Hardware Implementation of Remote Laboratory for Digital Electronics

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Abstract— **This short paper presents a new hardware system that lets develop labs of Digital Electronics. The system is focused on the verification of logic functions, so teachers can create new experiments only changing the problem proposed, within the range of input variables and output functions that system supports. The students have to solve the problems finding and simplifying the functions. Then, they must implement the results in the proposed system.**

Keywords - logic design; laboratories; practice assesment

I. INTRODUCTION

This paper shows how an experiment about realization of logic functions using logic gates can be performed with a flexible, computer based hardware. This system is initially designed for used in remote labs, but can also be used “in-situ” for normal labs.

This work is a demonstrative part of the Project S-Labs “Open services integration for distributed, reusable and secure remote and virtual laboratories”, sponsored by Spanish Ministry of Education and Science. The main objective of this Project is to integrate technologies for learning theoretical and practical using any Learning Management System (LMS) [1].

The proposed system has several characteristics that make it different from other existing remote laboratories.

First, the experiments can be performed using the services offered by the LMS used by any University involved in this project. Then this remote laboratory will be a new resource, like other material published in Digital Electronics Courses over the LMS’s. With this feature we don’t need to create again the basic services that a remote laboratory uses, like administration, content packaging, etc., because they are included in all LMS.

For teachers, has the advantage of being able to share the laboratory between different departments or Universities, with little investment and, of course, a sharing policy. Then the system can be fully productive.

For students, the main advantage is the use of the familiar environment provided by the LMS, so make remote practice becomes easier.

On the other hand, the second important feature is that the system allows the realization of logic functions without restrictions, so you can perform many different practices. With few changes you can prepare different experiments for different groups of students, or you can change the remote practice from one course to another, avoiding that student’s lab results could be passed on to “next year” students [2].

In the following paragraphs of this paper will be listed the objectives to be achieved with this laboratory and the physical description for the elements of the system.

II. OBJECTIVES

The main objectives of this work are:

- Get flexible and reusable systems for remote labs.

  The laboratory proposed is very flexible: the professors of different courses can implement different practices even at the same time. Also the system can be used for other kind of practices, for example to check a given logic function or to study maxi- and miniterns.

- Enhance the students’ skills in logic design.

  With this tool the students can test any function they obtain in the problems that the professor proposes. They can test their solutions in real hardware with real results, instead of simulations.

- Enable the students to control the experiment.

  There are remote labs that are like “black box” for the students. We try to show them all the process involved in the experiment, and avoid any component that can be difficult to understand for beginners in Digital Electronics.

- Get an adequate use for the remote labs.

  If the equipment needed for the remote lab is used only by one group of students in a University, the ratio between material and personal cost and use of laboratory is poor, because it will be used only one or two weeks a year. Sharing the lab between several courses and Universities will increase this ratio.

- Get a cost reduction in remote labs.

  The equipment needed for a remote lab can be expensive [3]. In this approach, we use elements that can be achieved at an affordable price.

III. DESCRIPTION OF THE SYSTEM

To achieve the objectives listed below, we are developing a hardware set and the computer programs needed for the control of the hardware. The system is an evolution of another one developed to teach practices "in situ" [4]. The system is a useful tool for the students, which have the opportunity to experiment with digital circuits outside of the laboratory. In the following paragraphs we explain the hardware components and the software programs needed to build this new laboratory system.

A. Hardware set

The physical system has four main parts. In Fig. 1 you have a block diagram of the whole platform:

- A computer.

  The main tasks for the computer are the control of the correct performance of practices and the lab server. It receives the logic function to be performed, set up the function board which will be described in the next paragraph and sends back the functions results.

  The computer selected for this purpose has special specifications. Thus, being a computer that will operate 24 hours a day must have reduced power consumption. On the other hand, a small and low-cost computer will be the better option.

  We have chosen for this remote lab a mini-ITX mainboard [5]. The Mini-ITX form factor (just 17 cm x 17 cm) is designed to fit in the mounting points of a standard ATX board, enabling to use a standard case to fit all the system components. The Mini-ITX embedded boards are used on a variety of applications: in-vehicle computers, digital kiosk and advertisement, Network Attached Storage (NAS), etc. The main features of these boards are: X86 architecture, low power consumption, rich integration (LAN 10/100, USB, Serial, ATA, SATA, PCI connections, etc.). For our purposes, the most important are the consumption and the USB and PCI connectivity. We used a fan less VIA EPIA 6000 board with a Compact Flash based Solid State hard disk for storage, giving a reliable and cost effective platform without mechanical parts.

- The function board.

  This is the circuit that performs the logic functions. It's based on LSI integrated circuits, and its main parts are an AND gate array followed by an OR gate array, with programmable connections between the two arrays, and also between inputs and the AND array. The state of the switching matrix is stored in a memory builded with shift registers that control directly the switches. Fig. 2 shows the diagram for this board. This configuration for a circuit that performance logic functions is intuitive, because is like the wire diagram that students can write. We prefer this more complex approach instead of the use of a field programmable gate array (FPGA) because the FPGA is like a "black box" for the student, and its more complicate layout probably will be inaccessible for beginners. In addition, the use of FPGA forces students to make programs that probably needs more knowledge of digital electronics that they have. With this circuit you can generate a modest performance: up to 4 functions of 4 variables each, sufficient for the most of the practices.

- A digital acquisition board.

  This board has two different tasks. First, the card programs the logic functions to be performed in the function board, putting into the memory the switch configuration. Second, several of his digital lines enters the values of the variables into the function board and others read the generated functions and send the results to the computer.

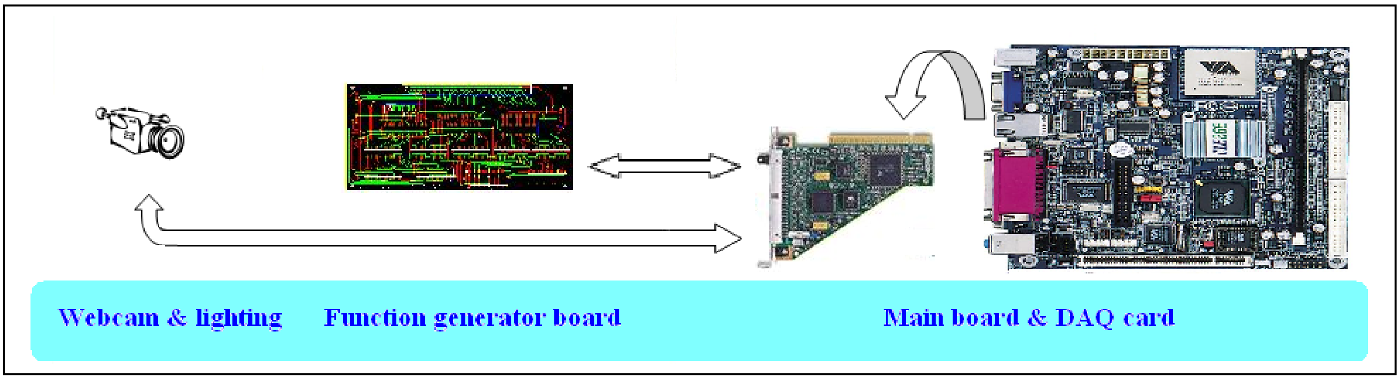

Figure 1. Block diagram for the hardware.

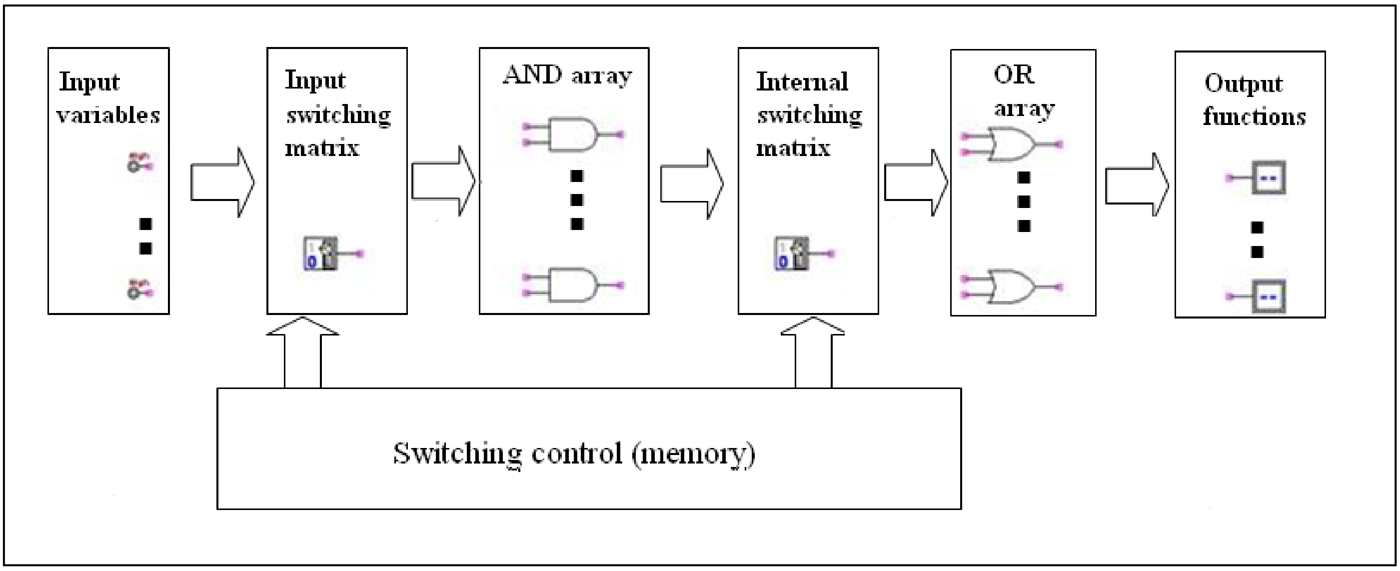

Figure 2. Block diagram for the function generator card .

For this prototype we have chosen a NI-PCI-6503 acquisition board from National Instruments [6]. This is an acquisition card with 24 digital input/output lines organized in three 8 bit ports, and PCI connection to the computer. The board is in the basic range for this manufacturer, and its price is low compared with other solutions. For our purposes, one port is used as output and sets up the four variable values, other port is set up as input and his four lower bits reads the functions results and in the last one several bits are set up as output to put the switch values into the memory and others act as inputs for handshaking.

- A webcam.

The webcam is used to receive visual feedback from the function generator circuit. The circuit has LEDs for inputs and outputs. A view of the circuit lets the students check out the state of the variables and functions. There are no moving parts in the circuit, and the changes on the LEDs state are slow, so a rate of one frame per second is enough for our purposes. The webcam have extra illumination with LED lighting that only goes on when an experiment is running.

All these elements are housed in a desktop PC case, so that the laboratory is a compact set well isolated from ambient light interference and possible mishandling. Figure 3 is a set of pictures of this prototype.

B. *Software*

If we want to run this lab in a remote way, we need two software applications. This paper is really focused on the hardware, but it is necessary to point out some aspects of the software.

The server software application is now under first stage of development. The main tasks of this software are:

- Receive the functions to be performed. The format used for the functions representation is a vector containing all the variables and its opposite, e.g. A and $\overline{A}$, being $\overline{A}$ =NOT (A). If a position have a

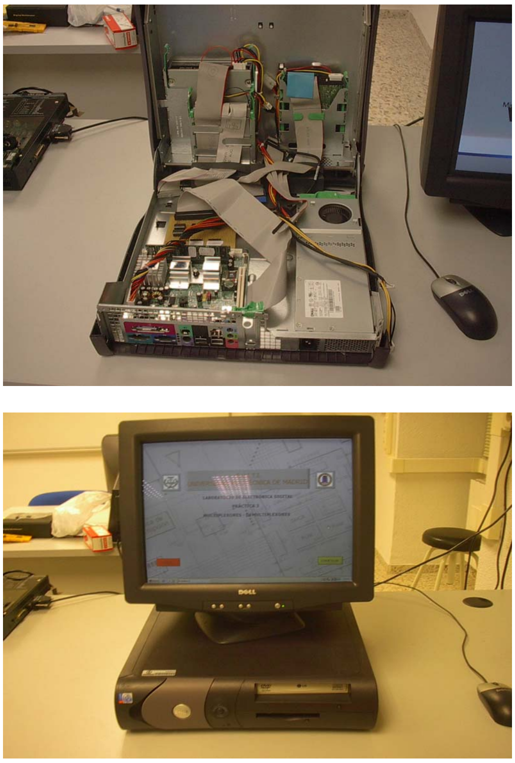

Figure 3. Photographs of the prototype.

"1", the variable is present, if have a "0" not. An example could be the following function:

$$F = B\overline{C} + A\overline{B}C + \overline{A}D \qquad (1)$$

That can be represented as:

$$F(ABCD\overline{A}\overline{B}\overline{C}\,\overline{D}) = 01000010$$
$$10100100 \qquad (2)$$
$$00011000$$

- Program the switches. The software takes the vector representation, like the example shows in (2), and programs the switching matrix according to the function. Every value of an element of the vector is an input switch, and the number of elements of the vector determines how many internal switch will be closed.
- Put input values on the variables. Once the functions are programmed, the user can select one input variables combination to be sent to the function, and the software will put these values in the function generator card inputs.
- Take output values of the functions. The acquisition card reads the results from the functions implemented in the function generator card and sends to the user for verification.
- Makes the truth table. If it is desired, the software can build the truth table for the functions.

This software has been developed in Labview environment [7] [8]. This developed software kit allows an easy communication with the DAQ card, and has been used in older similar projects [4].

The software can add new features to improve the system, or even to change its functionality. For example, with a new version of software we can transform the remote laboratory in an "in situ" laboratory. With this example version, the students could build the switch matrix by themselves selecting in a schematic view of the function generator board the state of all the switches.

On the other hand, the remote laboratory needs to be connected to one or several LMS to be useful for students. This feature can be achieved if we define, design and develop a middleware capable of communicating an E-learning platform with the laboratory, as shown in Fig. 4. The LMS environments arise as distributed systems and must operate in real time processing of data from heterogeneous systems, databases, directory services and applications, and integrate with other environments. To be able to integrate all these pieces is necessary an universal medium, neutral with regard to the platform, to describe, transport and transform data between distributed systems: XML. Using XML as a standard representation would develop multiple types of interfaces based on other technologies such as AJAX or dotNET that have interactive components lighter burden in terms of their own Java applets.

IV. AN EXAMPLE OF USE

With the system proposed, the students can check their knowledge for solving problems that involve digital logic. The professors will put on one or several LMS's courses problems about logic design. When a student access to the LMS's course, there will be two links, at least, along with other LMS services (chats, forums, contents of course, etc.). When the students click on the first link a proposed problem will be shown in a frame of an LMS. Then he will have to find the relationships between variables and functions and to obtain the corresponding truth tables. Finally, he will have to simplify the

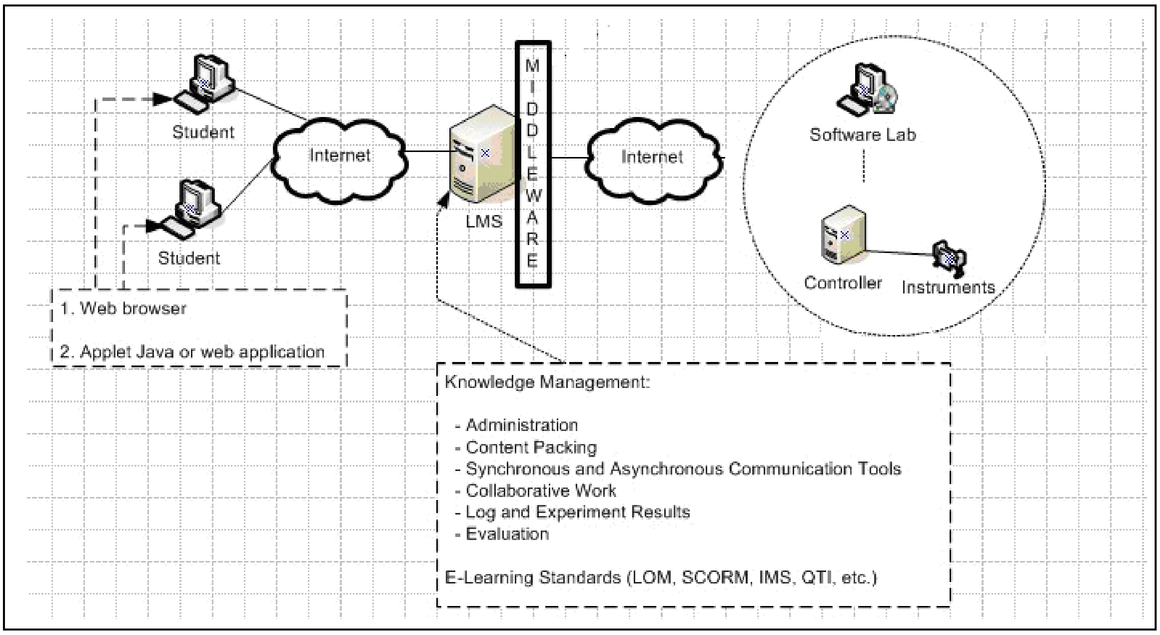

Figure 4. Integration of LMS with remote laboratories.

functions using any method (e.g. K-maps). Once the problem is done by the student, he goes back to the second link and the student can enter the remote laboratory through LMS`s course and intro the functions obtained. A comparison between the truth tables obtained and the ones offered by the remote laboratory will be the final result of the experiment. The log file of the sessions helps the professors to evaluate the student skills. It important to say that the students beside of working with the problem and the remote lab, he can use the services offered by LMS as chats forums, etc.

V. CONCLUSIONS

A remote laboratory developed to check digital functions has been presented. At this moment, only hardware is on an advanced step, therefore not been possible to obtain results of its application in a group of students.

The main features of this approach are:

- It's a laboratory designed for use inside any LMS.
- It's a low cost, low power consumption system.
- Simplify the implementation of truth tables.
- It's very versatile.
- It can be used "in situ" only with a new software development.
- It's open to future developments.

VI. ACKNOWLEDGMENTS

This work has been developed inside the framework of the S-Labs ("Open services integration for distributed, reusable and secure remote and virtual laboratories") Project, supported by the Spanish National Plan for R&D (2008 – 2011) of the Science Ministry. Our thanks to all the people involved in this Project.

The authors would like to thank the help of the students who have worked in the early stages of design, especially Fernando Ortiz Benito and Jesús María Gutiérrez Calzada, and those who have tested the system and provided critical feedback on their performance.

Also we would like to acknowledge the help of the UPM and the UNED for the publication and attendance to the conference.

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