SENSOR SYSTEM USING INTERNET COMMUNICATION
Measuring via Internet

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Abstract: The paper describes a sensor system for measurement and transfer of data via internet. Sensor data are measured at different locations. The concept of read up sensor data, data transfer and data display is presented in the paper. The realized system for measurement of air temperature, pressure and humidity is described. Hardware and software of the measuring device have been realized. Eight physical quantities can be measured by basic sensor system. The system consists of 16 configurations input/output for sensor connection. Additionally, sensors can be used by the support of software widespread. RS-232 interface has been used for its simplicity. Ethernet interface can be used by the converter. The control software of the whole system has been designed. There are many program functions implemented. The design has been were verified by the realized system sample. All implemented functions can be displayed on WEB pages. Common software equipment can be used to view the web pages (PDA or mobile phone).

1 INTRODUCTION

The paper describes design and implementation of a system solving transfer of measured sensor data via the Internet. A web page has been created on an Internet server where information is stored, processed, and displayed. The system is divided into four basic function blocs and each bloc can be used at a different location.

Measuring equipment. Measuring equipment acquires the data from the sensors, e.g. temperature, pressure or humidity. The device consists from the hardware and software for handling the sensors and sending the measured data to the computer. The measuring equipment is able to be active without external power supply for certain time period. Measured data are stored into the internal memory and later sent to the computer.

Program for reading. The program is determined for reading the data and saving them into the computer. If the measuring equipment is connected to the computer the program is able to read the saved data from the internal memory of the device. The program sets up the measuring equipment for correct addressing the data from the sensors, i.e. where to store the data from which sensor. The configuration of the measuring equipment determines the number of the active sensors, the position of the inputs and other properties. The measuring equipment is connected to the computer through corresponding interface, e.g. serial port. It is essential to ensure sufficient memory of the computer for saving the measured data. Successive distribution of the measured data is realized using the Internet connection.

Software for data transfer. This software cooperates with the *presentation layer* and it is running on the same computer or server as the *program for reading*. The software is reading the data which have been stored by the *program for reading*; it is modifying them and consequently storing them into the database. If the data are not stored on the same computer as the *software for data transfer* is running on, the data must be in the same format. The software can run on the Linux as well as on the MS Windows platforms.

Presentation layer. This part is used for generating dynamic web pages. The web pages combine the text information and the graphical curves which are representing the measured data or some previously recorded data. The presentation layer consists of the set of the PHP scripts. The scripts are changing the server configuration, specifying the way of the data presentation, loading

the data from the database, changing the data, computing the statistics from the measured data, creating the graphical characteristics, etc.
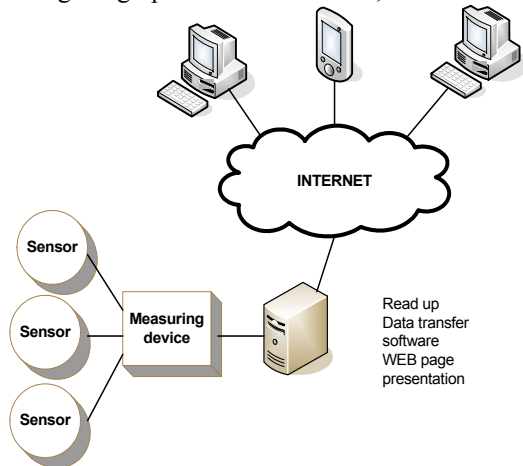

Figure 1: The simplest configuration of the measuring system.

Web pages are generated by the web server and MySQL database server. These applications can be run on the several kinds of the operating systems. The simplest configuration of the system is shown in Figure 1. All software is running on the one computer, which is connected with the sensors.
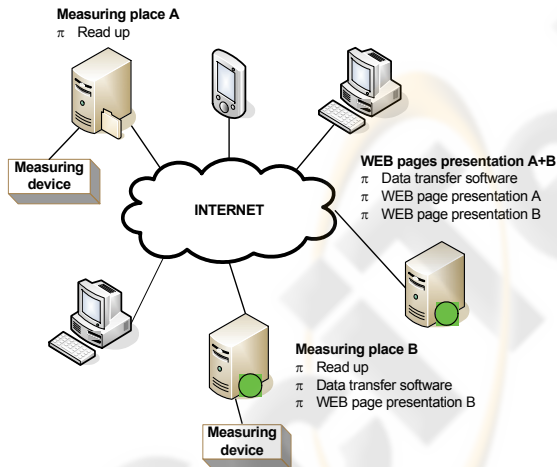

Figure 2: System measuring at different locations.

The system configuration for measuring the data at different locations is illustrated in Figure 2. The system has one presentation layer, which is common for all other parts. Each measuring point can differ in the hardware and software equipment. This difference is caused by different demands laid on the measuring function of each part of the system.

2 DESIGN OF MEASUREMENT INSTRUMENTATION HARDWARE

A measurement equipment enabling connection of sensors has been designed. The sensors are aimed at measuring various physical quantities. Both analogue and advanced digital-output sensors can be used. The sensors are designed as single-chip combinations with signal-processing circuits. The sensors can be connected directly to a microprocessor. The microprocessor takes care of the communication with multiple peripheral instruments. The analogue-output sensors are connected to the microprocessor via an A/D converter. The connection to the PC is through a RS-232 interface. A logic level converter matches the microprocessor signal to the RS-232 voltage levels. A character display has been selected for displaying the data to the operator.

2.1 Microprocessor and its Supporting Circuits

An ATMEL 89S9252 type has been selected as the control processor. The clock frequency generator circuit has been selected with an 11.0592 MHz crystal. The crystal frequency selected is suitable for accurate setting of serial communication speed. In order to prevent undefined states from appearing on switch-on conditions, the processor start is delayed. The delay can be set by connecting a RC network to the reset input of the processor – see Figure 3.
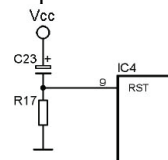

Figure 3: Reset circuit of the processor.

After the 5 V V_{CC} supply voltage is applied, a logical zero appears at the RST input (defined as V_L = 0 ... 3.5 V). The run-up time to the logical zero can be calculated as

$$t = RC \cdot \ln \frac{V_{CC}}{V_L} \qquad (1)$$

where V_{CC} = 5 V and V_L = 3.5 V. The processor supports a connection of external memory to the input/output ports P0 and P1. When no memory is connected, these ports must be voltage-treated properly.

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2.2 Connection of Sensors

Digital-output sensors are connected via an AD converter – see Figure 4. The sensors are connected to inputs marked as D0 to D6. Analogue output sensors can be connected through an AD converter. For the required applications, an 11-bit converter is sufficient. A MCP3208 type has been selected. It is a 12-bit successive-approximation AD converter. The converter has 8 inputs (programmable as 4 pseudo-differential inputs or as 8 independent inputs). The converter communicates through a four-wire serial bus, compatible with the SPI protocol. Conversion speed is up to 10^5 samples per second.
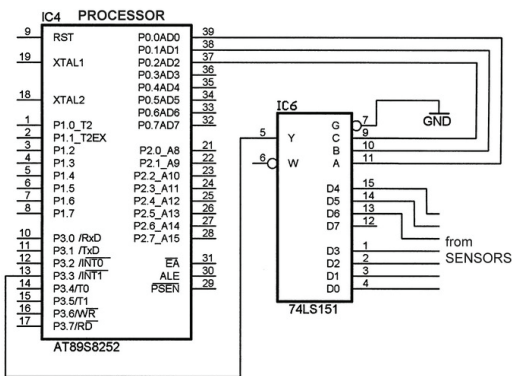

Figure 4: Connection of digital sensors to the processor through a multiplexer.

2.3 Output Circuits and Power Supply

The RS-232 interface is used for PC connection, because RS-232 implementation is very simple (having preference over USB). The interface is connected to UART of the
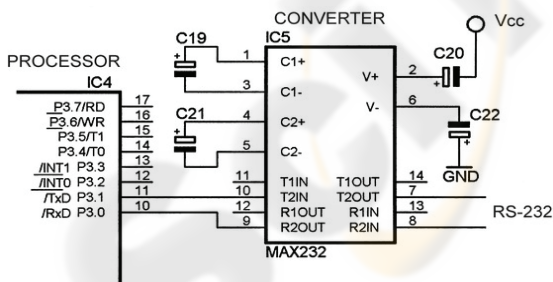

Figure 5: Circuit connection of serial bus.

processor. The converter MAX232 is used for change of logical levels – Figure 5. The switch power supply is used in circuit powered – Figure 6. The MC34063A is used (ON Semiconductor).
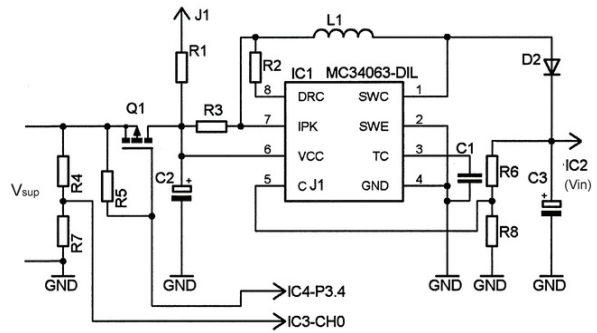

Figure 6: The circuit connection of power supply.

2.4 Used Sensors

The SMT160-30 sensor can be used for the measurement of temperature (SMARTEC). The sensor is 3-pin integrated Si sensor. The output signal has the form of mark-space ratio. The signal can be connected to a multiplexer. The mark-space ratio must be measured and converted using a counter.

The SHT11T integrated sensor can be used for the measurement of humidity or temperature (Sensirion). The output signal is in digital form. The sensor is connected to a 2-wire digital bus (signal clock SCK and a data bidirectional signal DATA). The output signal as function of humidity is nonlinear. The temperature compensation must be applied.

The MPX4115A sensor is used for pressure measurement (Freescale). A circuit is integrated one-chip Si sensor of absolute pressure. The sensor has signal processing on chip together with pressure measurement and temperature compensation. The output signal has analogue form in the range of 0.2 V to 4.8 V (range of pressure is from 15 kPa to 115 kPa). The sensitivity in the pressure range is 46mV/kPa. The pressure resolution is 0.045 kPa.

3 SOFTWARE OF MEASUREMENT INSTRUMENTATION HARDWARE

The control program is divided to different functions. Individual functions control behaviour of the corresponding instrumentation parts. The program for communication with AD converter is simple implementation of the SPI protocol. Another function performs data read-up and saving from/to

the EEPROM inner memory of the processor. Another function controls character LCD display. 8-wire bus is used for data transfer. Further function performs data transfer using serial bus and communication with the SHT11 sensor.

3.1 Program Operation

After initialization the program runs in the infinity loop. The PC instructions are loaded form the computer in the loop. Individual functions might be called from these instructions. All functions are periodically running in the PC interruption.

a) Device initialization. The program starts from the processor memory after power supply switch on. The output ports of the processor are set up to the initial state. The timer parameters are set up for interruption generation. The counter is set up to the speed of 9600 baude per second. The Watchdog circuit is triggered. The configuration information is read from the EEPROM memory of the processor. The configuration information contains:

- Number of connected sensors (1-8)
- Interval of data record to inner memory - when data are not processed in the PC
- EEPROM dimension of processor
- Frequency of measurement (frequency is determined by frequency of interruption calls)
- Configuration bytes of individual sensors

b) Interruption timer service. The interruption service provides: reading the data, data processing, data displayed and data transmission to the PC – Figure 7.

The program uses three counters in that interruption. The counters are saved in the global variables. The global variables are saved during individual calls of the interruptions. The counters are:

- Counter with number of currently active sensor
- Counter for providing averaging number
- Counter for providing number of measured characteristics to be saved in the memory

The program decides by the two latter counters to ramify – Figure 7. Basic functions are displayed in the flow diagram.

Reading data from sensors. The sensor counter decides which sensor to use. The program reads data from that sensor.

Value calculation. Value calculation is performed after averaging cycle. Value output is periodical after each calculation.

Value display. Values are displayed and sent to the PC. The information contains sensor number, sensor type, measured value and quantity.
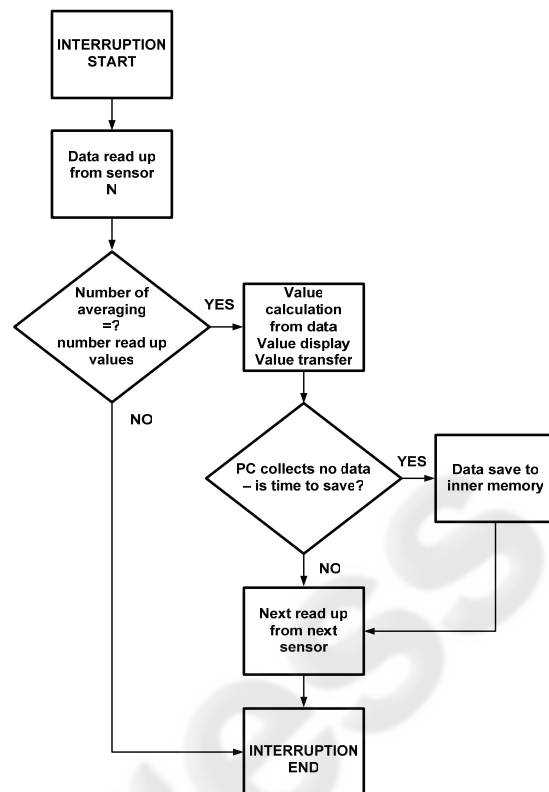

Figure 7: Interruption service.

c) Instruction reception. The program reads the instructions from the PC in the program loop. The functions are called by these instructions. The functions execute these instructions. The instructions are represented only by a single character (for simplicity).

d) Function callable from computer. The configuration function is defined for the device configuration. The function is very simple, it overwrites fifty configuration bytes by new data. Automatic processor restart is performed after reading the new configuration.

4 DATA READING AND TRANSFER SOFTWARE

The software performs data reading from the measuring device. Then it performs data transfer via internet to the web server– Figure 8. The software is divided into two parts. The first part executes data reading from the measuring device. That software part is running always on the PC connected with the measuring device. The second software part formats data for the web pages. The software supporting the

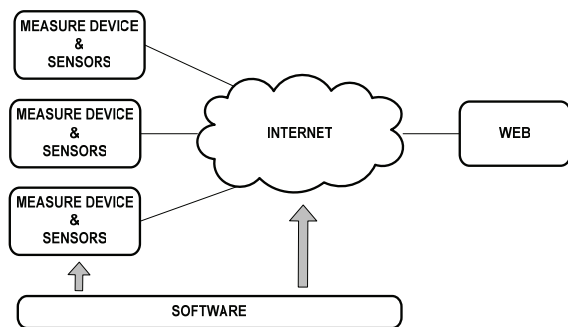web pages is written in the PHP language (PHP: Hypertext Preprocessor)..

Figure 8: Read up and transfer via internet software

4.1 Software Support of Measuring Device Control

a) Configuration File.
The configuration file sets up the PC. It defines location for saving read values; it contains setup information for connecting the device. Setup information contains:

- Setup of serial port number connection
- Measuring frequency of the device
- Interval of data record in device
- Memory size of the device processor
- Setup of individual sensors

Individual sensors have in the setup items:

- Sensor data directory for saving
- Sensor type
- Specific sensor setup (input position)
- Corrective constants

b) Program operation.
Initialization. After start the script performs several operations (setup of infinite time limit for script running, setup of start up limit of one script installation, PHP process identifier is saved to the file). The next step is reading the configuration file.

Data reading. The script starts reading data from the measuring device using serial bus.

Data processing and saving. Sensor data are sent to the PC. Data are processed in the PC (more precise calculation). The output values are corrected by setup constants. Final values are checked (a presence in the defined interval).

Virtual sensor. Special properties can be set up in the program. It is possible to have a sensor that is not in the measuring device in reality. The sensor value is calculated as a mathematic operation.

4.2 Software Support of Data Transfer via Internet

This part of software performs data saving to a database. The data are acquired from the measuring device. The transfer and saving of data is realized using a PHP script. Since the script uses database access, it is necessary to install support for the MySQL database. Another extension is represented by CURL that provides comfortable access to data via internet.

Setup. The setup contains „*data series*". Data of individual sensors build up the data series. Individual series are defined by the configuration files.

Data copy. The source path, the target path, and the filename are necessary information for creation of a data copy. The data are saved in several files. The interval of copying is set up to three minutes.

Database format. SQL database (Structured Query Language) is suitable for data saving and their use on the web pages. Using SQL queries allows very simple reading of data according to the requested parameters.

The database structure is very simple. Data series corresponds to the measured sensor value with assigned time value (the first column contains time, the second column contains measured value). The measured data are changing very slowly. The data are saved to the database only in the case of change (the result is acceleration of data operation). That limits the calculation of various statistic characteristics (data absence in time). Therefore additional column is inserted to the structure. The duration of a certain value is saved in this column. The format „Unix Timestamp" is used for saving time information. Time values are represented by 32-bit number. PHP script converts that format. Other two matrices have been designed (they save time and space for data processing). The matrices contain partially preprocessed data, namely average values, minima, and maxima. The matrices serve for using data from a longer time interval.

Data saving. Data are read from data series in the files. Data are transformed to correct format and saved to the database. Data are not saved as a single series. One single SQL query is created. All new data are saved in batch mode. Operation speed is higher in that case.

5 WEB PAGES AND RESULTS

The basic requirements have been defined for the design of the web pages: Simple layout and well-arranged design, text display of current measure values, current measured characteristics within day, measured characteristics and text outputs for arbitrary data interval.

The page layout is shown in Figure 9. Very large number of operation is necessary for display of one web page. Individual files control different attributes of the web page, for example: web page layout, data preparation from database, access interface to database records, conversion of common call database function to concrete instruction, reading concrete database record, reading web page setup, probing extreme values.
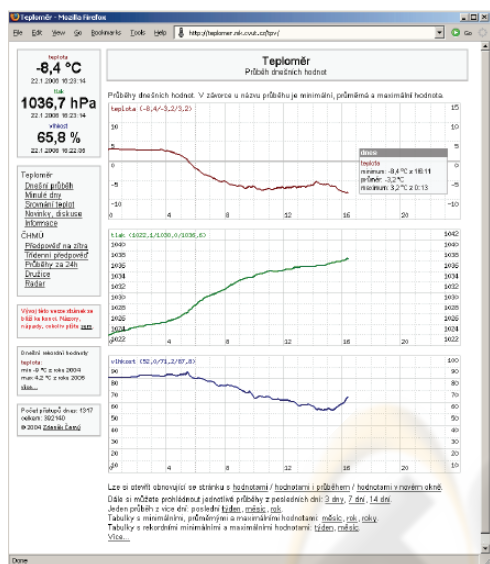

Figure 9: Web page layout.

The main file controls a skeleton of the page. Current values are displayed in current day. Additional information of extreme values is added to the pictures.

Page "history" allows to visualize the information in different way, for example: One picture with characteristics in the concrete time interval, table with minimum, average, maximum values for concrete days, months, years, table with minimum, average, maximum value through current day.

Another file performs generation of all pictures. Pictures can be saved to the database. Different parameters of pictures can be set up: File name, Displayed time interval, Picture dimensions, Picture captions, Axis ranges.

6 CONCLUSIONS

Hardware and software of measuring device have been realized. The basic system measures eight physical quantities. In the paper, the system for measurement of air temperature, pressure and humidity is described. Measured data are transfered via internet.

Measuring device. The system consists of 16 configurable inputs/outputs for sensor connection. Five sensor types have been designed for the system. Eight measuring devices can be used in the system. Additional sensors can be used – the extension is software supported. The RS-232 interface has been used due to simplicity of connection. Ethernet interface can be used for the converter.

Software equipment. Control software of the whole system has been designed. Many program functions constitute the whole software. Individual functions perform individual operations of the system. The design has been verified by a realized system sample. All functions can be displayed on the web pages. Common software equipment can be used for viewing the web pages (PDA or mobile phone).

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