Measurement 82 (2016) 123–134

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Remote measurement and instrumentation laboratory for training in real analog electronic experiments

Unai Hernandez-Jayo *, Javier Garcia-Zubia

University of Deusto, Av. Universidades 24, 48007 Bilbao, Spain

ARTICLE INFO

Article history:
Received 7 February 2015
Received in revised form 18 November 2015
Accepted 14 December 2015
Available online 30 December 2015

Keywords:
Remote laboratory
Instruments control
Distance learning
Analog electronics

ABSTRACT

A new system for building and measuring real analog electronic circuits has been developed and validated in the area of remote laboratories. The innovation of this work lies in the use of standardized solutions and non-proprietary solutions for designing and developing remote labs. This decision facilitates and improves the set-up, maintenance and update of the hardware used during the configuration, control and measurement of the instruments and experiments included in the lab. The experimental setup does not reduce the performance of the lab, allowing the users to carry out the same actions and activities as if they were in a hands-on laboratory. This paper describes how this application has been designed and developed, starting with an introduction to the requirements and motivations of this work, following with the description of the proposed architecture. The validation of the prototype that has been built to test the application concludes the presented work.

1. Introduction

Practical exercises and experiments are fundamental in any technical discipline either in educational or investigation areas. Using the words of Ingvar Gustavsson (inspired in Max Planck):

> *"Experimenting could be compared to a conversation with nature. The experimenter asks and nature answers. The tricky thing is formulating a useful question and above all interpreting the answer. The only way to learn the language of nature is performing many experiments in laboratories that can be hands-on or remote."*

To achieve that, the easiest way to implement these activities is to go to hands-on laboratories, which offer real hardware, instruments and experiments. However, sometimes many of these experiments require special and expensive instruments or the number of equipment units is insufficient for all the potential users due to their size or maintenance requirements.

Alternatively, virtual laboratories, simulators and remote laboratories can play a key role in teaching specific areas of technical courses such as analog [1–6] or digital electronics [7,8], and other disciplines such as radio communications [9] or automatism and instrumentation control [10–12]. While virtual laboratories can be used in certain experimental activities where simulation may be enough, they are not as effective as the laboratories in which users can play and interact with real equipment [13], according to the learning-by-touching or active learning approaches [14]. Moreover, according to the Accreditation Board for Engineering and Technology (ABET), practical exercises should help students achieve a set of competences that virtual labs cannot satisfy [15,16] .

In a remote lab, the workbench is not in front of the student, because it is instead provided through the Internet [17]. Using this approach the experiment can be performed anywhere there is an Internet connection (at home, on the street, at a café...). As del Alamo said "If you can't come to the lab... the lab will come to you" [18].

* Corresponding author.
E-mail addresses: unai.hernandez@deusto.es (U. Hernandez-Jayo), zubia@deusto.es (J. Garcia-Zubia).

http://dx.doi.org/10.1016/j.measurement.2015.12.017
0263-2241/

A remote lab can be defined as an educational resource that allows the access to practical learning materials through the Internet, making possible the configuration, control and/or monitoring of the physical parameters which occur in a real experiment, going further than passive experimentation platforms where user only can observe how the experiment is executed or virtual interfaces based only on simulations [21].

Then remote labs do not pretend to be a substitute of hands-on lab, but a complement of them and an active learning tool at the service of teachers and students. Therefore, the use of remote labs can be completed with other resources as simulations or virtual scenarios according to the requirements and needs of the teachers and learning outcomes to be achieved by the students.

There are remote labs for many different scientific and technological areas [13,19,20], but this paper is devoted only to analog electronics, describing an approach for the design of a control, measurement and configuration system of electronic circuits to be deployed in remote laboratories. Thanks to this approach, users can build experiments based on real circuits and carry out measurements on them with the typical instruments of an electronic workbench: oscilloscope, function generator, power supply and digital multimeter. The analog electronics area is of particular interest because its main technical objective is to measure a circuit with instruments, and this activity can be affected by the instruments themselves and by the Internet connection using in the remote lab.

Knowing that the main challenges of a remote lab can be grouped into technical or didactical, this work has been faced from the technical point of view because the use of the VISIR (Virtual Instrument Systems in Reality) platform, on which this application is based, has already been validated as an educational tool in other works [22–24]. Then it can be assumed the conclusion of Marques et al. [22] that asserts that VISIR lab (referenced as Native-VISIR in the rest of the paper) is a good learning tool when it is combined with hands-on labs because it provides one scenario where students can practice freely and autonomously in order to feel more confident when they face real experiments and practices. This assertion also can be supported by the work of De Jong et al. [25], that concludes that the combination of virtual and physical experiments allows students to gain a more nuanced understanding of scientific phenomena and a more understanding of inquiry.

This paper is structured as follows: Section 2 presents the main requirements for the deployment of analog electronic remote labs aiming to the goals of this work. Section 3 introduces the architecture proposed while Section 4 steps through the process of its validation in a real remote lab. Finally, Section 5 presents the conclusions and future work.

2. Requirements of remote laboratories in analog electronics and motivations

Although in 2000, Soysal [26] established that remote labs were not an optimal solution for experiments with analog electronics, the main goal of a remote lab this area is to reproduce remotely as faithfully as possible the actions that the user carries out during a local lab session (Fig. 1):

1. The student builds the Circuit Under Test (CUT) whether provided or not by the teacher of the course.
2. The student configures and connects the available instruments to the CUT.
3. Thanks to the instruments, the output measurements are displayed and monitored.
4. The student analyzes the outputs and performs modifications over the CUT in order to obtain the results requested in the practical exercise.

In the particular framework of analog electronics, it can be established different kinds of remote labs according to the control and interaction levels that they offer to the users:

- Level 1. Remote labs in which users can control special instruments to carry out specific experiments. One example of these labs is the iLAB Microelectronics Device Characterization Lab [27,28].
- Level 2. Remote labs in which the user can make practical exercises only with predefined or prebuilt experiments. This is the case of the ISILab [4].
- Level 3. Remote labs where the user manages to modify certain predefined parameters in the Circuit Under Test (CUT) as in the RemotElectLab [29].
- Level 4. Finally, remote labs in which the user has the chance to build a CUT from the beginning using the discrete electronic components provided by the lecturer before a lab session, as in the VISIR or NetLab [30,31].

Each of these remote labs presents particular characteristics which define its performance and level of user interaction in the lab. Thereby, depending on the deployed control and measurement system, the user can define, implement and carry out real measurements at any point on the CUT (Level 4) or he/she is restricted to monitor and visualize how the experiments are executed without any interaction activities (Level 1).

From the afore mentioned platforms, the VISIR and NetLab are the ones enabling all the steps mentioned above and which are required in an experimentation process. From the user's point of view, VISIR allows the user to create complex circuits, its interface is immersive and it allows multiuser access. VISIR is the conceptualization defined by Professor Ingvar Gustavsson in BTH (Sweden) and is being using as learning tool by 8 educational institutions [32]. Due to this fact VISIR is considered as a reference platform in the field of remote labs for analog electronics [20,21].

Under this scenario, the aims of the work presented in this paper result from the analysis of the performance, availability and the cost of new electronics technologies and our experience deploying and using the Native-VISIR platform. Thus the main goal of this work is, by starting with the statements defined by the Native-VISIR [30], to overcome its drawbacks, and to put forward a methodology that allows the deployment of a remote lab with the following characteristics and requirements: