e-Learning System for Temperature and Humidity Sensors and Distributed Measurement

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Abstract- In our paper we present an e-learning system that students can use for learning different topics related to temperature and humidity sensors. The system consists of three different temperature sensors and a temperature/humidity sensor, all controlled with the aid of a development board based on the PICmicro 18F452 microcontroller. Students can have access to the system over the Internet using a set of web based interfaces to the sensors. Using this system student can learn: the use of integrated temperature sensors, software implementation of different communication protocols (I^2C, 1-wire, CMOSens), distributed measurement systems based on these sensors, microcontroller based instrumentation, data logging and web control of measurement systems.

I. Introduction

Today considerable importance is placed on measurement and controlling temperature and humidity as these parameters are essential for a large set of applications involving industrial, medical, telecommunication, HVAC, computing or home equipment. In the same time, temperature-sensing technologies have been accepted as a standard for a large set of applications.

Modern computers combined with recent development of Internet give the possibility to build systems that can extend the availability of the laboratory equipment beyond normal class hours as they can be accessed using a web browser from remote locations such as student's homes, student dormitories or internet cafes. These remote access interfaces have to be attractive, must provide interactivity and animation and must offer a flexible, faster and friendlier learning experience.

Our paper presents a temperature and humidity measuring system connected to the Internet that can help students learn how to use of integrated temperature sensors, software implementation of different communication protocols (I^2C, 1-wire, CMOSens), distributed measurement systems based on these protocols, microcontroller based instrumentation, data logging and control of measurement systems. The system was integrated in a large adopted content and learning management system in order to provide students a useful complementary learning tool.

II. Equipment

The temperature measuring system was developed starting from different individual lab applications conceived to demonstrate the operation and industrial applications of temperature sensors [1, 2]. The equipment was put together into a single system and consists of following components:

- PICDEM 2 PLUS board - a microcontroller development board based on the PICmicro 18F452 microcontroller.
- temperature sensors:
    - 10-bit digital temperature sensor AD7416 [3],
    - 8 - bit digital temperature sensor TC74 [4],
    - 9-12 bit temperature sensor DS18B20 [5],
    - 12-14 bit temperature and humidity sensor SHT11 [6],
- PC Pentium – measurement and data storage server used to collect data from sensors, store data on hard disk and eventually display data locally on the screen in different formats.
- PC Pentium - web based server configured with Fedora Core 3 OS and running the Apache v.2.0 HTTP server.

If we use more than one microcontroller based development board system components can also be organized into a distributed sensor network. One development board can control one or more sensors and the boards can be connected to different computers or, if it has multiple serial ports, to a single computer.

When the system is used in the laboratory the following supplementary devices are employed in conjunction with the system: multimeters, oscilloscopes, heaters, lab temperature and humidity meters.

III. Software

The development of the presented e-learning system required all or part of different software tools. The software was needed for addressing the different areas of application development implied by the use of intelligent sensors, microcontrollers, PCs and Internet. The software tools have been used for:

- writing and debugging software for the communication between sensors and microcontroller (microcontroller programs can be written in C or assembler language). The actual microcontroller program is written in assembler using Microchip MPLAB IDE software development tools [7].
- writing scripts for communication between the microcontroller and computer using the serial port. For this purpose we have used CGI scripts written in C language [8].
- development of interfaces between user and measurement system. The interfaces used also CGI scripts written in C language. The interfaces are now rewritten in PHP in order to fully integrate them with other components of the content management system which are based on PHP.
- management of the e-learning system.

For the management of the e-learning system we have used an existent content management system named Moodle (which stands for Modular Object Oriented Dynamic Learning Environment) [9]. The choice was influenced by following facts:

- it is open source which means it is free and also the source code is available and can be modified to add new functionalities;
- it is widely used for e-learning purposes;
- it has a large set of modules that implement all kind of e-learning activities;
- the available modules are increasing in number constantly as the development community of the system, which is open source, is very active.
- we had previous experience using the system for teaching other courses.

A new module was developed in order to handle activities related to web accessible laboratories.

IV. Communication protocols

The measurement system consists of different sensors which use different communication protocols. Communication is performed both for configuring or calibrating the intelligent sensors and for initiating and getting the measurement data. Communication between sensors and the microcontroller based measurement system is done using different interfaces either using standard or proprietary communication protocols:

- AD7416 and TC74 sensors are using the I^2C protocol;
- DS18B20 sensor uses the 1-wire protocol;
- SHT11 sensor is using the proprietary CMOSens protocol.

In order to understand how the measurement process is controlled and how measurement data are read from the sensor, student will have to learn:

- interfaces of the sensors (two are standard);
- communication protocols (two are standard and one is proprietary);
- how to implement communication between sensor and microcontroller using dedicated peripheral in the microcontroller (ex. I^2C);
- how to implement the communication between sensor and microcontroller when the microcontroller does not have a corresponding peripheral. The protocol is implemented in software.

A new protocol was developed for the communication between the PC and the microcontroller in order to control multiple sensors. Using this protocol sensor configuration, measurement start and data read commands are sent from the PC to the sensors and the answers from the sensors containing configuration and measured data are sent from the microcontroller to the PC.

V. Measuring set-up

All sensors we have chosen have different degree of intelligence. This implies that the sensors can be configured at the initialization of the system and also during the measurement protocol. In order to obtain accurate measured values special conditions must be taken into considerations.
Using the system student can learn:

- how to initialize sensors;

- how to refresh sensor calibration constants;
- how to adopt a certain resolution in concordance with the measurement application;
- how to configure different features available in each sensor;
- how different parameters influence the measurement process and what action should be taken in order to reduce the negative influences of:
    - distance between sensor and data collecting system;
    - electromagnetic perturbations.

Each sensor type has an internal structure different form the others. Therefore students can learn:

- which are the sensors internal registers;
- available commands for reading and writing the internal registers;
- sequence of commands for configuring different sensor features;
- using existing low-power features;

Figure 1 depicts the measurement system diagram composed of the PICDEM 2 PLUS development board and the four temperature sensors connected to the board. Communication between the measurement system and the PC is done using the serial port of the microcontroller which is connected to the PC serial port.

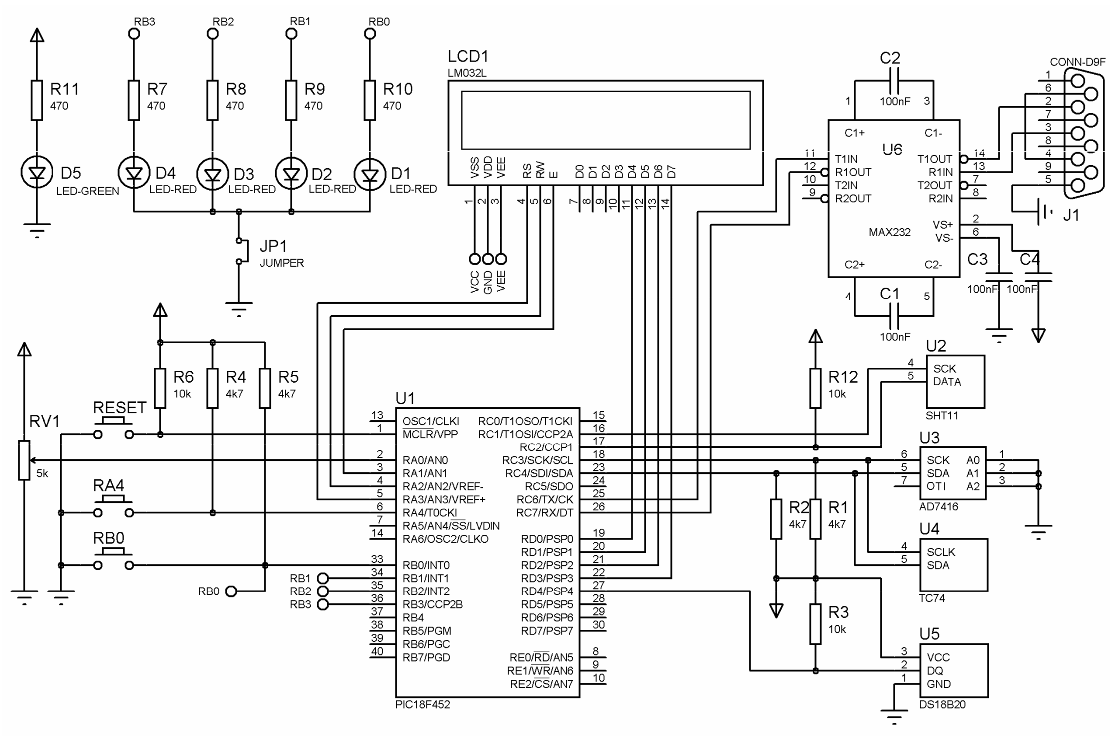


Figure 1. Circuit diagram of the measurement system.

VI. Controlling sensors over Internet

Configuration and measurement of temperature and humidity is performed by a microsystem based on the PICmicro 18F452 microcontroller. For each sensor there have been developed subroutines that can be called to configure, start data measurement and read measured data from sensor registers [10].

System can be used in laboratory or can be accessed from Internet using a web browser. When used n laboratory students can use the programs already written to work with sensors or can write their own programs and load them into the microcontroller memory. When accessed from Internet, students can run only the programs already loaded in the microcontroller memory. In order to have a better understanding of how sensors can be controlled using microcontrollers, code for performing different tasks with sensors can be revealed from the corresponding sensor interface by clicking a “Show code” button.

For each sensor we have created web interfaces that allow students to perform most of the tasks remotely. Push buttons, check box, lists and other form elements are used in the interfaces allowing students to configure sensors and make measurements with the sensors on the system. For the protocols that allow multiple sensors to be connected on the same bus, we have created web interfaces that can handle multiple sensors. Figure 2 depicts a web interface for controlling four AD7416 sensors.

The access to the measurement system using web browser must be managed so that only one student at a time can work with a temperature sensor. Access to the temperature measurement system must be restricted only to students enrolled in the corresponding course. For this purpose we use the Moodle content management system. Moodle has a lot of modules that allows a large set of e-learning activities: student registration and activity tracking, content management for courses and laboratories, chat, professor and student forums, assignment management, student continuous and final evaluation tools (questionnaires, tests and quizzes) and others.
In order to allow access to the measurement system within a single content management system, we have created a new activity module that can be integrated in the Moodle system to create a laboratory like activity. Laboratories which are created must be composed of laboratory equipment that can be accessed via Internet. Like other modules integrated in the Moodle system, our module use two interfaces, one for the administrator of the measurement system and one for students (each one has its entry point in the corresponding administrator or student view, see Figure 3. The measurement system administration can be done by one of the educators that are assigned for the laboratory works.

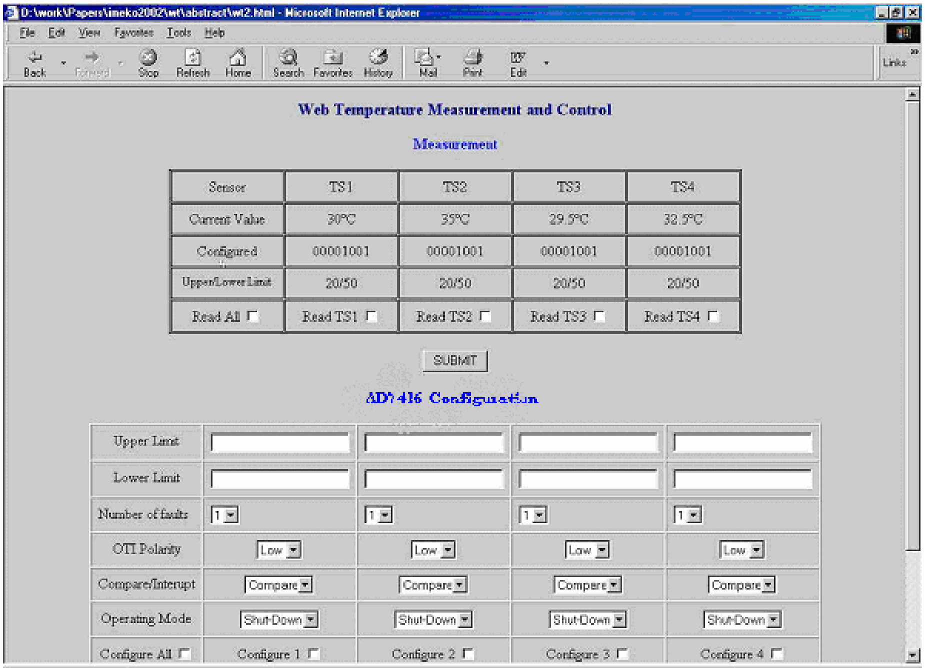
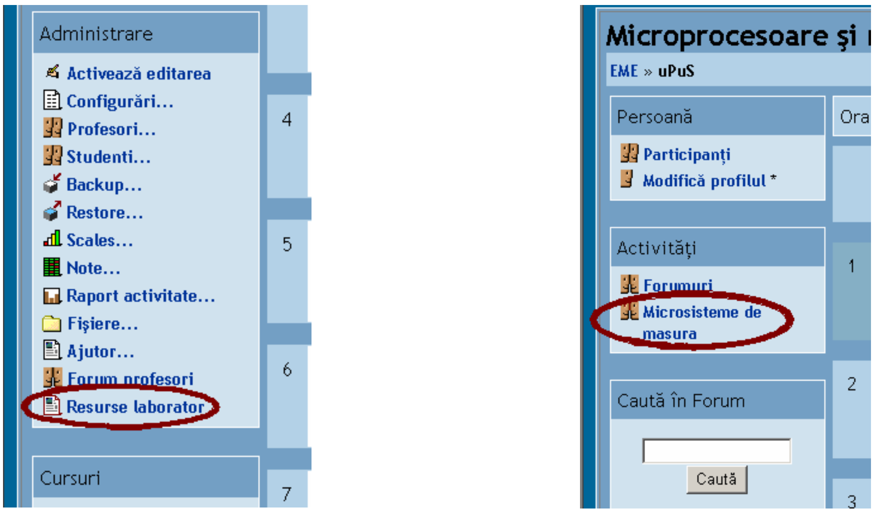


Figure 2. Web interface for AD7416 sensors.



a) b)
Figure 3. Laboratory resources entries for a) administrator, b) students.

Using the administration interface (Figure 4), an educator can create a laboratory set-up consisting of one or more devices connected to the Internet. For every device the IP of the server that control that device must be provided and, if applicable, the port to which the device is connected (usually a parallel or serial port). For each device, administrator will add a short description of the device and a picture of the device. Usually the picture will be that of the device or the evaluation board containing the device existent in the laboratory and which is familiar to the student.

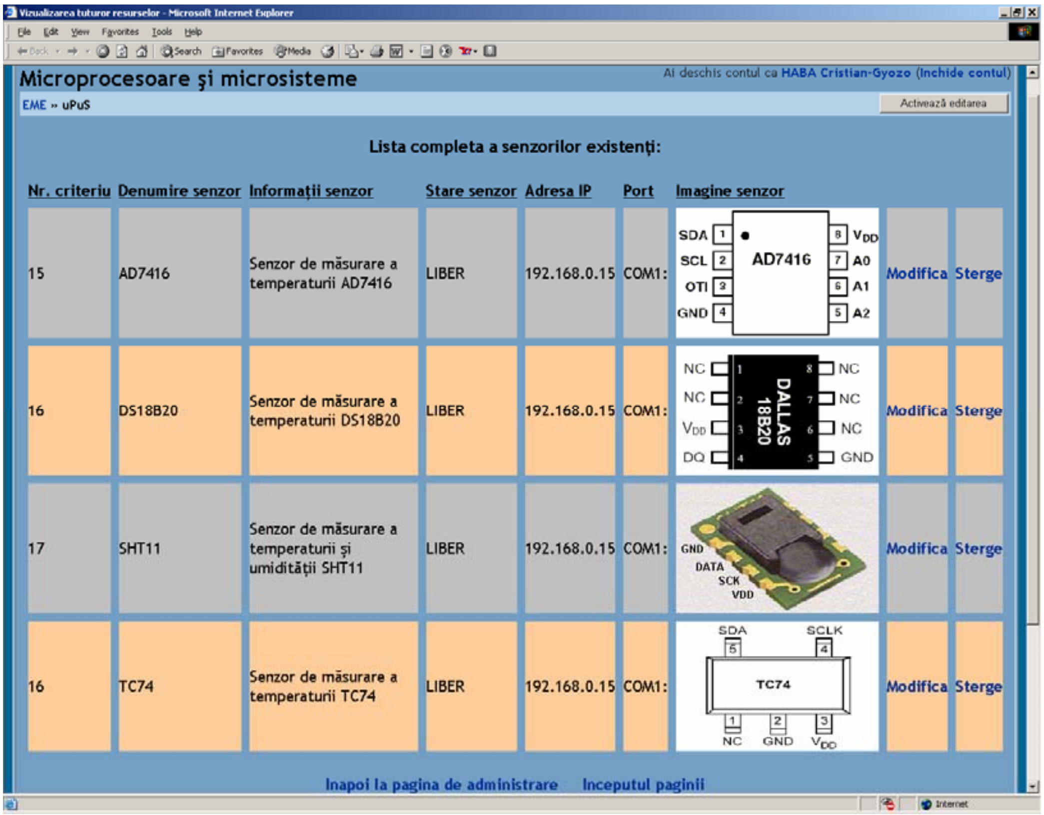


Figure 4. Administrator's page for management of available sensors in the measurement system.

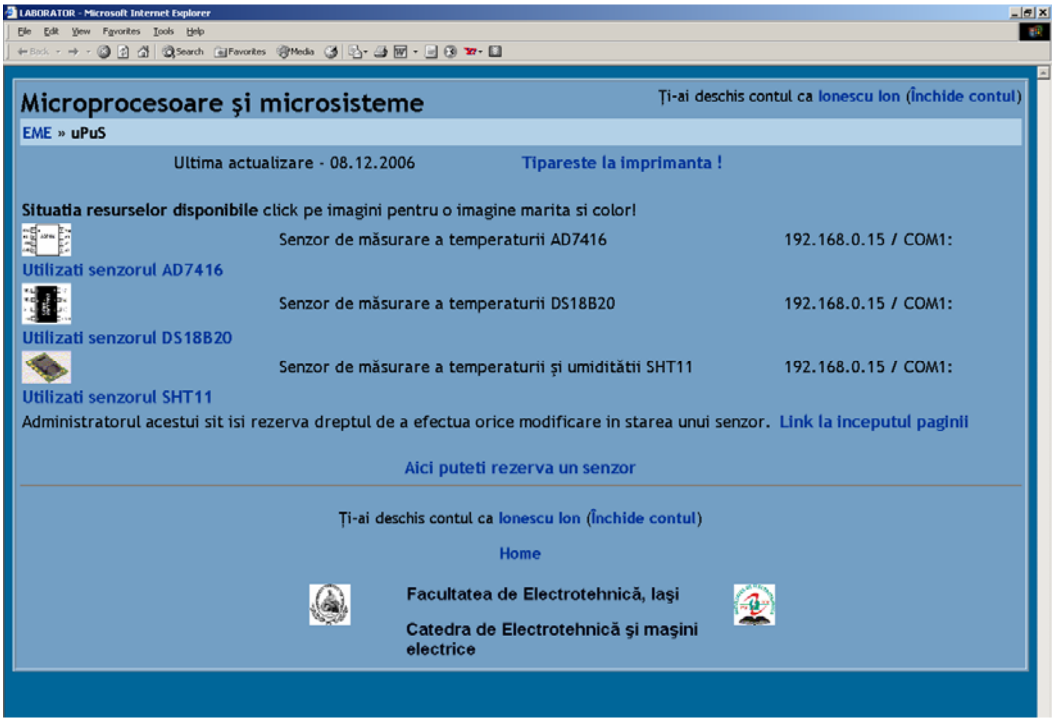


Figure 5. Student's view of the sensors not in use in the measurement system.

The administrator can add or delete devices, can change their IP or port and can make the device either available or not to the students.

Students interface (Figure 5) contains the list of the available sensors in the measurement system which are not currently used by other students and the links to these sensors web interfaces (for example that in Figure 2). In Figure 5, there are available only 3 sensors that can be used, one (TC74) being used by other student.

Using the same interface, student can make reservations at a later date for the sensors not currently available.

VII. Conclusions

We have presented an e-learning system based on a temperature measurement system which uses three temperature sensors and a temperature/humidity sensor. The measurement system is integrated in the content management system Moodle allowing educator to create a large set of e-learning activities related to temperature measurement, study of intelligent temperature and humidity sensors, communication protocols, distributed measurement systems.

Acknowledgements

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