A TRADITIONAL ELECTRONICS LABORATORY WITH INTERNET ACCESS

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Abstract

An electronics laboratory with Internet access emulating a traditional university laboratory for undergraduate education has been set up at Blekinge Institute of Technology (BTH) in Sweden. People located in different places around the globe can perform experiments simultaneously using client PCs connected to the BTH lab server via the Internet. Only a 56 kbit/s modem and MS Internet Explorer are required. The client software can be downloaded from the laboratory web site. Equipment such as power supply, function generator, digital multi-meter, oscilloscope, and breadboard are provided. A breadboard is used by the students to form the circuits and connect the test probes. This paper describes the laboratory and discusses some implementation issues.

Introduction

Real experiments are indispensable in engineering education as a means of developing skills to deal with physical processes and instrumentation. Laboratory sessions are integrated into many courses. Traditional experiments are usually performed in university laboratories where the students work in teams and receive tutorial help from instructors. 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 [1, 2]. So-called remote laboratories have been set up by a number of universities around the world. These offer remote access to laboratory equipment and experimental setups to facilitate Web-based measurement and manipulation [3, 4]. Conventional laboratory sessions have for many decades been used with success to teach science and engineering. To design a remote laboratory where students can perform laboratory sessions from home or elsewhere seems to be a good starting point from which new teaching methods may emerge.

Eight identical lab stations are available in a traditional undergraduate electronics laboratory at BTH. At each station there is a lab box with a white plastic breadboard and some desk top instruments (see Figure 1). An instructor provides the components necessary for each laboratory session. Every experiment is described in an instruction manual. In the remote laboratory at BTH the traditional desk top instruments are replaced by computer-based ones with virtual front panels; the breadboard is replaced by a virtual one. The instructor cannot hand over the components to be used in a lab session to the students; instead he/she mounts them in sockets in a switch matrix in the lab server [5]. The virtual breadboard, which controls the switch matrix, is a photograph of a traditional breadboard displayed on the client PC screen. Photographs of the components mounted in the switch matrix are displayed in a window below the breadboard. To form a circuit students use the mouse pointer to move the components to the breadboard and connect them. Students control the instruments in the same way as they would in a traditional laboratory. The only difference is that they do not handle the components and the test probes manually. The laboratory is a client/server application (see Figure 2). The Internet provides the communication infrastructure between a client and the lab server (see Figure 3).

Simulations cannot replace experiments

During the last decades there has been a trend towards increased use of simulation in engineering education. One reason is that physical experiments are expensive both to implement and maintain.

Another obvious reason is the belief that simulators can replace physical experiments [6]. The Greek philosopher Aristotle (ca. 340 B.C.) asserted in relation to the falling of a body that after a brief period, during which its speed increases, a body falls at a constant speed which is proportional to its weight. Thus, a body which is twice the weight of another would take half as long to fall from a given height. For Aristotle no experiment was necessary. Almost two thousand years later, in 1586, the Dutch mathematician Simon Stevin performed an experiment to test the ancient "natural law". He dropped two lead balls, one ten times the weight of the other, and noted that their impact on a board on the ground produced "a single sensation of sound" [7]. Experiments are indispensable for students if they are to trust physical laws and test their limitations. Practical projects concentrated into a few intensive weeks on campus provide the framework for students to learn to cope with real-world problems such as EMC issues, finding bad connections etc. Many physical laws and other mathematical models are complicated and difficult to understand; simulations are a useful tool to demonstrate how the models can be used to solve problems.

The remote laboratory at BTH emulates a traditional one

The normal procedure for performing a single experiment in the remote laboratory is as follows:

- A student logs on and selects a lab session. If there is a free lab station the student will be signed in and the circuit assembly panel will be displayed on the screen together with the components to be used in the session selected (see Figure 4). A student with good eyes should be able to read the color code of the resistors. If this is not possible, the student has to put it onto the breadboard and use the multi-meter to measure resistance.
- The experiments to be performed are described in a laboratory instruction manual on paper or on-line in pdf format. The student forms each circuit in the manual and connects the test probes using the mouse pointer. The student then clicks on an instrument button and the corresponding front panel is displayed; the panel invites the student to select specific settings (see Figure 5). Finally, when the circuit is formed and all settings selected the student presses the button *Perform Experiment*. The client PC sends a message containing a net list which describes the circuit and all settings to the lab server.
- When the user request is dequeued on the server side, a virtual instructor compares the list received with a number of check lists in order to ascertain that the desired circuit is safe. Where this is the case, the circuit is formed, the instruments set, the test probes connected, and the voltage applied. The outcome is then be sent to the client computer within a fraction of a second. In all other cases an error message will be returned.
- If there is no error message, the student will read the result on the virtual front panels of the instruments used and evaluate it. If the result is acceptable, the student 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 if present on-line.

The reason why 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 that it is essential that the hardware is engaged for only a short time. In this way, a number of students or student teams can share the same server. The main stages in the server response time are divided up as follows:

- The server decodes the message received.
- The virtual instructor checks the desired circuit.
- Some switches are opened; others are closed to turn the preceding circuit into the desired circuit.
- The sources in the desired circuit are activated. Transients will now appear. A delay is entered here to let these disappear before the oscilloscope is armed or the multi-meter is read.
- If the oscilloscope is used, the time needed to sample a signal depends on the time/division setting. The oscilloscope provides one sweep per message.

- When data from the instruments are available the outcome is converted into a message to be returned to the client PC.

Cabling and the relays in the switch matrix limit the bandwidth somewhat; the oscilloscope time base is currently restricted to 1 μs/division. The teacher can choose an appropriate time scale for the experiments by selecting proper values for the components to be used by the students. Time settings on the oscilloscope in circuit theory and electronics experiments normally range between 1 μs/division and 10 ms/division. Thus, a single shot is usually 10 μs to 100 ms because the time axis is 10 divisions on most oscilloscopes. It is possible to achieve a server response time below 1 s with eight simultaneous users i.e. the same number as in the traditional laboratory.

Conclusions

It is possible to design a laboratory for undergraduate courses in circuit analysis and electronics where students and others can conduct physical experiments remotely from the comfort of their own home or from elsewhere. The only difference between this form and a traditional laboratory is that the students will not handle components and test probes with their fingers. One can anticipate that computer-based instruments with virtual front panels will gradually replace desktop ones. It thus makes no difference if you handle instruments in traditional laboratories or by remote control. Nevertheless, students need a great deal of hands-on practice. At BTH students gain this experience in practical projects, which provide the right methodology to cope with real-world problems.

The virtual breadboard will soon be released. Today (November 2003) a simpler user interface for the circuit assembly based on PSpice compatible net lists is provided but the laboratory functionality is still the same. The address of the electronics laboratory web site is http://www.its.bth.se/distancelab/english/Kretsteorilabbar/intro.html.

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Figures

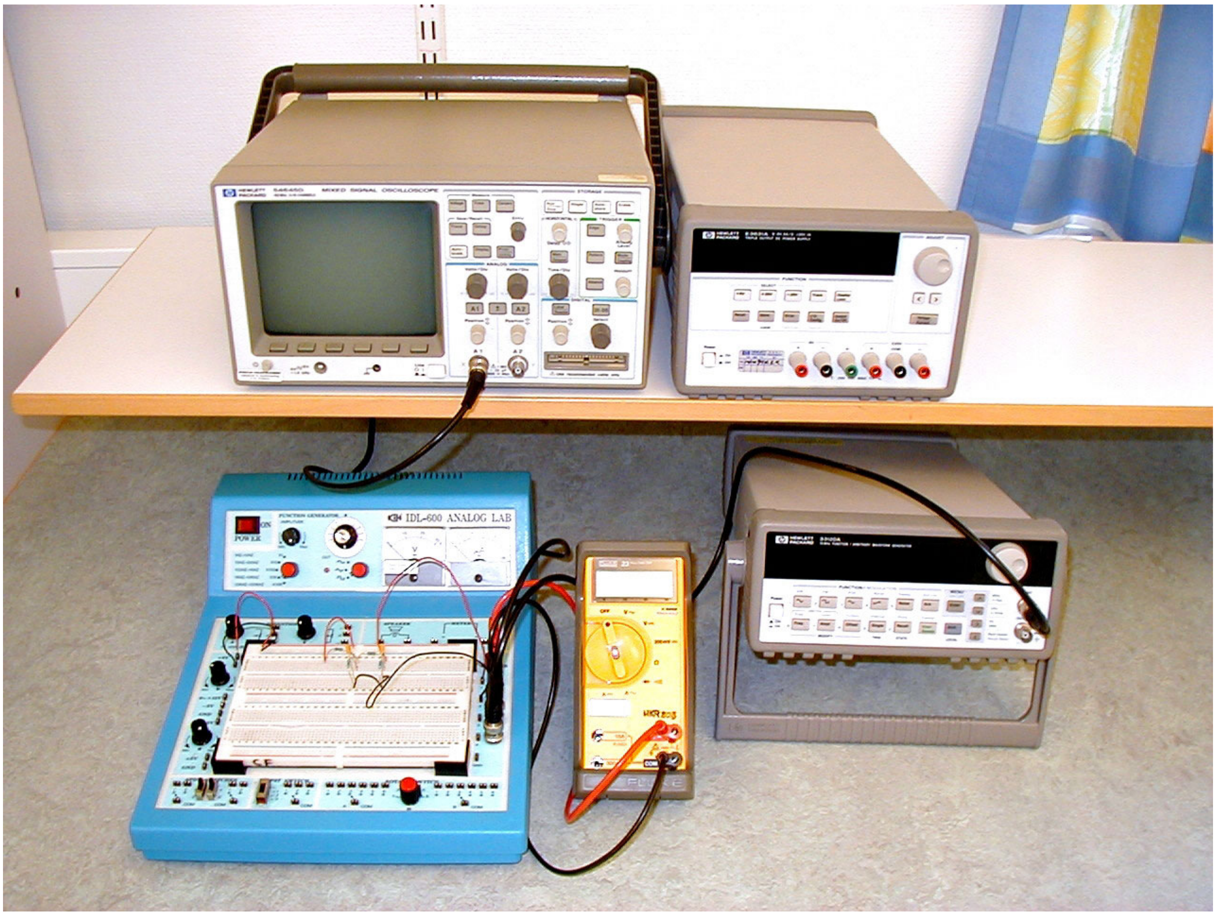

Figure 1. A traditional lab station in a laboratory for undergraduate education in electrical engineering at BTH.

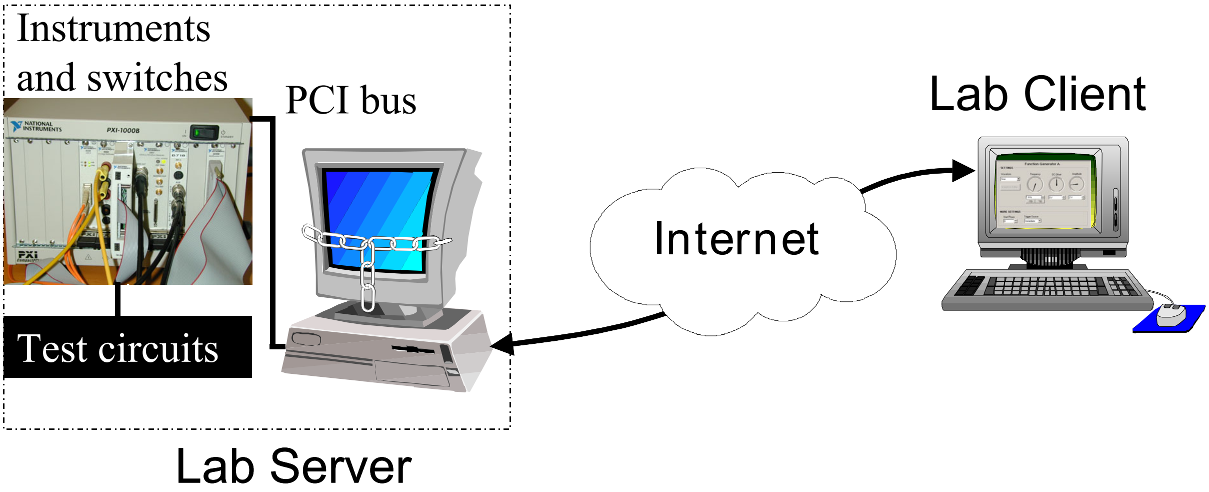

Figure 2. The remote lab at BTH. The instruments are plugged into a separate low noise box connected to the server PC via a PCI bridge.

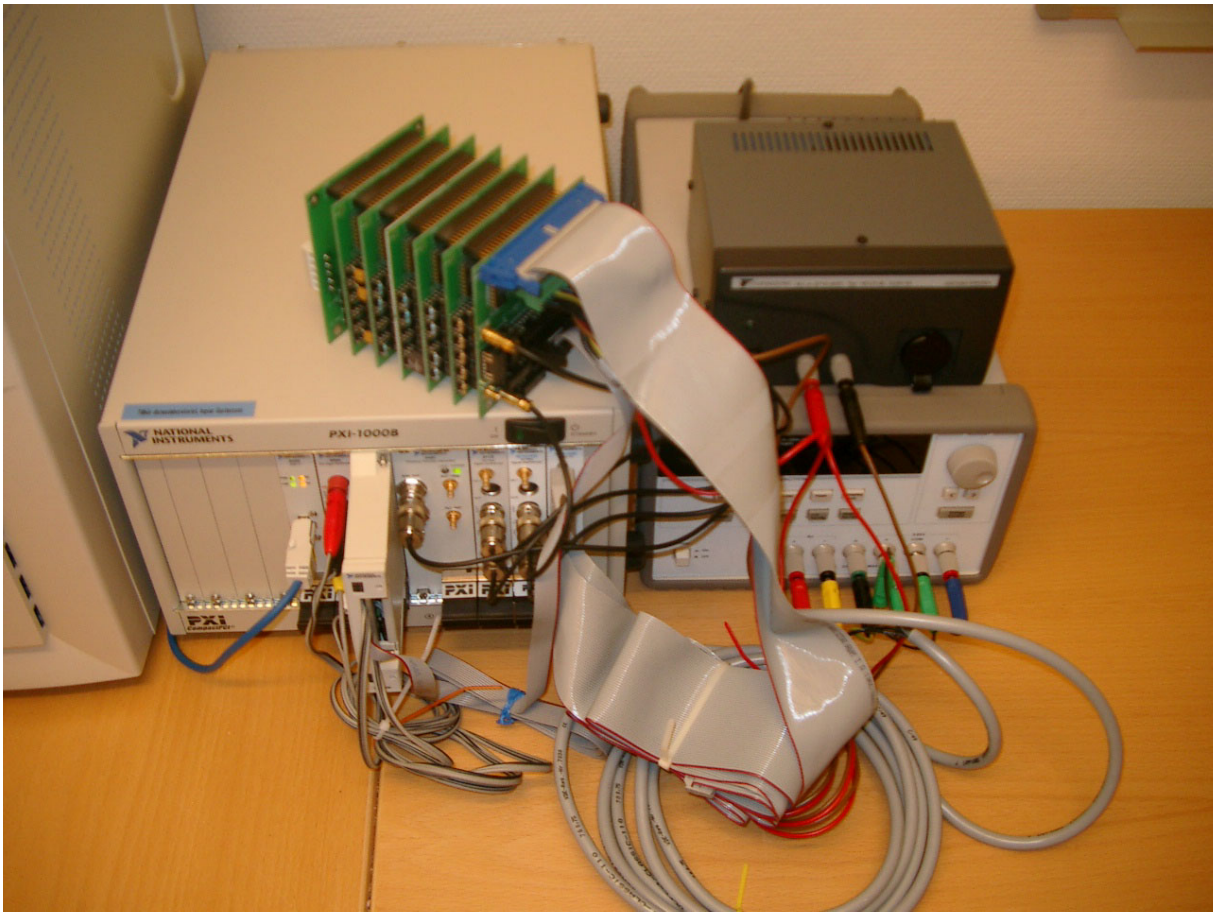

Figure 3. The lab server. The card stack on the instrument box replaces the conventional breadboard. To the left is the server PC and to the right are two power supplies.

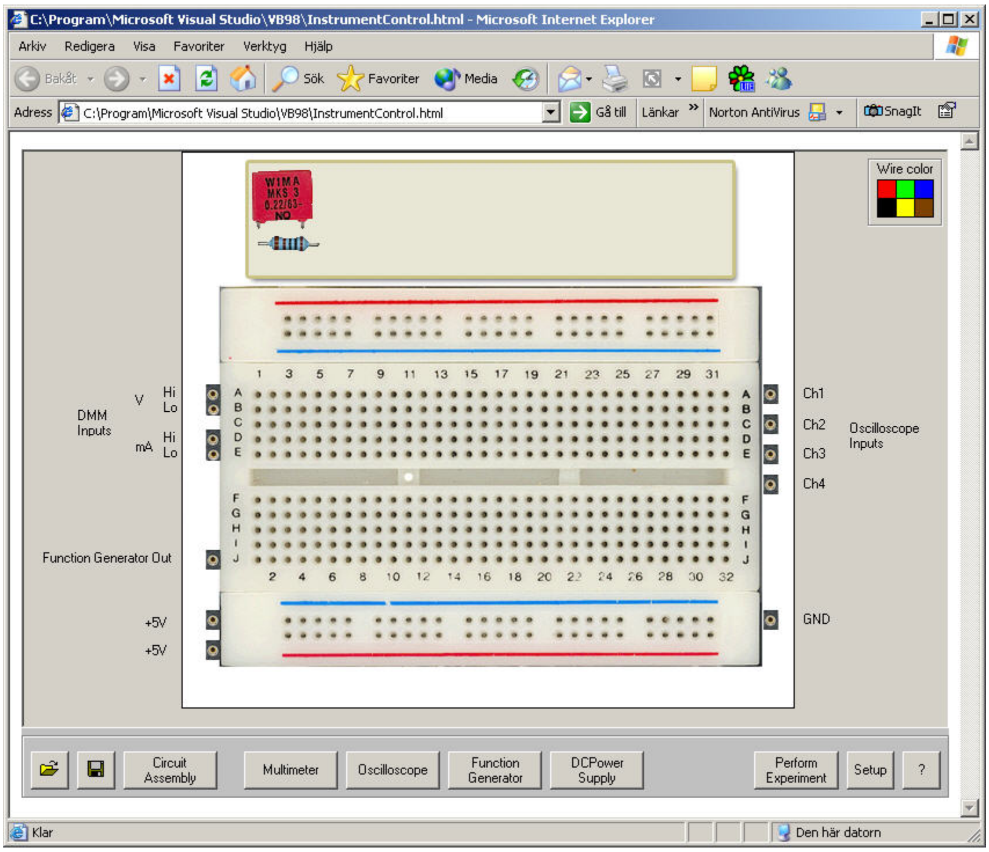

Figure 4. Circuit assembly panel. Wires of different colors are used to assemble the circuits and connect the instruments.

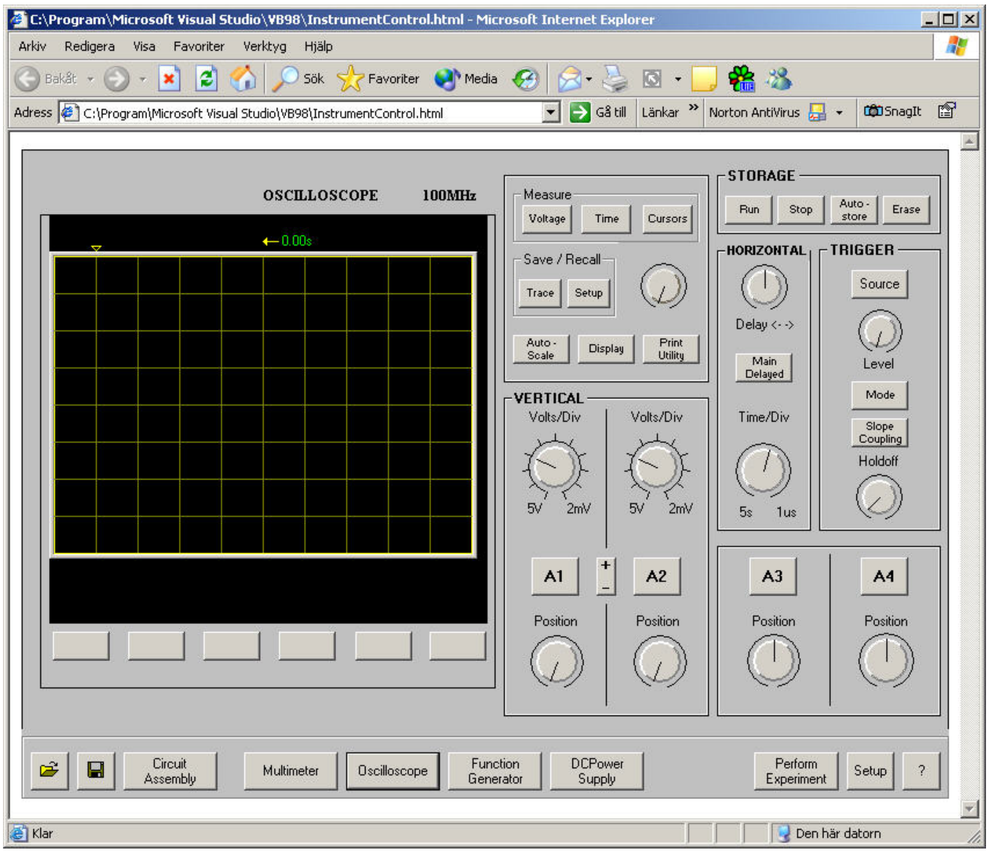

Figure 5. The oscilloscope panel. It is easy to introduce alternative front panels for other oscilloscope models.