wireless sensor measuring systems design which might be used in education process of computer science faculty. The work shows the integration of a simple measuring system, data management system, visual system and the hardware. Education set is designed to consolidate knowledge in many fields of computer science and the interdependence between them, as programming techniques, database, Web server, communications protocols, software and hardware. Presented measuring sensor system consists of a number of measurement nodes, whose role is to provide information about certain desirable characteristics, warning against natural hazards or violation of the physical safety. An important part of the sensor system is a measuring subsystem and the collecting measurement data subsystem. The article presents the temperature measurement sensor system concepts and measurement data storage and visualization methods.*
Keywords: *microcontrollers AVR, sensor, wireless sensor networks protocols, measuring system.*

I. Introduction

The emergence of new communication technologies, especially the wireless ones, radically changed the approach to the design and construction of the distributed control and measurement systems. Certain examples of these technologies are definitely wireless sensor networks, consisting of autonomous sensors, distributed in space, capable of monitoring physical parameters (temperature, sound, vibration, pressure, motion, etc.). This allows for permanent recording, controlling specific tasks and processes, and responding appropriately to events as they happen.These systems, used with adequate data management system, allow automatic collection and wireless transmission of data to a central location. Moreover, this makes possible to build a self-adapting system, which, depending on the time or other factors can help in saving energy such as heat or electricity in public buildings. In addition, low-power broadcast systems create a new area for the implementation of a wireless measurement systems. The future is focused on the gradual replacement of wired systems with wireless solutions, which are more comfortable. The new technology is gaining recognition not only in the various measurement systems, but in virtually every field of human activity [1, 2, 3, 5].

To create presented system engineer must have knowledge about current programming techniques (C++, Java, PHP, SQL), database management, ability to create and configure the Web server by choosing the appropriate communication protocols and their software for specific microcontrollers, sensors and working conditions.This article describes briefly mentioned elements.

II. Wireless Measuring System

This paper presents the conception of an education set used for support the computer science students learning process. The education set presents the wireless measuring system consisting of autonomous sensors based on wireless communication. The microprocessor was used to construct the measurement node, which executes calculations and puts control functions. The measuring system was build based on ATMEGA16L microcontroller, RFM12S transmitter and DS18B20 temperature sensor. The data coming from measurement node are routed directly to the receiver – the gateway. Wireless communication is achieved through RFM12S transmitter system. This requires a suitable configuration and the appropriate transmission parameters.

The microcontroller used in every node of designed devices is Atmel AVR (Fig. 1). AVR is a family of 8-bit microcontrollers based on RISC (Reduced Instruction Set Computer) schemeprocessor and Harvard architecture principles. The characteristic feature of this architecture is the separation of the memory address space of the program and memory, obtained through the use of separate address bus. Systems belonging to the RISC processors group are characterized by a reduced list of commands and high computing performance (most commands are executed in one clock cycle). In addition, AVR microcontrollers have implemented a number of data registers, which can perform storage functions during the execution of arithmetic and logical operations. This solution minimizes the number of internal messages between registers, thereby increasing the program execution speed [4, 10, 12].

The stages of software development can be divided into three phases: creating the source code, compiling the source code and loading the program into memory. First phase begins from selecting the programming language. AVR features make it ideal to use high-level programming languages (such as C/C++, Java), so the C language was chosen for measurement nodes software [6, 11].Characteristic properties of the 8-bit RISC processing unit, reprogrammable flash memory and high-level programming language techniques allows the extensive use of microcontrollers in many functional solutions. The measurement node will be reading and transmitting the collected information to the gateway. The parameters of the node incorporates an ATMEGA16L microcontroller was presented in [12]. An important element used for the construction of the sensor node is RFM12S radio module, manufactured by HOPE RF [14]. It is used as a transmitter and receiver, working in one of three possible radio bands: 433 MHz, 868 MHz or 915 MHz. Using one of these frequencies allows broadcast without special licences. Radio communication performs FSK modulation or FM modulation for digital signals (carrier frequency is changed at constant signal amplitude). Radio module has implemented the PLL (phase locked loop) and automatic frequency control, so there is FSK modulation with continuous phase (CPFSK) causing rapid disappearance of the signal spectrum [14].

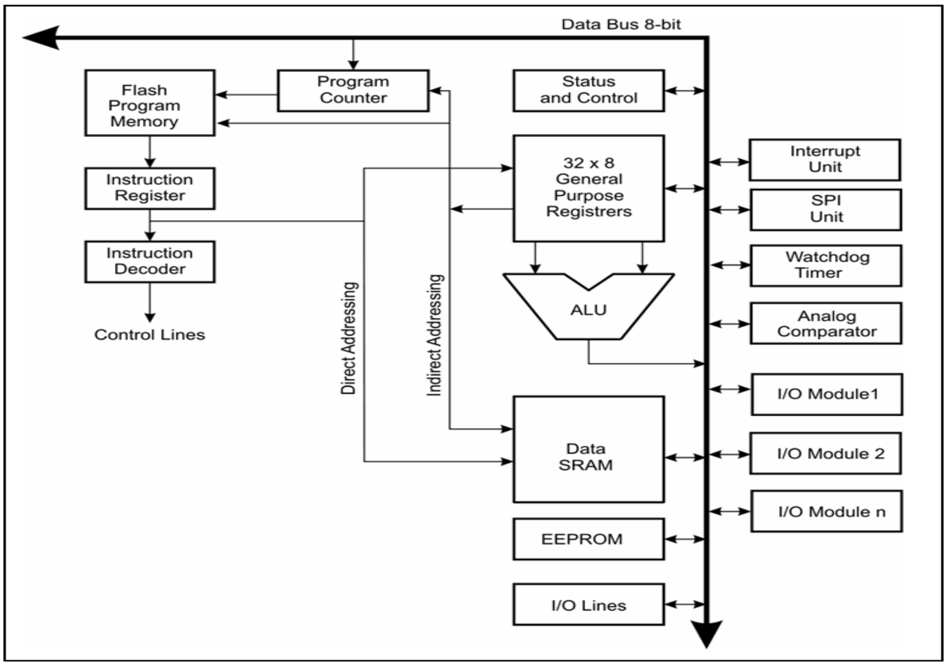

Fig. 1. The block diagram of the AVR architecture [12]

The antenna determines the range and quality of transmission. The specificity of sensor networks enforces the use of omnidirectional antennas. The use of quarter-wave length wire (82 mm for 868 MHz) provides desirable characteristics and good transmission parameters [13]. Module parameters are set by software using the SPI interface of microcontroller. SPI serial bus allows synchronous data transfer between the microprocessor (master unit) and peripheral circuits (slave) in duplex mode. There are two data lines in the interface: MOSI (Master Output Slave Input) – data from master to slave system, MISO (Master Input Slave Output) – data from slave to host system. The third line is SCLK (Serial Clock output from master), used to synchronize transmission, and the fourth line is SS (Slave Select), used for slave device selecting [9, 13].

III. CONSTRUCTION OF THE MEASUREMENT NODE

Measuring sensor collects data describing ambient temperature. It can also perform a number of additional features, however it can have a significant impact on the energy consumption of a whole system. The device transmits data or control commands wirelessly to the master node. Temperature measurement is performed based upon the DS18B20 module, which is a digital thermometer with programmable resolution, manufactured by Dallas Semiconductor. The main features of the DS18B20 are mentioned in [7,8, 9].This kind of a system is pretty popular thanks to the simplicity of the connection to the microcontroller (one I/O line is used) and digital reading of the temperature. With these features it is possible to apply these systems with most microcontrollers having one free digital line. The use of 1-Wire bus also allows to connect several sensors (thermometers) to one microcontroller input line. The service of the system is limited to the correct implementation of 1-Wire operating procedures and an appropriate interpretation of the results.

1-Wire interface is used to transfer data between the master device (microcontroller) and peripheral devices (such as sensors, SRAM and EEPROM memory). Communication takes place in both directions, using just one signal line. Data exchange takes place in four phases: initialization (reset interface), send (write) zero, send (write) one, read bit. Initialization begins from sending reset signal (from 480 to 960 µs), which switches the microcontroller into the receiving state. Peripheral device waits from 15 to 60 µs and sends the presence pulse, lasting from 60 to 240 µs. This sequence allows the detection of the connected systems. Transfer of information to the peripheral device is performed by sending over the low-level pulse of a suitable length , thus defining the logic states “0” and “1”. Low state is generated with a pulse length of 60 to 120 µs, pulse length from 1 to 15 µs corresponds to the logic one. When reading the data, master unit generates a pulse lasting from 1 µs to 15 µs, then returns to the high state on the data line. If the slave device sends a logical one, it leaves a high state on the line. Otherwise, if zero is broadcast, it shorts the data line to ground for 60 µs [8, 13].The logical structure of the DS18B20 is shown in Fig. 2. 64-bit ROM contains a unique unit address. Scratchpad has a 2-byte register that contains the value passed by temperature sensor. Additionally, it provides access to the compare registers (TH and TL) and configuration register, which can be used to set the resolution conversion of temperature value (9, 10, 11 or 12 bits). The default setting is 12 bits.Conversion between the USART interface (microcontroller) and USB interface is based on FT232RL chip, produced by FDTI. The two-way USART interface (integrated into the microcontroller) implements communication between computer and the microcontroller. This allows for advanced configuration and easy operation, while keeping CPU free. DS18B20 (in sleep mode) receives a command to convert temperature value Convert T (0x44) from microcontroller. After measurement, data are written into 2 bytes of register memory, then the unit switches back to the sleep state.

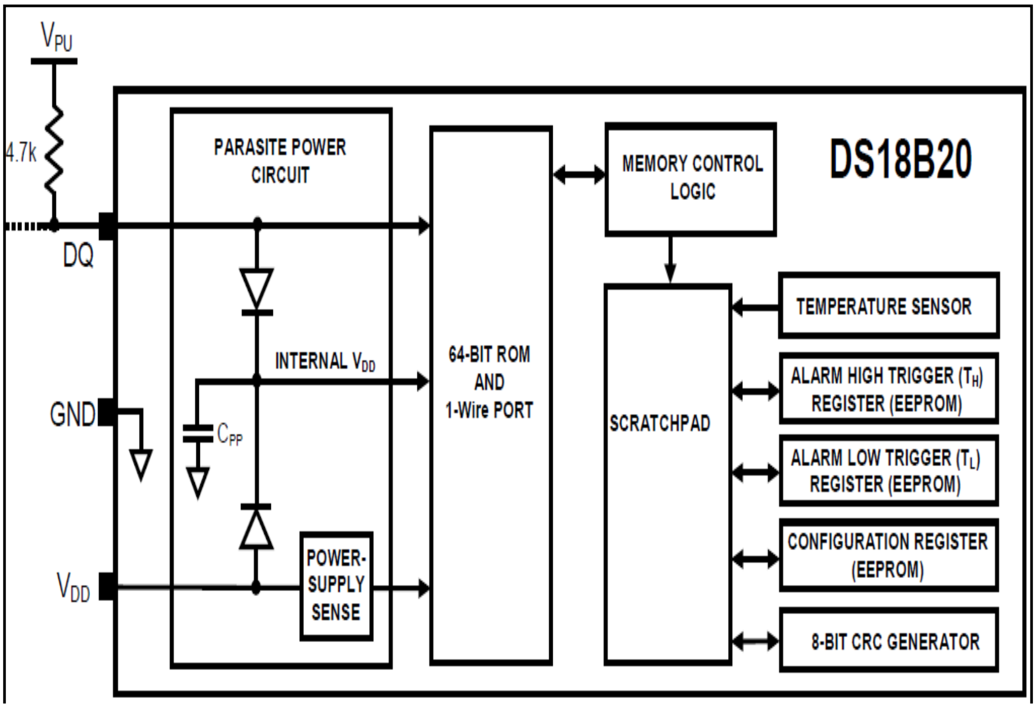

Fig. 2. The logical structure of the DS18B20 [1,8].

Information about the sign of the temperature value is stored in first five MSB bits. Three MSB bits and whole LSB byte contain 12 bit value (multiplied by 16). Commercial solutions (xComfort, Teletask) perform additional remote device control functions, in addition to the basic measurement of selected physical properties. The measurement node described in this paper is equipped with the ATMEGA16L microcontroller, which has 32 I/O lines. Only one line is used to collect the data from measurements of the temperature, the other ones can be used to implement control functions.

The presented system allows to specify the data reading interval. User can choose between four possible options: 1 s, 2 s, 3 s or 4 s. To select the desirable interval, user has to press the button, connected to port D of pin 7. Pressing the button changes the value to an adjacent one. The task of the master node is also to send the measurement parameters and the status of selected sensors (e.g. light switch status) using USART bus and USB to the database on the PC. To correctly exchange the data, an appropriate transfer speed establishment is required. In order to determine the transmission rate, appropriate values of UBRR registers must be set. They can be determined from the following formula [12]:

$$UBRR = \frac{f_{osc}}{16 * BAUD} - 1$$

where f_{osc} represents the frequency of the oscillator and BAUD represents fixed transmission rate. In this system, communication speed is set to 57 000 bps.

IV. STORAGE AND VISUALIZATION OF MEASUREMENT DATA

Measurement data from the sensors are sent to the server. Data storage is based on the software with XAMPP environment installed. XAMPP stands for: cross-platform (X), Apache, MySQL, PHP, Perl. It is a simple, integrated suite, consisting of the Apache server, MySQL database, PHP and Perl script interpreters. It is distributed under the General Public Licence (GNU) as a free web server for dynamic pages. XAMPP is available for the four operating system platforms: MS Windows, Linux, Oracle Solaris and Mac OS X. In this project, MS Windows platform is used.The concept of this system is based on the currently popular concept of intelligent building. The data received from the measurement system describe selected parameters of the monitored building. The database, which is used to store measurement data and additional information, has four main tables: customer, house, room, sensor.Each customer has: name, surname, username, password and a unique identifier. Username and password are needed to log into the application and into the management website. They are also used to search the customer database. ID (identifier) is a foreign key, which is used in relation to the “house” table. Having customer ID, it is easy to find assigned house (one or more). Information obtained from the “house” table are house ID and its address. Additional information about number of floors in house is used in the visualization process. Each house has several rooms, hence the need to identify them by using unique ID. Rooms have names and data describing floor number. “Sensor” table provides information about the type and status of sensors, which are grouped by room they are located in. The assignment of identifiers allows easiness of reading and updating data.The information obtained for presentation in user interface (Web site) are delivered using SQL queries. Access to the database is achieved by establishing connection and using PHP scripts. If the connection is successful, there is possibility to search for desired information. The user can monitor the status of the sensors by observing the interactive diagram of the building. Through the interactive fields, it is easy to keep track of the values of individual sensors, which are changing dynamically. Depending on the type of application it is also possible to expand the functionality to a visual representation of the building area, presentation of data in tabular form showing a list and status of all sensors of the building and the ability to manage sensors state using WebGUI (switching on/off, e.g. lighting) [1, 4, 11].

The frequency of sending measurement data varies from 1 to 4 seconds, with 1 second step. Page refreshing time is independent from the transmission frequency. Refreshing is done carried out every 3 second. Temperature reading time in non-commercial use is not a strategic factor, hence the delay of 3 seconds does not affect adversely the operation of the system. Additional lighting control function implemented on the Web page refreshes database parameters transparently to the user. LED status update is done along the transfer of parameters via USART bus, so the faster data are read, the faster system response is. Using the remote control button executes the transfer of data to the MySQL database and also updates the status of the microcontroller pins.

V. CONCLUSION

Sensors networks nowadays are an integral part of the construction of wireless measurement systems, which monitor the variability of certain phenomena.

This article presents a new approach to the use of solutions from computer networks, databases and measurement technologies. Fast access to data and visualization, which takes into account the distribution of the sensors increases the efficiency and speed of response to physical factors. Presented ways to manage and exchange data in wireless sensor networks using RFM12 radio modules open new directions for development of measurement systems. Developing own data exchange protocols, fitting functionality of the application and selected parameters of the system allows it to operate infallibly, taking into account its low cost, high reliability and low power consumption. Measurement network consisting of thousands of sensors spread across different geographical areas are already in use, therefore presented sensor network and database integration can provide the basis for a modern measurement system taking into account the constraints related to power consumption and maximum operating distance (range) from the base station.

The presented design may be successfully involved in a computer science or automatic students learning process as a modern multifunctional education setand what is the most important an open source and low cost education set.

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