X Congreso de Tecnologías Aplicadas a la Enseñanza de la Electrónica
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XUNTA DE GALICIA

Putting Fundamentals of Electronic Circuits Practices Online

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***Abstract*—Fundamentals of electronic circuits' practices have a central role in all the electrical engineering education disciplines. They teach the student the basics of electronic circuit's components and the adjustment of electrical instruments, and allow him to wire and build circuits in order to realize and monitor measurements. Unfortunately, and despite the importance of this type of practices, they are not usually available at many universities owing to geographical, cost, and time constraints. With the evolving of communication and computer technologies, and the advent of E-Learning, it was possible to vanish these constrains by the powerful tools provided by E-Learning, among them the remote laboratories. Thus, recently, many universities have shifted from traditional hands-on laboratories to remote laboratories in order to tackle these constrains bringing fundamentals of electronic circuits practices on-line to students. This has allowed students to access the lab at any time and from anywhere and to design, wire and measure electronic circuits remotely, achieving a significant increase in the lab availability and cost reduction. This paper reports on the current trends in remote laboratories for fundamentals of electronic circuits practices, pointing out significant projects such as Virtual Instrument Systems in Reality (VISIR), NetLab, and remote labs based on NI ELVIS II, which have been successfully adopted at many universities and deployed in the electrical engineering curricula. The paper, also, addresses other common independent approaches based on Data Acquisition Systems (DASs) in combination with measurement and control environments, such as LabVIEW and MATLAB.**

Keywords-component; VISIR, NI ELVIS II, NetLab, electronics, remote laboratory

I. INTRODUCTION

Fundamentals of electronic circuit's practices encompass the basics of electronic circuit's components such as resistors, diodes, capacitors and inductors. As well, the adjustment of electrical instruments such as power supply, function generator, oscilloscope, and multi-meter, and wiring and building circuits in order to realize and monitor measurements. Thus, they have an intrinsic role in electrical engineering education. Remote laboratories have made this type of practices affordable and accessed at any time and from anywhere. Remote laboratories are those laboratories that can be controlled and administrated online. The common generic architecture design of remote laboratory is shown in Figure 1. The user interface is the virtual end-user workbench that handles all the lab administration process. It is a web site that runs on the user's web browser and usually requires a server-side programming language to retrieve user's data from database, along with a Graphical User Interface (GUI), which is built by an animation technology embedded in the HTML code to resemble the real lab workbench. The webserver hosts the web site and the database files and sends the user requests to the lab server in the form of XML messages through TCP/IP model over HTTP layer. The lab server hosts the instrumentation control software and it is connected directly to the instruments. The instrumentation control software sends commands to the object under control with regarding to the received requests from the user.

In this paper, different scenarios for development of remote laboratories for fundamentals of electronic circuits' practices are going to be discussed. The paper addresses the development stages and highlights the main features and objectives of the most outstanding solutions. The addressed solutions are: NetLab and VISIR projects, both are remote laboratories, deployed at several universities, for wiring and measuring electronic circuits; remote laboratories based on the versatile design and prototyping educational platform NI ELVIS II, along with developed applications examples at several universities; and finally other common approaches based on Data Acquisition Systems (DASs) in combination with measurement and control environments, such as LabVIEW and MATLAB.

The paper is structured as follows: Section II discusses the NetLab project. Section III discusses the VISIR project. Section IV discusses the NI ELVIS II project and its adoption

Figure 1. Generic architecture design of remote laboratories.

in remote laboratories applications. Section V addresses other remote laboratories approaches for fundamentals of electronic circuit practices. Finally, a conclusion is derived in Section VI.

II. NETLAB

The NetLab [1, 2] project has been developed at the Iniversity of South Australia (UniSA) since 2002. It is a remote laboratory project that allows electronic circuit's wiring and measurement. The available components are: resistors, capacitors, inductors, transformers and programmable variable resistors. Other components can be easily added or removed. The General Purpose Interface Bus (GPIB or IEEE-488) instruments (an oscilloscope, a function generator, and a multi-meter) are connected to the lab server and also connected to a 16x16 programmable relay switching matrix from Agilent [3] that switches the connection between the components and the instruments. The switching matrix is connected to the server via RS-232 protocol and to the components via Inter-Integrated Circuit (I^2C) protocol. Figure 2 shows the NetLab set-up. The lab server software is written in LabVIEW and uses a Virtual Instrumentation Software Architecture (VISA) [4] Application Programming Interface (API) to direct the commands to the appropriate programmable instrument. The VISA API allows LabVIEW [5] to communicate with various hardware devices, based on VISA standard, using connections from the same software interface. The software application is written in JAVA; therefore, the Java Runtime Environment (JRE) must be installed on the user-PC to allow the NetLab application to run. A Web-Cam is included, which has its own web server and is fully controllable by the user. A Chat window is provided within the software application as shown in Figure 3, for communication and collaboration during the online lab sessions; it displays the names of all logged-on users, including administrators. A booking system is also provided within the software application. NetLab supports are limited to a maximum of 16 two-terminal components.

III. VIRTUAL INSTRUMENT SYSTEMS IN REALITY (VISIR)

The VISIR project [1, 6-8] was launched at Bleking Institute of Technology (BTH) in Sweden by the end of 2006. It is an open source remote laboratory project that allows electric and electronic circuit's wiring and measurement on a breadboard. The PCI eXtensions for Instrumentation (PXI) [9] instruments (an oscilloscope, a power supply, a function generator and a multi-meter), from National Instruments [10], are connected to a relay switching matrix and altogether are connected to the lab server. The relay switching matrix is a stack of PCI/104 [11] sized boards (instrument and component boards), fabricated at Bleking Institute of Technology (BTH), which acts as a circuit-wiring robot. Each instrument board handles the connection of the terminals of its corresponding PXI instruments. Each component board can hold up to 10 two-terminal components (or 6 two-terminal components and 8 single terminals of any component or complex circuit to be added). The matrix can hold up to 16 component boards. A common 10 nodes propagates across the entire matrix, and on which the instruments and components terminals are connected to build a circuit. The lab server software is written in LabVIEW. An additional measurement server (written in Visual C++) is added to verify the circuit parameters before being passed to the lab server and thus, to prevent hazard connections. The website is written in PHP/MySQL and includes a booking system and different account types, e.g., administrator account, teacher account, student account, and guest account. Each account has its own privileges and limitations. The GUI is written in Adobe Flash, where the entire workbench is simulated and the wiring is done on a virtual breadboard. VISIR software is IVI (Interchangeable Virtual Instrument) [12] standard Compliance to allow choosing different instrumentation platforms and different virtual front panels. VISIR is shown in Figure 4; the student connects to the lab online and wires his circuit through a virtual workbench to be executed and transformed into a real circuit by the PXI platform and the relay switching matrix. Then the results are received by the students on his virtual workbench. In [13], VISIR is developed with LAN eXtensions for Instrumentation (LXI) [14] platform to reduce cost and increase flexibility. So far, six universities have already implemented VISIR after Blekinge Institute of Technology (BTH): Carinthia University of Applied Sciences and FH Campus Wien

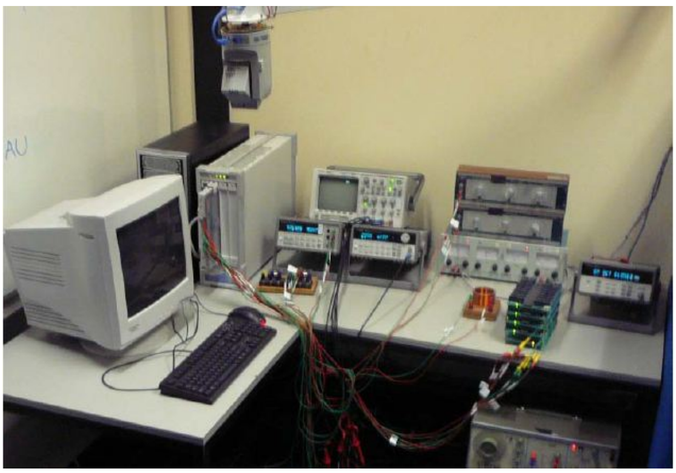

Figure 2. NetLab

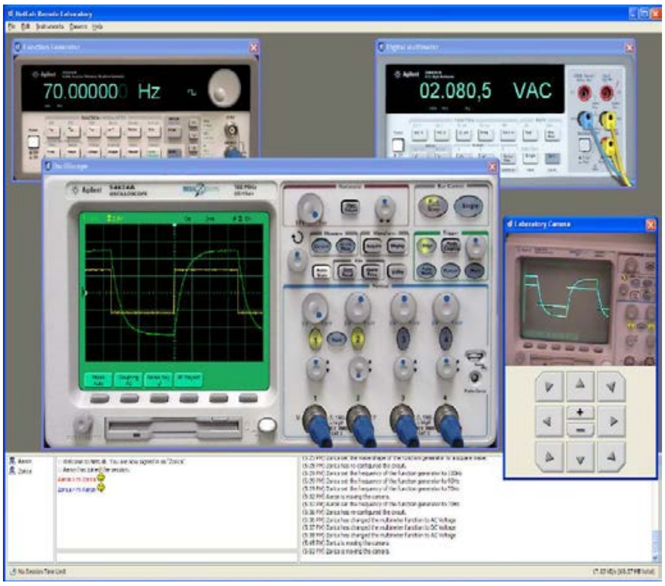

Figure 3. A Chat integrated in the GUI of NetLab.

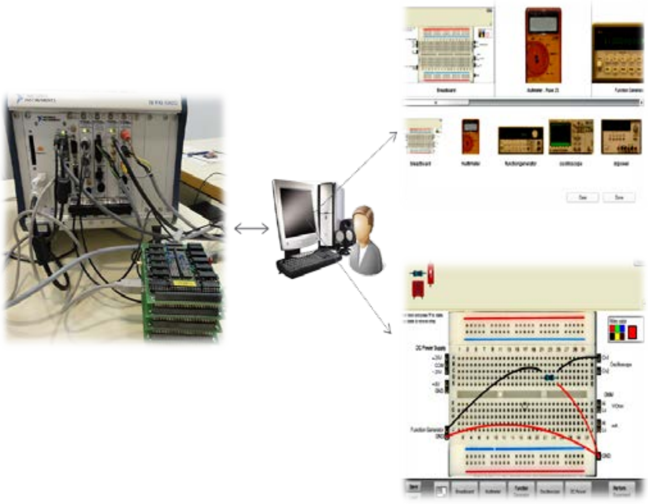

Figure 4. Virtual Instrument Systems in Reality (VISIR)

University of Applied Sciences, both in Austria; Polytechnic Institute of Porto (ISEP) in Portugal; University of Deusto and Spanish University for Distance Education (UNED), both in Spain; and Indian Institute of Technology Madras (IIT-M) in India. Among these universities, VISIR has been applied in the undergraduate engineering practices, with pleasant results, to carry out different types of experiments online such as half-wave Rectifier with and without filter, regulator with zener diode, inverter and non-inverter operational amplifier, Common emitter BJT, and Common collector BJT [8].

IV. REMOTE LABORATORIES BASED ON NI ELVIS II

NI ELVIS II [15] is a versatile design and prototyping educational integrated platform released by National Instruments. It is suited for remote control and integrated with 12 of the most commonly used laboratory instruments (oscilloscope, DMM, function generator, power supply, dynamic signal analyzer, a bode analyzer, 2- and 3-wire current-voltage analyzer, arbitrary waveform generator, digital reader/writer, and impedance analyze). It has a variety of experiment plug-in boards and kits from National Instruments and from other third-party companies, Figure 5, for teaching concepts in control, telecommunication, fiber optics, embedded design, bioinstrumentation, digital electronics, and Field-Programmable Gate Arrays (FPGAs), such as:

- NI digital electronics FPGA board: teach digital electronics and digital design concepts.
- Emona (http://www.emona.com.au/) boards:
  - ➢ FOTEX-fiber Optic and DATex Telecommunication: to teach analog, digital, and fiber optics telecommunications concepts.
  - ➢ Signal and Systems: to teach concepts such as characterizing linear and nonlinear signals, understanding convolution, poles and zeros in the Laplace domain.
  - ➢ HELEx Green Engineering: to teach the fundamentals of solar cells, electrolysis, and hydrogen fuel cell theory.
- Quanser (http://www.quanser.com/) QNET boards (DC motor control, rotary inverted pendulum, HVAC, VTOL 1DOF Helicopter plant, and mechatronics sensors): to teach control design and simulation concepts such as PID and Root Locus.
- Freescale (http://www.freescale.com/) microcontroller prototype board: to teach students how to design and test Microcontroller unit (MCU) systems.
- Vernier (http://www.vernier.com/) sensor kits: to teach green engineering and bioinstrumentation.

Unlimited number of applications and experiments can be mounted on the plug-in boards. The plug-in boards and all the integrated instruments are totally controlled with LabVIEW and thusly, are suited to be controlled remotely. However, the instruments can be controlled by hands, and the plug-in boards can be used separately without the NI ELVIS II platform. For instance, in [16], a remote laboratory is developed for measuring non-inverting, inverting, and differential amplifier circuits. A similar approach for operational amplifier circuits experiments is found in [17]. Mounting circuits on the plug-in boards of NI ELVIS II must be done by hands. However, in RemotElectLab [18], a relay switching matrix has been developed for NI ELVIS (the older version) to allow instruments to measure voltage or currents at different nodes of the circuit remotely, Figure 6. In [19], a LabVIEW API and a simple cross-platform interface have been created to facilitate publishing NI ELVIS II laboratories. NI ELVIS II is integrated with NI Multisim (a leading tool in spice simulation) [16], which allows comparing the simulated data with real-world data by a single click.

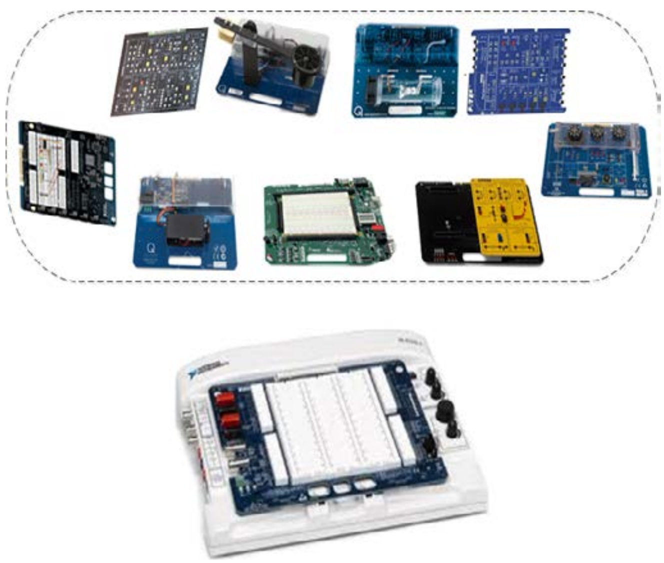

Figure 5. NI ELVIS II and a variety of plug-in boards.

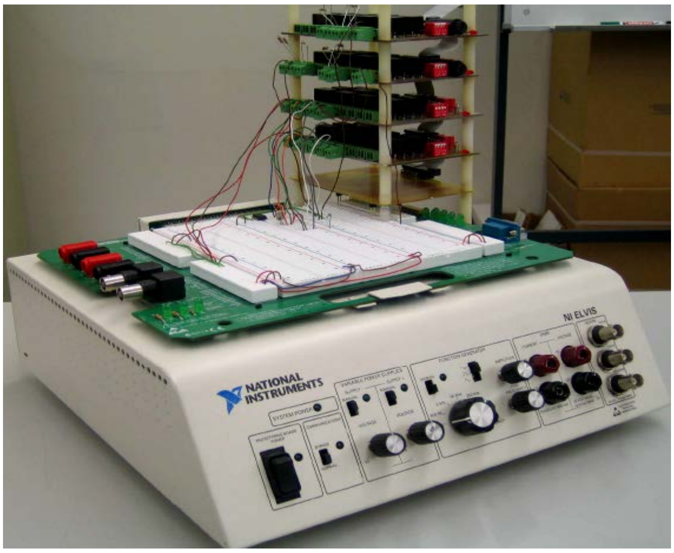

Figure 6. RemotElecLab.

V. OTHER APPROACHES

Remote laboratories for could be simply built by selecting appropriate lab server software such as Matlab, LabVIEW or other software written from scratch by a high-level programming language, with connection to a Data Acquisition Cards (DAQ) that retrieves and send digital and analog signals between the lab server and the measured circuit, Figure 7. Besides, there are several modular types of instrumentation platforms, such as PXI, LXI, and GPIB, that could be connected to the lab server in order to change the circuit's parameters values remotely. This combination has allowed the development of a wide range of remote Digital Signal Processing (DSP) applications, among them electronic circuits' measurements. For instance, in [20] a remote lab is developed for recording the amplitude characteristics of a T-notch filter, diode I/O characteristics, I/O characteristics of PNP and NPN transistors, characteristic of A and B class amplifiers, and RC filters characteristics, and measuring circuits with operational amplifiers (adder, subtractor). In [21] a remote lab is developed for running experiments on a normal BJT common emitter amplifier circuit, while maintaining the possibility for the students to use a wide range of different setups. In [22] a remote lab is developed for measuring the characteristics of non-inverting operational amplifier, integrators and differentiators, and half and full wave rectifier. In [23], a remote lab is developed for measuring I/O characteristics of Linear Variable Differential Transformer (LVDT). In each of the aforementioned approaches a GUI is developed for students as a virtual workbench. Also, the aforementioned approaches are based on changing the circuits parameter values and don't provide wiring mechanism, as in case of VISIR, NetLab, and RemotElecLab. However, they still present a better alternative for their traditional counterparts.

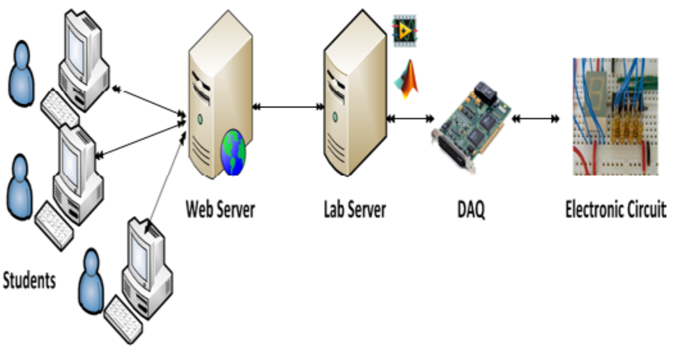

Figure 7. Remote lab architecture for DSP applications.

VI. CONCLUSION AND FUTURE CHALLANGES

In this paper several solutions for putting fundamentals of electronic circuits' practices online have been presented. The purpose is to promote and foster the deployment of these types of laboratories in an essential subject for all engineering education disciplines. But taking into account that most of these approaches are confined to their owner university, moreover some of these laboratories are replicated at many universities, thus, several initiative has started to integrate these developed laboratories into a sharable architecture such as iLab [24-26] and Labshare [27, 28] to allow their interinstitutional operation and sharing in an efficient way, and thereby, to reduce cost and increase availability. A sharable architecture provides a common framework that allows the student to access to remote laboratories, which could be installed at other university, Figure 8, along with many services for remote laboratories operation such as profile roles, scheduling, queuing, tracking, and others. For instance, NetLab has been totally integrated within Labshare [29]. Similarly, VISIR has been integrated within iLab [30]. On the other hand, several approaches attempt to integrate these laboratories within Learning Management Systems (LMSs) of open source, such as Moodle [31], Sakai [32], and DotLRN [33], in order to make use of the services provided by LMSs, when it comes to deploying these laboratories in the learning process, such as administration, assessment, evaluation, synchronous and asynchronous communications tools, and others [34-37].

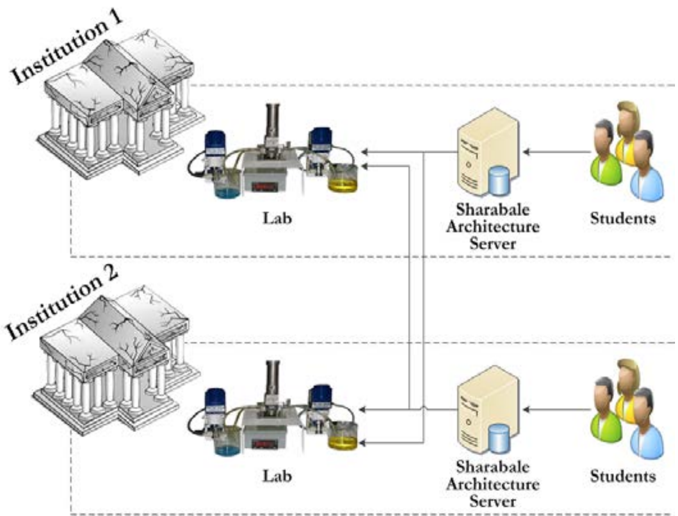

Figure 8. Remote laboratories integration with sharable architecture.

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