Remote laboratory with WEB interface

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Presentation of selected structures of remote laboratory. The presented structure enables remote control through the Internet and the acquisition of measurement data. The measurement data are presented using a web interface. The final result is microcontroller measuring and control system with web server. System flexibility and ease of access to its resources allow parallel planning an experiment to multiple users simultaneously.

1. Introduction

The laboratory is an important element of student education. Allows the verification of theoretical knowledge in practice. Properly prepared laboratory makes it possible to solve problematic issues. An important feature is also a collaboration on the issue. In order to ensure a sufficient level of training laboratory is equipped with control and measuring equipment. Devices should be safe for the user, and resistant to damage due to the very frequent use. Another issue is the timely access to the room. It is limited to normal operating hours of institution and laboratory supervisor work time. Execution of experiment by students at home is not always possible. There is no doubt it is required a solution to whole day access to the laboratory. The use of virtual or remote laboratory allows all time access[1]. It also allows laboratory to obtain completely safe for the user. Proposed to remotely execute the experiment. Web based user interface allow prepare and present experiment. The solution allows multiple people to use the remote laboratory at the same time [2].

2. Remote control structures

A. Direct control

The idea of direct control is the ability to directly interact with the hardware. A general diagram of the network structure is shown in Fig. 1. System contains the following elements: network client, network and control system witch network module. Network modules are available in performing all the layers even the HTTP (Hypertext Transfer Protocol) or just the physical layer of Ethernet (ENC28J60, Digi Connect ME).

Fig. 1. Structure of system in direct control

Direct control allows immediate execution of the requested operations by the system. A disadvantage of this structure is the limited resources of embedded system that must fulfill two roles: WWW (World Wide Web) server and process control system.

A simple control system consists of 8-bit microcontroller and Ethernet controller. The entire user interface is included in the program memory chip as a static HTML (Hyper Text Markup Language) page. Interactivity can be introduced through the use of technology, which performs all operations on the client side. JavaScript may be used for this purpose [3]. The disadvantage of presented structure solution is additional task for control system that must support microcontroller.

This structure is recommended for small applications, where users require a direct response of the system. Please note that such systems can handle a small number of users.

B. Control via dedicated server

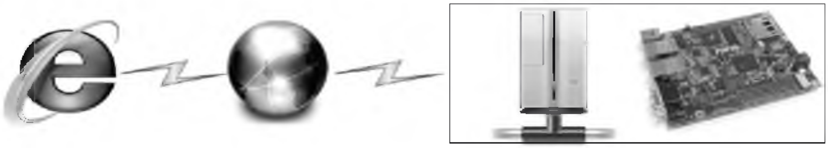

Fig. 2. Structure of system with dedicated server

Figure 2 shows the structure extended from the point A. The system has been expanded to include additional dedicated server directly connected to the control system.

The presented system has all the advantages of direct control, but introduces additional cost during installation and operation. Dedicated server performs the function of a web server with dynamic web pages. Page content is dependent on the state of the control system. In system, the controller containing microcontroller performs only certain control functions. The entire bandwidth generated by the user interface is handled by a dedicated server. It is required physical integration of the server and control system. Such a connection is not always possible because of the bigger dimensions of the server in relation to the size of the controller. Connecting a server with a controller on long routes adds delay.

Use a proxy server allows to collect the history of the control system and placing them in a database. Additionally, can be implemented any network services, including the need to install and configure the appropriate software.

C. Control via virtual server

Structure of the system using a virtual server is shown on Fig. 3. Virtual server provides own resources: processor, memory and disk space without specifying a physical location. The user is connected by the network to the virtual server in the same way as with dedicated server. The difference is imperceptible to the user.

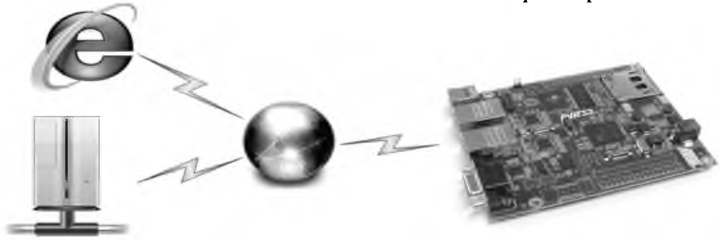

Fig. 3. Structure of system with virtual server

The controller based on microcontroller must be equipped with a network module that allows for communication over the Internet. Embedded system can connect to the virtual server in two ways: demand-response or continuous. Universal solution is to request-response mode, where the controller is a client and the virtual server is a server. This configuration does not require assigning global static IP (Internet Protocol) address for network module driver. Virtual server can be any free server provided by hosting company. It is recommended to use the XML-RCP (Extensible Markup Language - Remote Procedure Call) for data transmission (Fig. 4).

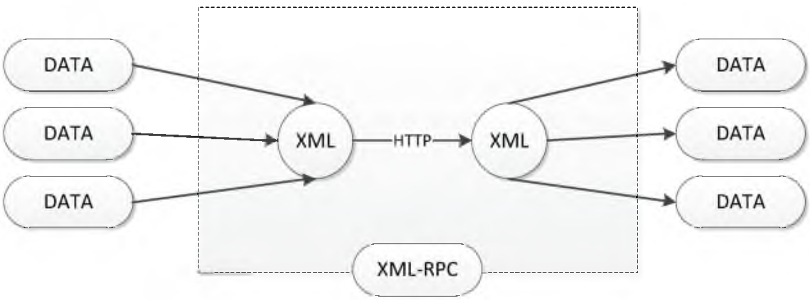

Fig. 4. Data transfer using XML-RPC

Using XML-RCP standardizes how data is transferred. It allows to simplify the client requests to the server. The driver calls the remote procedure with the appropriate parameters allows to: put current state of the system in database virtual server and download commands for execution.

An important design parameter is the frequency of queries performed by the embedded system. Too frequent polling of the server on new tasks can generate unnecessary network traffic and server load when the user does not change anything in the system. The use of long periods of questioning may result in loss of interaction with the hardware.

D. Choosing the structure of remote control

In carrying out the work was used the structure from the point B. It allows for direct user interaction with the hardware and allows for the extension of the hardware with new control systems. The control system was implemented as a separate system coupled to a dedicated server. In the role of a dedicated server was used NGW100 (Network Gateway) Atmel . The controller is connected to the server via RS232 serial interface (Recommended Standard 232).

3. Example of remote laboratory

A. Basic design goals

Performed the experiment should allow the user to interact directly with the object. The proposed scheme of experiment was shown on Fig. 5. System consists of temperature sensor and two actuators: fan used for cooling and heater used to heat the object. All components are used by the controller. Experiment can by executed in automatic mode with implemented two-state controller. Available is in the Control Panel to change the set point temperature of the object and the width of the zone of hysteresis controller. Figure 6 shows the system realization.

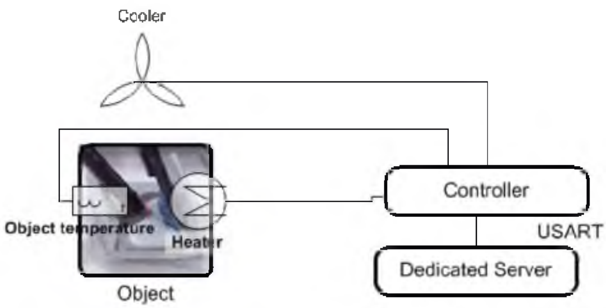

Fig. 5. Scheme of experiment

Fig. 6. Hardware realization

The aim of this study was to design and execution of an electronic system allowing remote control via the Internet. The object of the remote control is an experiment showing selected physical phenomenon. It is assumed the limited size of the entire system to compact closing in a cube of side 30 cm. User should be able to interact with an object through a simple web interface. The interface should allow the client to direct interaction with the object in order to monitor the effects of certain parameters to change the object. The system should have an automatic operation mode to record changes in the object for a specific set of parameters of the experiment.

The author proposed the observation of temperature changes the object depending on the settings of the cooling element at a constant heating of the object. Cooling is forced convection. HMI (Human Machine Interface) allows a user-friendly way to control object. The study used a web page as the user interface. Temperature changes of the object are presented on the chart. Client has the ability to control an object in manual mode or automatic mode with two state regulation.

B. Proposed project

Performed the experiment should allow the user to interact directly with the object. The proposed scheme was an experiment equipped with a temperature sensor and an object implementing two components: the fan used to cool and the heater used to heat object. All components are handled by the driver.

Transmittance of the control object should have a large rise time - first order inertial object. As object was used aluminum radiator. It is possible to measure object temperature and control heating or cooling element.

The heating system was completed attached permanently without the possibility of exemption by the user. Client observes the current temperature. Attaching a fan on or off record changes in temperature at constant heating facility. Added are three LEDs signal which an operator can control directly. So that with one click on the website can change the state of the system. Discussed was manual mode. Two-state controller was implemented to use in automatic mode. It is available in control panel to change setpoint temperature of the facility and the width of the hysteresis zone controller.

Regulation is carried out according to the formula 1. The fan is switched on when the temperature of the object y(t) rises above the setpoint temperature x(t) plus half of the hysteresis zone H/2. The fan turns off when the temperature of the object y(t) decreases below the setpoint x(t) minus half zone of hysteresis -H/2.

$$u(t) = \begin{cases} \text{OFF when } e(t) > \dfrac{H}{2} \\ \text{ON when } e(t) < \dfrac{-H}{2} \end{cases} \tag{1}$$

where e (t) = x (t)-y (t), x - setpoint signal, y - output value object, H - width of the hysteresis. Two-state controller have static characteristics shown in Figure 7.

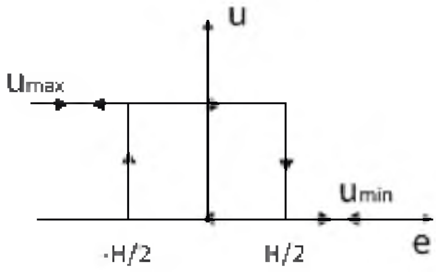

Fig. 5. Static characteristics of two-state element

Changing the width of the hysteresis controller change the quality of the two-state regulation. When setting up a narrow zone of hysteresis is observed and the frequent switching off the fan. Using a broad zone of hysteresis is made smaller number of switching windmill. The result is a deterioration in the quality of regulation.

C. Implementation of the control system

Designed board corresponds to the location of joints J5, J6, J7 and J16 NGW100 board. The module is applied to the board from the top. Board is made entirely by hand on a plate with universal elements mounted in THT (Through-Hole Technology). The result of the work is board in Figure 8. System elements: 1st power outlet, 2nd ATmega8L microcontroller, 3rd programming interface standard ISP-6 (In-System Programming), 4th three pin connector for fan, 5th fan, 6th thermistor, 7th object, 8th heater, 9th 3 pins available with voltage 3.3 V, 10th 3 pins available with the voltage of 0 V, 11th quick connector for the heater, 12th quick connector for the fan, 13th NGW100 connection with the controller.

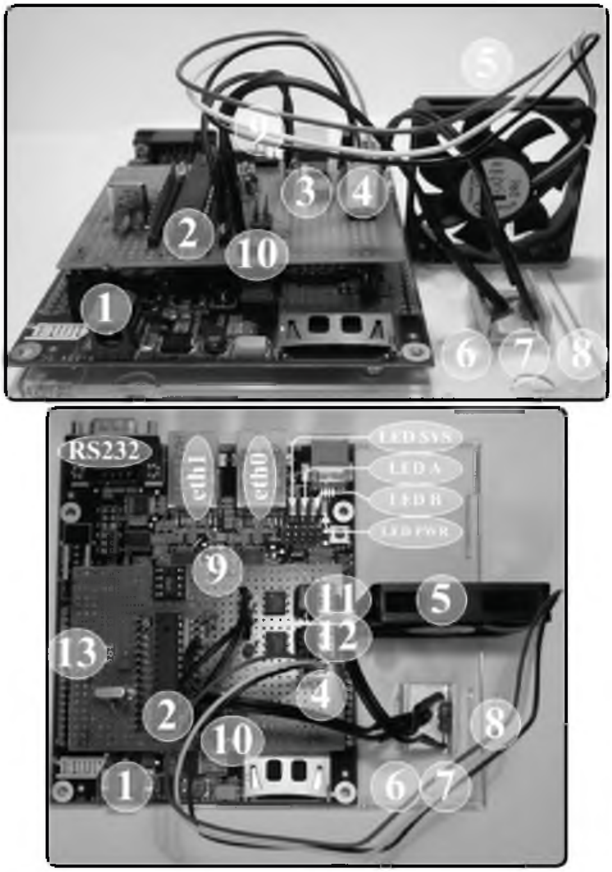

Fig. 6. Detailed hardware realization

D. *User Interface*

Application user interface only requires to installed browser (preferably Mozilla Firefox). The interface was made in PHP, HTML and JavaScript - JS library Charts and jQuery. JS Charts allows to draw multiple series charts. In order to place the chart in the website code to create <div> </ div> and set its id. Id element is used by JS Charts to be placed in the chart area. jQuery extends the basic elements of: buttons, sliders, dialog boxes and tabs. All user input data are checking on the server side using the validator class. Login can be a string containing the digits with a minimum length of 3 characters. The password can be a string containing the digits with a minimum length of 4 characters.

The system allows to log in. Without logging user can access to information about the author, information about the project, links and logging capabilities or registration. Figure 9 shows the page without a valid session: 1st login panel or registration, 2nd Additional information is categorized in the tab.

Fig.7. Login screen

After properly logged in user can change settings (Figure 10). Session information is stored on the server in PHP $_SESSION variable. Settings tab will be opened by default after logging. Available options on the settings tab: 1st setpoint change through the slider - the range 10 - 80 ° C, the pitch of 1, 2nd change the width of the hysteresis zone through the slider - the range 0 - 4 ° C, the pitch of 0.1, 3rd change chart history by slider - the range 10 - 300 s, the pitch of 1, 4th temperature from the current measurement, 5th setpoint set on the controller, 6th hysteresis width of the zone in the controller setpoint, 7th The status of the fan 1 - on, 0 - off, 8th sequence number of readout data.

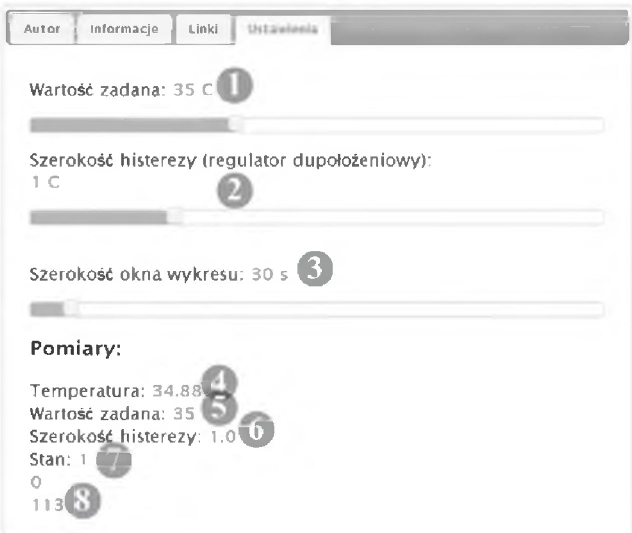

Fig. 8. Control settings

User can become familiar with the operation of two-state controller or can control the object manually. Manual control interface is shown in Figure 11.

Manual control interface elements: 1st logout button, 2nd sets / hide markers on the graph to allow the temperature reading after moving the mouse in the area of measurement, 3rd Manual Control diode SYS - On, Off, pulsation, 4th A Manual Control diode - On, Off, pulsation, 5th Manual control of diode B - On, Off, pulsation, 6th the inclusion of a manual fan control - the control is turned off - there will be two buttons for switching on / off fan, 7th temperature chart drawing area, 8th preview of the selected measuring mouse over the field measurement, 9th temperature chart, 10th tabs.

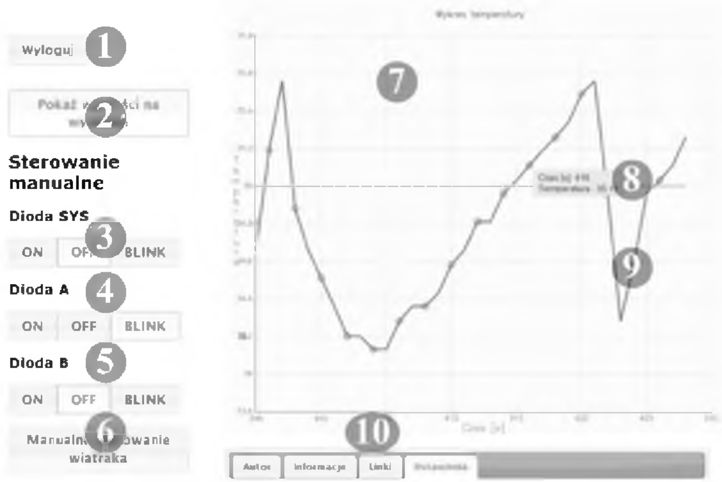

Fig. 9. Control system screen

The user interface exchanges data with the server using AJAX (Asynchronous JavaScript and XML). Ajax is best solution for remote laboratory[4]. All read commands are sent to the script in the background read.php. From the PHP opens the device to read the Linux / dev/ttyS3 before data transfer to the control system is in the background send.php file is used. The PHP commands are executed directly from the system console. Sending data via the serial port requires *echo'command to send'>>/dev/ttyS3*. In PHP system performs this function, the *system ("echo' command to send '>>/dev/ttyS3");*.

The application user interface requires him only installed browser (preferably Mozilla Firefox). The interface has been implemented in PHP, HTML and JavaScript - JS Charts and jQuery library were used.

E. Preparing experiment

To perform an experiment, need to set operating conditions of the system, connect necessary cable hardware to the computer and configure the client software. The maximum temperature which was read on the object during testing

was approximately 50 °C. The minimum possible temperature of an object is equal to ambient temperature, it is caused by cooling by forced convection.
Experiment should be carried out under the same environmental conditions. Recommended room conditions: 20-22 ° C ambient temperature and relative humidity of 70-80%. Ambient temperature influences characteristics of heating, cooling, and the maximum temperature of the object. The system should be set in place without additional air circulation (open window, door or the air conditioning).

F. Performing experiment

Sets of experiments were made for manual and automatic control. The first series shows system in the control manual. Object was cooled by the constant switching on cooling. The experiment starts with recording excluding cooling and heating characteristics. It was a measured manually time 200 seconds, after which the attached cooling. The second step allows to record the cooling curve of the object. Heating and cooling characteristics of the object is shown in Figure 12.

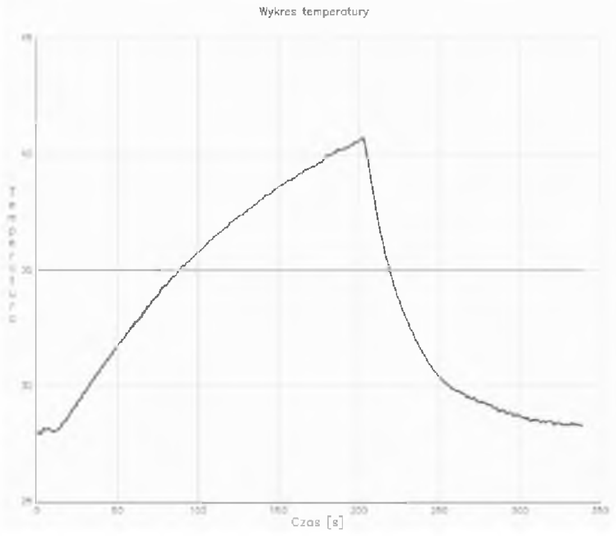

Fig. 10. Manual control

To prepare an experiment in automatic mode must be specified: setpoint temperature of controlling object and width of controller hysteresis zone.

Figure 13 shows temperature regulation. It is part of web interface view. Set point was changed from 35 °C to 40 °C with constant hysteresis width of 1 °C. The change is made in 150 seconds.

Figure 14 illustrates the impact of changing the width of the hysteresis control zone on the quality of regulation. H changed from a value of 1 ° C to 2 °C in 75 seconds. Increasing H causes a smaller number of cycles of cooling but reduce the quality of regulation.

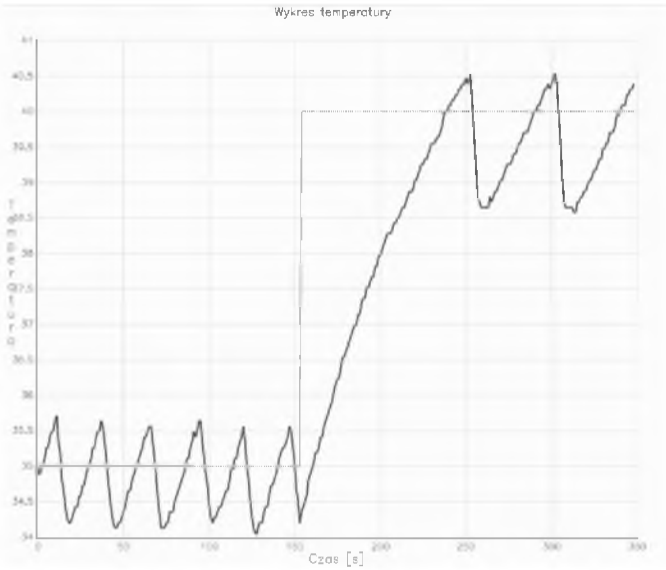

Fig. 11. Setpoint change

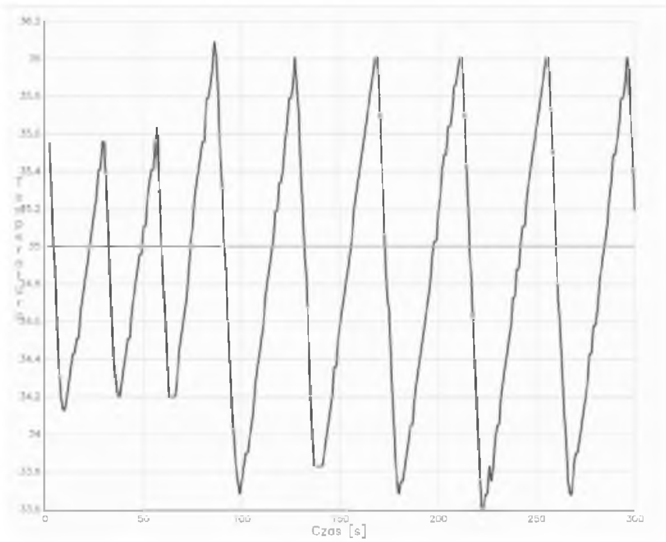

Fig. 12. Impact of changing the width of hysteresis zone for control quality

4. Conclusion

Embedded Systems with Web interface allow to control any object in a simple manner. The web browser is required. The use of extended structure consisting of: dedicated server and microserver controller creates many opportunities for designers. The designer is relieved from the multiple implementations of different network protocols. Modularity of the structure allows for the preparation of many different experiments. Common element will be a dedicated server, while the controller is implemented separately.

Embedded systems with interface web allow to control any object in a simple manner. Just Internet browser. Using the extensive structure consisting of: a dedicated server and controller offers many opportunities for designers. Designer is relieved from multiple implementations of different protocols. By using Linux, there are a variety of applications, including enriching the functionality of the whole network system. Dedicated server supports queries made by users - the execution of these operations is not critical. Separation of the control allows to increase the reliability of the control object. In the event that the operating system will be suspended driver will continue to perform his task at last entered data.

Performed experiments are characteristic for first-order inertial object with a high time constant. Object has a long time determining the value of the temperature. Slowly objects allow to observation of variables by a man of their parameters in real time.

System has been designed and constructed in a modular way. Controller of the object can be disconnected from a dedicated server and replaced with a newer. Controller board has two quick release to allow exchange of heater and cooling element. When changing the components it is necessary to remembered about a rating of the power components. All I/O of microcontroller ATmega8 were derived to a simple one-strip strip peg. Strip allows to extend the system with additional modules. Hardware changes require additional software updates. Sources of the website can be freely changed. A dedicated server allows to be freely configured.

References

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