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Modular Workbench for In-Situ and Remote Laboratories

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Abstract *– This communication describes a learning platform which is being developed at the Technical University of Catalonia (UPC) in Barcelona, Spain. The goal was to solve the trade-off between the need for performing real laboratory practices in engineering education and the emergent implantation of distance learning in our curricula. Most of our courses in Electronic Engineering have 50% of the load devoted to laboratory work. The semi-distance EE degree allows the students to carry out at home the theory and problems study but keeps the in-situ laboratories.*

We developed a previous remote laboratory [1], based on a VXI system, an experiments board and a web-server that is working since 2002 but which cannot serve simultaneous users and which is difficult to expand and maintain.

The workbench we popose intends to preserve the experimental work but allowing the students to perform a variable number of laboratory activities remotely, using the same platform than the in-situ laboratories. This approach preserves not only the feeling of reality but the knowledge of the experimental set-up features. The subject of the experience is the sensors and signal conditioning laboratory.

The solution is based on a modular set of electronic boards. Two kind of base or mother boards allow the connection of several daughterboards which implement the different experiments. One of the motherboards is only intended for in-situ experiments but the other includes an Ethernet capable microcontroller and A/D and D/A converters which allow the realisation of both in-situ and remote laboratory activities over the same set-up.

The microcontroller firmware is based on a command parser that accepts SCPI strings. The board is controlled through LabView drivers which use the TCP/IP sockets and the specific applications can be controlled using remote pannels in LabView 7.1 both in-situ and remotely. Access control, register and scheduling will be performed using the UPC virtual campus Atenea, which is implemented using Moodle (Modular Object Oriented Distance Learning Environment) [17].

Keywords *– e-learning, remote laboratory, smart sensors.*

I. INTRODUCTION

Laboratory courses with real experiments are necessary not only to develop skills but to attain in-depth comprehension of theoretical aspects in EE courses. The use of Information Technologies can provide means to extend these experiences to distance-learning students but also to enhance the conventional educational experiences and optimize the use of resources [2], [3]. Leaving aside virtual laboratories based only on simulation, there is a considerable amount of remote laboratories that provide real-time access to real instruments. There are educational research lines devoted to the study of is topic [4]. Most of the remote labs for engineering education are found in control [5],[6],[7] and electronics or circuit theory [8],[9],[10] areas. The aim of remote laboratories could be to provide complementary learning tools but also to give access to big equipments [12] or to fully implement the laboratory activities [13].

From the technical implementation point of view, most of the solutions proposed in the literature require the download or installation of software in the client computer (Java applets[6,8]; ActiveX [9], Visual Basic specific application [10], and in some cases subject to manufacturer license (LabView) [7]. The systematic structuration of the remote laboratory access and architecture in order to optimize the resources is receiving a big attention [14], [15].

The Telecommunication Engineering School of the Technical University of Catalonia (Telecom BCN) offers a semi-distance degree (Master level) in Electronic Engineering. Our aim is to achieve for students that combine professional activities with scholarship a similar level of theoretical and experimental training than reached by full-time students while reducing their physical presence at the university. Another objective is to reach a success rate for this kind of students comparable to the rate obtained by full-time students [11].

To complete and modernize the laboratory contents, and also to reduce the number of conventional sessions, we designed and implemented a remote workbench [1], which is based on a VXI system, an experiments board and a web-server that is working since 2002. The system security and the minimum data interchange with the studend were the main design criteria. A web-based interface provides parameters and gets data from a LabView experiments server. The system cannot serve simultaneous users and is difficult to expand and maintain. The access is controlled by password and the system does not implement users logging nor scheduling.

Given that most of our semi-distance EE students (>80%) are simultaneously working in the industry, there is a need to provide flexibility to the laboratory activity access. A solution which does not involve experimental load loss could be a modular laboratory which uses the same platform for in-situ and remote practices. The students could program their activities by alternating both type of practicals depending on their time availability.

II. PROPOSED APPROACH

The main field of application is the Sensors and Signal Conditioning [16] subject but is also used in Electronic

Instrumentation subject. The topics to cover will be thus related to understanding different measurement techniques, signal conditioning and acquisition, error compensation, systems calibration and data processing.

The requirements we have established for the laboratory design are the next:

- Remote sessions complementary to the conventional sessions and planned to optimize the use of time in the laboratory.
- Interactive structure: need for the student of performing additional data processing to access the different steps of the remote sessions
- Experiment control performed under LabView and user interface through LabView Remote pannels.
- User access, activity logging and activity scheduling guaranteed by the autentification of the users in the UPC virtual campus Atenea, which is based on Moodle.

A. System hardware:

The modular laboratory platform is based on a set of printed circuit boards. Each laboratory activity is implemented on a separate application circuit board (10 cm x 10 cm) which is connected to a motherboard from which power supply, analog and digital inputs and outputs and some of the adjustments are provided. The motherboards are implemented on Europa format (16 cm x 10 cm) cards (figures 1 and 2). There are two versions of the motherboard. Analog, intended for in-class laboratory activities with manual adjustments and Microcontroller-based, which includes A/D and D/A converters and an embedded controller which provides TCP-IP access to the acquired signals. This board will be used in some of the in-class activities and in all the remote activities.

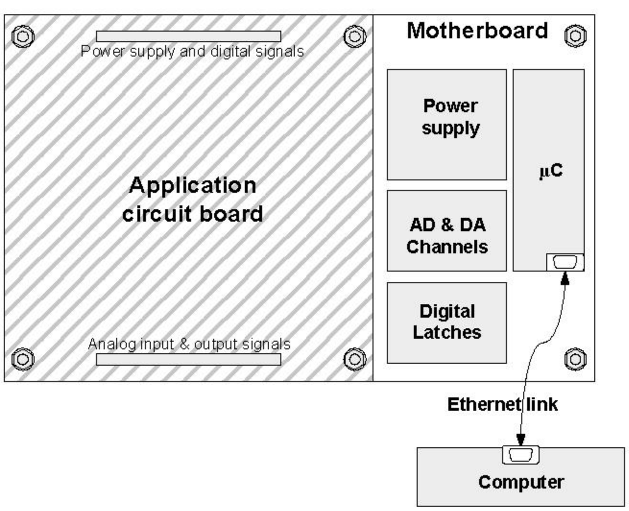

Fig. 1.- Mixed-mode motherboard with Ethernet link.

An embedded microprocessor, based in Rabbit RCM2200, controls the device's board via SPI serial comunication and allows to connect the board via ethernet using a RJ-45 port to to the laboratory server, who runs the Labview applications and displays the interested magnitudes in-situ or remotely.

The motherboard PCB includes the following devices:

- Rabbit Semiconductor RCM2200 microprocessor module.
- Analog Devices AD7734 four channels analog to digital converter (each channels with 16 or 24 bits configurable).
- Analog Devices AD5327 four channel digital to analog converter (each channels with 12 bits).
- ST Microelectronics M95256 expansion memory (256kb) with pinout compatible with larger memories for data-logging applications.
- Analog Devices AD780 voltage reference (2.5V) for A/D and D/A.
- Linear Technology LT1964 dc to dc converter with positive and negative outputs and shut-down pin.
- Linear Technology LT1521 positive linear regulator.
- Linear Technology LT1964 negative linear regulator.
- Analog and digital signals are buffered to protect the devices.

From a single 5V DC power input, ± 5 V are provided to the experiment board and 5V to the auxiliar digital circuits, being these power supplies enabled by the microcontroller.

The microcontroller firmware (under Dynamic C v9.10), implements a command parser that accepts SCPI commands via an ethernet link which configure the acquisition channels and output signals, acquires input signals in several modes and sends the desired information to the TCP/IP client. At the same time, personal computer hosts the LabView server, running specific software for each experiment processes the data transfered and controls the comunication. This software has been made using specific LabView drivers wich translate application measurement parameters to TCP-IP socket control strings commands.

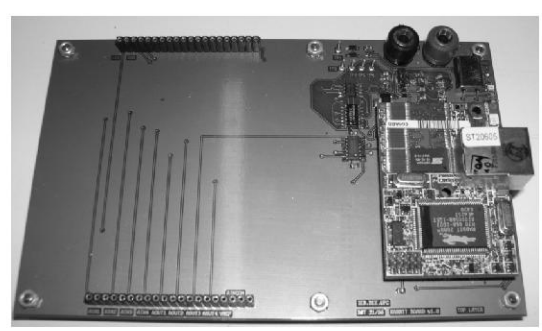

Fig. 2.- Mixed-mode motherboard with ethernet link

B. System architecture

The general structure of the system is shown in Figure 3. This part of the project is currently under development and is being tested along the current semester. Given the maintenance problems encountered with the previous system, the current approach is to minimize the interface applications and to rely on the University virtual campus structure for the access support. Some complements have been added (IP range restriction and validation to avoid access to experiment applications from outside the virtual campus).

The school's server updates the related information of all the students after the period of enrolment. Then, is only possible to the registered student, using his username and password, to access to the intranet and enter to the subjects area. Once inside after the validation, the student has avalaible the differents links, one for each experiment, which connect with the LabView server to make the remote activity (figure 4). Some remote activities are duplicated in differents boards to facilitate multiple access to the same experiment and to reduce the wait time. The student activity is logged and reported to the teacher. The reports are required as deliverables during a lapse of time through the same virtual campus.

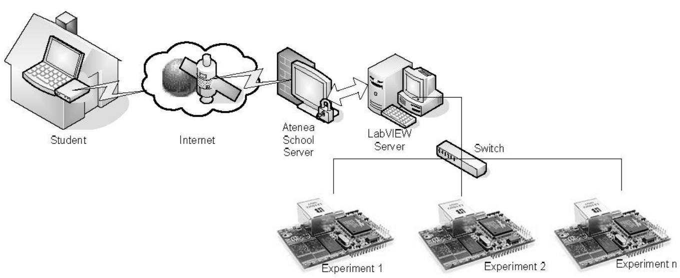

Fig. 3.- General structure.

After selecting the experiment link, the associated remote pannel appears in the student's web browser. The student runs the LabView remote pannel with a time limit specified by the laboratory master. To visualize and control the remote pannels through the web browser it is necessary to hold LabVIEW Remote Panel Servers Licenses for each simultaneous user, but they are inexpensive for academic institutions. A running LabView remote pannel avoids the capture by a second user while is being used and also limits the operating time. The rejected student is asked to try later in single realisation experiments or to link to a replica of the same experiment. Each experiment board is identified by the system using its TCP/IP address.

In real time, the student receives the data information through the LabView Webserver. This system allows to the student to compare the theorical results of previous calculations, to the real results. Most experiments need for a double access to the system. A first access to get data from the experiment and a second access to re-configure the system with parameters calculated from data processing and get new data.

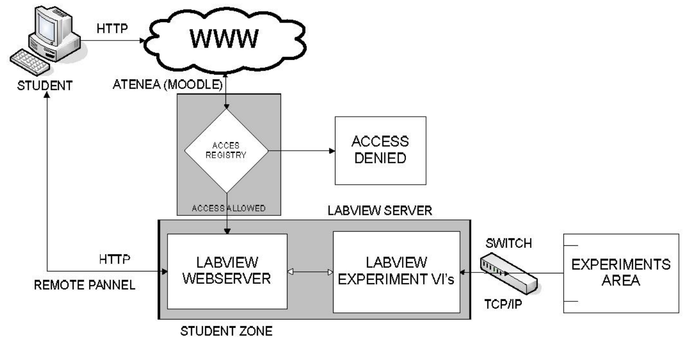

Fig. 4.- Resource organization

III. RESULTS

As a result of this project we considered the implemented experiments and the way they are used by the students.

Some of the laboratory activities can be only performed in-situ:

- pH signal conditioning and temperature compensation
- Design and calibration of a 10 kg F.E. scale. The calibration, zero and full span, is performed in two steps: first with manual adjustments and second inplementing an automatic calibration strategy through the D/A, A/D, processor and Labview software.
- Signal conditioning for a capacitive sensor including non-coherent and coherent AC detection techniques.
- Cooperative activities (multisensor data fusion) could be performed with this structure.

Other laboratory activities allow both in-situ and remote realisation:

- Characterization of pressure sensors: static characteristic, linearity error, hystheresis. Pressure changes are produced by a linear stepper motor connected with a pneumatic piston (figure 5).
- Software assisted calibration (zero and full span) of a PT100 thermometer by switching resistors that emulate 0ºC and 50ºC temperatures.
- Characterization of a thermal system based in a Peltier cell and aluminium block with different temperature sensors (figure 6).
  - Open loop system response identification
  - PID controller tuning
  - Static characteristics of a NTC thermistor and two PT100 connected to different conditioning circuits.
- Configuration and acquisition through a TI-Burr-Brown PGA309 programmable sensor conditioner.
- Smart sensors management using IEEE 1451.2

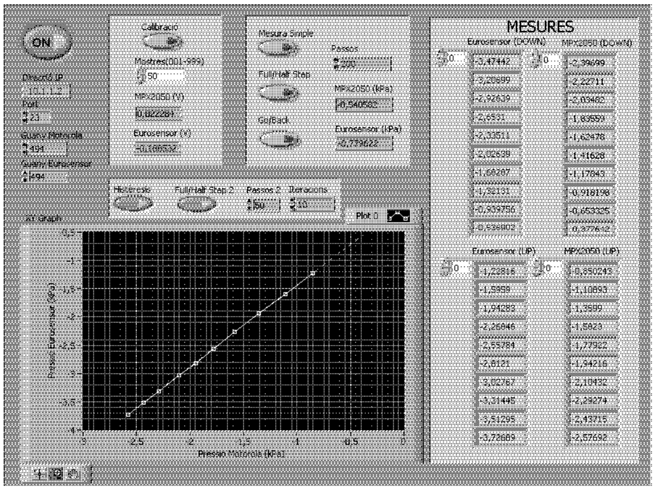

Fig. 5.- Remote pannel for the characterization of pressure sensors

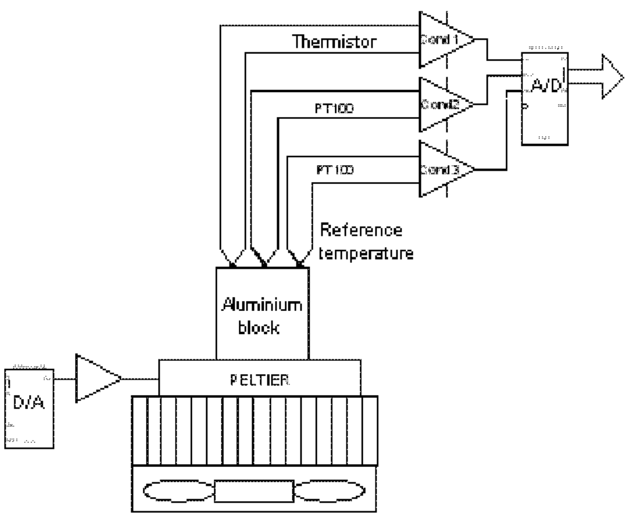

Fig. 6.- Block diagram of the of the thermal system characterization setup.

IV. CONCLUSIONS

There is a considerable amount of remote labs and plenty of simulated, virtual labs. The aim of our work was not the definition of an original solution but the implementation of a remote laboratory that solved our educational needs. The resulting design offers a set of features and characteristics that differentiate this remote lab from others and, from our point of view, presents several advantages:

- Specifically focused to Instrumentation and Signal Conditioning for Sensors.
- Remote sessions planned as a complement to normal lab sessions, allowing the separation between the experiment success and the data collection and processing.
- Interactive structure of the remote sessions, with an initial data collection, experiment set-up from the students' calculation results with these data, and final data collection with modified parameters.
- Remote sessions planned to allow both in-situ and remote realisation, providing flexibility to students that are simultaneously working in the industry.
- System access not depending on the laboratory resources but on the University virtual campus

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