Traditional Lab Sessions in a Remote Laboratory for Circuit Analysis

Ingvar Gustavsson[1], Johan Zackrisson[1], Thomas Olsson[2]

Dept. of Signal Processing, School of Engineering, Blekinge Institute of Technology[1]
P.O. Box 520, SE-372 25, Sweden.
Dept. of Electroscience, Lund University[2]
P.O. Box 118, SE-221 00, Lund, Sweden.
T.+46457385716; F.+4645727914; E. ingvar.gustavsson@bth.se.

Abstract

Traditional lab sessions are performed in many local university laboratories. Emulating a local laboratory, a remote laboratory for courses in circuit analysis and electronics has been set up at Blekinge Institute of Technology in Ronneby, Sweden. Students in different places around the globe can participate in lab sessions in which up to eight client PCs can be connected simultaneously to an experiment server via the Internet; students can also perform experiments individually and around the clock whenever the server is not fully occupied. Universities or other teaching organizations which make use of the laboratory for teaching purposes can use learning material in the language of their choice. The laboratory is always open and can be used by guest users outside regular lab sessions. The address of the web site is: http://distanslabserver.its.bth.se/.

1. Introduction

Hardware experiments are indispensable for students if they are to trust physical laws and be aware of their limitations. Lab sessions and practical projects also provide the framework for students to learn to cope with real-world problems. Simulations cannot replace hardware experiments because simulator programs are based on calculation methods emanating from physical laws or other mathematical models [1]. On the other hand, many laws and models are complicated, and the related calculation methods are difficult to use; where this is the case, simulations are a useful and convenient tool for solving problems or designing circuits if you know that the simulator used covers all aspects of the physical phenomena involved.

The traditional way of conducting experiments is to participate in a lab session in a local university laboratory where students work in teams and receive tutorial help from teachers. There is no doubt that nothing can replace synchronous learning through face-to-face interaction, but it is not always feasible for students to attend conventional classes. Models for using information technology to enhance the learning experience for students who are asynchronous in time and/or space and which are also suitable for on-campus students have been presented earlier [2]. A number of so-called remote labs have been set up by a number of universities around the world [3, 4, 5]. Most of these provide remote access to a few fixed experiments only.

The remote laboratory at Blekinge Institute of Technology (hereafter referred to as BTH) in Sweden is a client/server application which emulates a local university laboratory; it is used for courses in circuit analysis and electronics. It provides hardware experiments using computer-based instruments. The experiment server is located in a small, closed room in Ronneby (see Figure 1). Students in different places around the globe can participate in lab sessions supervised by an instructor who uses MS Netmeeting or some other means of communication [6]. The client software can be downloaded from the laboratory web site. Only a 56-kbit/s modem and MS Internet Explorer are required.

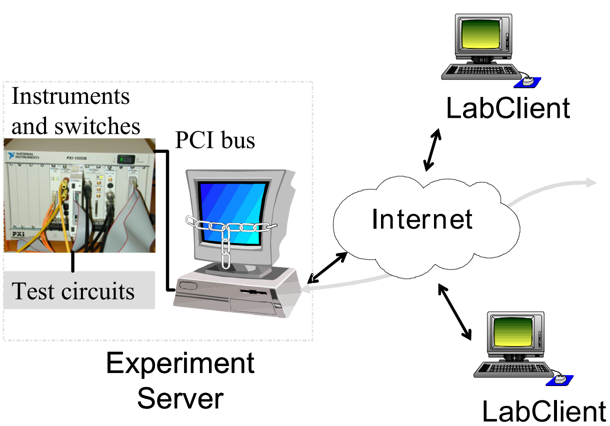

Figure 1. The remote lab at BTH.

Students in a local laboratory use a breadboard and components provided by the instructor to form the circuits assigned in the instruction manual and to connect the test probes. In the remote lab, a virtual breadboard and photographs of the components provided in the session selected are displayed on the client PC screen at startup [7, 8]. Students use the mouse to position components on the breadboard and do the wiring to assemble the circuits. The corresponding real components are mounted in sockets in a switching matrix in Ronneby controlled by the virtual breadboard routine. The instruments have virtual front panels which are displayed on the client PC screen. The time sharing scheme used to allow simultaneous access to one server imposes restrictions on the time period allowed for each experiment when it comes to using the server; in courses in electricity or electronics, however, it is easy to select the time constants involved from within an appropriate range. The number of nodes on the virtual breadboard is also limited due to the hardware complexity of the switching matrix; the number is, however, perfectly adequate for experiments in undergraduate education. Apart from the fact that each student or student team works in a virtual environment with no face-to-face contact with the instructor or other students in the laboratory, the difference between a remote laboratory and a traditional lab session is that it is not possible for students to manipulate the components and the wires with their fingers. The laboratory is always open and can be used by everybody outside regular lab sessions. This paper compares laboratory sessions in the remote laboratory in Ronneby with traditional lab sessions which have been used with success for many decades to teach science and engineering. Designing a remote laboratory where students can perform lab sessions from home or elsewhere promises to be a good starting point from which new teaching methods may emerge.

2. Sessions in a local laboratory

The local laboratory at BTH has eight identical lab stations allowing a number of students to perform experiments simultaneously. Two or three students work in a team and share one lab station. Each lab session is supervised by one instructor. At each station there is a lab box with a white plastic breadboard and some voltage sources and instruments as shown in Figure 2 [9]. Most laboratories at universities in Sweden have similar equipment. The breadboard is large enough to accommodate circuits with many components and nodes. The instructor provides the components necessary for each laboratory session to each student team. All experiments in a session are described in a lab instruction manual. The normal procedure for performing a single experiment is as follows:

- Every student team forms the circuit specified in the instruction manual using a voltage source, the breadboard, and some of the components provided. At least one of the instruments must be connected to test points in the circuit in order to collect experiment data.
- The instructor checks each circuit formed to avoid possible damage. If the circuit is safe, the student team is allowed to continue by activating the source. When the source is activated, transients will appear in the circuit. The duration of these transients is usually short in comparison with the time required for manual operations, and the students will not notice them.
- The students read the instruments and evaluate the results. If they are acceptable, the students record them in a laboratory report. Where this is not the case, troubleshooting may be necessary; this will be carried out with the support of the instructor.

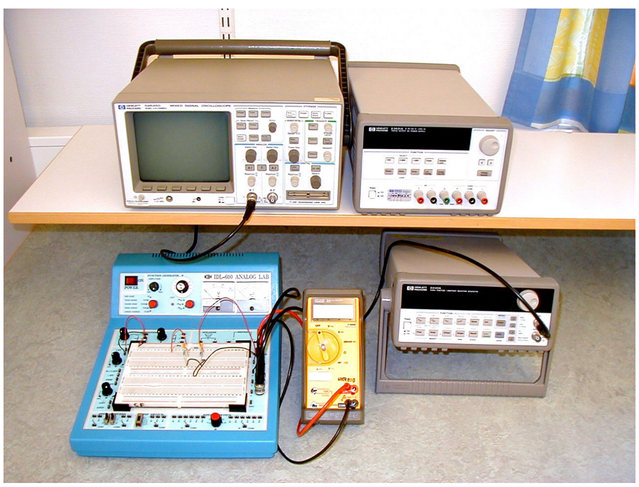

Figure 2. Traditional lab station in a local laboratory for undergraduate education in electrical engineering at BTH.

3. A server for electronics experiments

The experiment server at BTH is shown in Figure 3. To the right of the PC connected to the Internet there is a low noise PXI (PCI Extensions for Instrumentation) chassis containing plug-in boards from National Instruments. A PCI bridge connects the chassis to the PC which hosts the plug-in boards in the form of a function generator, a digital multi-meter, an oscilloscope, and a digital I/O board. The instrument settings are controlled from the host computer; there are no buttons or control knobs on the small instrument front panels, only connectors.

The traditional breadboard is replaced by a remotely controlled switching matrix consisting of relays, sockets for components, and instrument connectors. The matrix is the card stack on top of the PXI chassis. It is large enough to accommodate most of the circuits used in electrical and electronic experiments in undergraduate education. The teacher or a member of the lab staff mounts the components the students will use in their circuits in the sockets. Figure 3 shows two power supplies to the right. One of these, the Agilent E3631A, is controlled from the PC; it is used to feed active components in the circuits formed by the students.

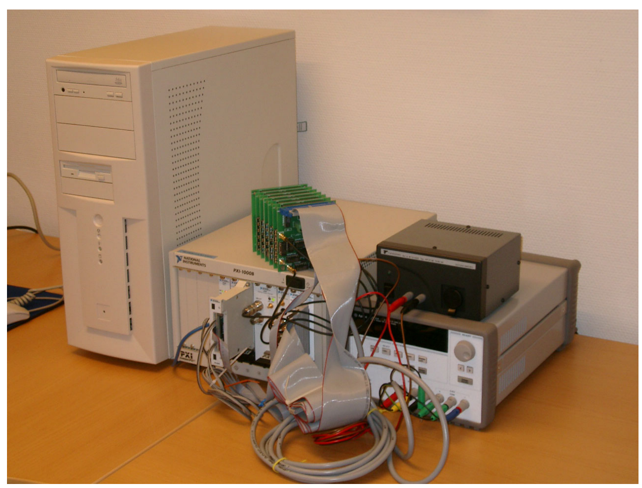

Figure 3. Experiment server.

The matrix has five nodes denoted A, B, C, D and GND which the students can access. Ten branches are required to connect the nodes. The ground terminals of the function generators and the oscilloscope are directly connected to GND and not via a switch. In the current configuration, each branch can be composed of a jumper lead or up to four components with two leads mounted in parallel in sockets on the printed circuit boards as shown in Figure 4 [10]. In this way, a total amount of 50 such components and jumpers can be accommodated. The server software is written in LabVIEW 7 (Laboratory Virtual Instrument Engineering Workbench) [11] and C++.

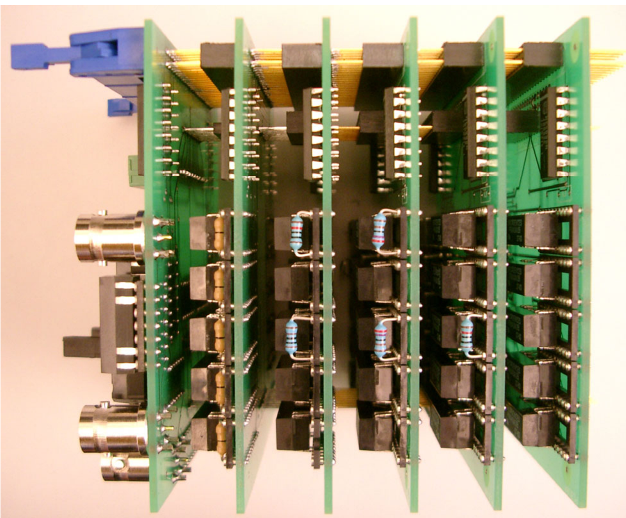

Figure 4. Switching matrix. The resistors are mounted in sockets and can easily be swapped.

4. Remote sessions

A system for reservation of lab sessions is attached to the remote laboratory. The teacher makes reservations for all lab sessions in his or her course. Students in that course can either perform the experiments in a session by themselves at any time when the laboratory is not fully occupied and/or reserve a session where there is at least one free station left. The normal procedure for performing a single experiment in the remote laboratory is as follows:

- The window appearing on the client PC screen when a session is started is shown in Figure 5. Photos of the components mounted in the switching matrix and available in the session are shown in the upper part of the window. Students use the mouse to position each virtual component on the breadboard and do the wiring to assemble the circuits and connect the instruments. Finally, the student presses the *Perform Experiment* button to send the list, the instrument settings, and the test probe connections to the server.
- When the user request is dequeued on the server side, a virtual instructor checks the desired circuit in order to ascertain that it is safe. Where this is the case, the circuit will be formed, the instruments set, the test probes connected, and the voltage applied. The outcome will then be sent back to the client computer. In all other cases an error message will be returned.
- If there is no error message, the student reads the result on the virtual front panels of the instruments and evaluates it. If the result is acceptable, s/he will record it in the laboratory report. Where the result is not acceptable, troubleshooting must be carried out - if necessary, with the support of a real human instructor.

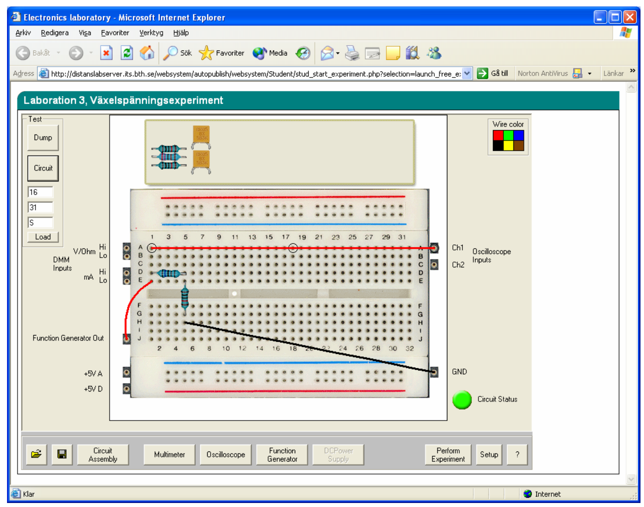

Figure 5. Virtual breadboard window with a small assembled circuit on top.

The circuit specification sent to the server is a netlist. The netlist for the circuit on the breadboard in Figure 5 is shown in Table 1. The reason that the list, all the instrument settings, and the test probe connections are sent to the server in one message when the user presses the *Perform Experiment* button is to ensure that the hardware is engaged for less than 100 ms. In this way, at least eight student teams can share the same server without a response time lower than one second.

The virtual front panel of the oscilloscope is shown in Figure 6. The local laboratories at BTH use 54600B desktop-type oscilloscopes from Agilent Technologies. The similarity between the oscillospes panels is intentional. Students have no problem using the front panel with the hard buttons when they are used to the virtual panel. Later on, other oscilloscope panels will also be provided.

Table 1. Example of a circuit specification.

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R_R2 A B 1.6k
R_R6 0 B 10k
VFGENA_FGENA A 0
PROBE1_1 A
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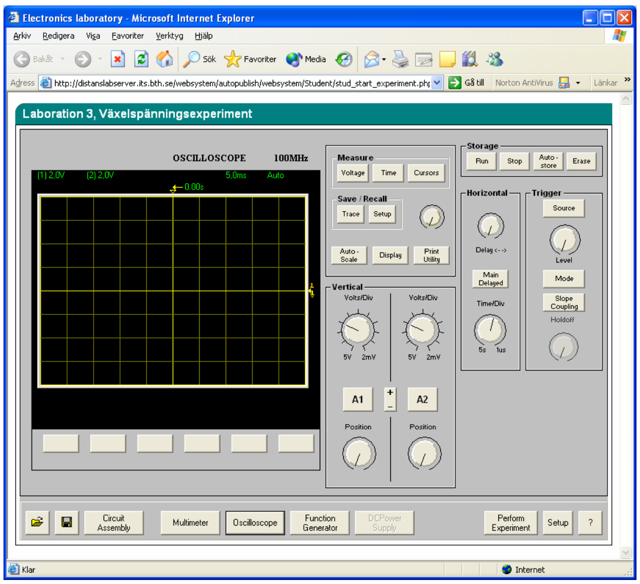

Figure 6. Oscilloscope front panel.

Figure 7 shows a circuit involving the sources and all the components mounted in the switching matrix for the four lab sessions included in a circuit analysis course. There are, however, many free sockets in the matrix. The node designations in Figure 7 show where every component is mounted in the switching matrix; all engaged switches have, however, been omitted. As an example of possible connections the inductor L3 can only be directly connected to nodes C and GND and not, for example, directly to the 1.6 kΩ resistor R2 between nodes A and B. If, however, the student connects these two components on the virtual breadboard, the jumper between nodes B and C will be installed in the switching matrix. The jumpers thus increase the number of connection possibilities; they also serve another purpose. It is only possible to measure the current using the multi-meter in loops containing a jumper. The instrument will then replace the jumper.

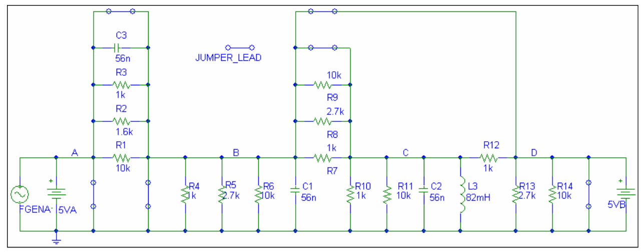

Figure 7. Circuit diagram showing all components mounted for lab sessions in a circuit analysis course

What happens if a student forms a circuit which could be destructive, e.g. could overload a resistor? In a remote laboratory with simultaneous access it would be fatal if a resistor were to be burnt. The maximum output voltage of the function generator is ± 10 V into a high impedance load, and the power limit of the resistors provided is 0.6 W. The minimum resistance of the resistors in figure 7 is 1 kΩ; the maximum power generated in one resistor is thus 0.1 W only. However, the resistance of the inductor is low and it can be burned if it is connected to the function generator set for maximum output. Thus it is vital to check the circuits before the voltage is applied just as an instructor would do in a traditional laboratory. The virtual instructor is a routine in the laboratory software. If there are no restrictions imposed on the components, sources, and instruments, the virtual instructor must check the following:

- The voltage appearing on each component terminal must not exceed the component specifications.
- The function generators are short-circuit protected; the load impedance should, however, be 50 Ω or greater.
- The output voltage of one source must not damage another source where more than one source is used.

- There must be no connections to the sources when the user wants to connect the multi-meter set as an ohm-meter.

One simple way to obey the rules is to put restrictions on the circuits to be assembled. The teacher creates a number of netlists, called check lists, to represent safe circuits. Subsets of each check list must also represent safe circuits. The virtual instructor compares the desired circuit with the check lists defined as well as their subsets.

The graphics part of the client software is written in Visual Basic 6 and Component Works. The logic part is written in C++. MySQL and PHP are used for the reservation system.

7. Conclusion

The new remote laboratory for hardware experiments at BTH emulates a local lab and was launched, on 10 March 2004. It is designed to support traditional lab sessions in electricity and electronics. The earlier text-based netlist input has been replaced by a virtual breadboard. Simulator experience is no longer required, and the laboratory will also be used by secondary schools. Immediately after the launching of the lab, a distance learning course in circuit analysis was started at BTH. This course will be the first real test of the new laboratory; an evaluation will be made shortly after completion of the course. Some experiments included in the course are available to guest users. The address of the laboratory web site is: http://distanslabserver.its.bth.se/.

8. Acknowledgments

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