

An Instructional Electronics Laboratory Opened for Remote Operation and Control

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Abstract - Blekinge Institute of Technology in Sweden has opened a local instructional laboratory for undergraduate education in electrical and electronic engineering for remote operation and control 24/7 as a complement and a supplement to traditional laboratories. It is equipped with a unique virtual interface enabling students to recognize on their own computer screen the desktop instruments and the breadboard most of them have already used in the local laboratory. The open laboratory is used in regular courses in circuit analysis for distant learning students dispersed all over Sweden and for campus students as well. The research is focused on what is perceived to be the greatest challenge, to give students laboratory experience that is as genuine as possible despite the lack of direct contact with the actual lab hardware. The goal is to produce an open international standard in cooperation with universities and other organizations around the world.

Index Terms - Electronics, remote, lab, lab session.

INTRODUCTION

Instructional laboratories are used for supervised lab sessions in, for example, electronics courses. In each such session learners are performing a number of physical experiments described in a lab instruction manual. Such experiments allow them to ascertain that mathematical models correspond with nature and to study the limitations of these models [1]. Such experiments also provide the framework for students to learn to cope with real-world problems and gain hands-on experience. However, during the last decades there has been a decline in the number of lab sessions in engineering courses. In many countries a trend may be observed towards an increased use of simulations which frequently replace physical experiments [2]. Generally speaking, simulator programs are based on mathematical models and are excellent tools for analysis and design when the limits of the models embedded in the software are known and the learner can cope with the abstraction level they represent.

Today, many academic institutions offer web-based experimentation environments that support remotely operated experiments [3]-[6]. Such remote experiments entail remote operation of distant physical equipment. Home experimentation in electronics is a method specially designed for distant learning students to acquire introductory hands-on experience and become familiar with components and wiring etc. [7]-[8]. However, affordable devices such as a cheap multi-meter and/or a soundcard-based oscilloscope are only adequate for elementary experiments.

Blekinge Institute of Technology (hereafter referred to as BTH) in Sweden has opened a local instructional electronics laboratory for remote operation and control. It is equipped with a unique virtual interface enabling the students to recognize on their own computer screen the desktop instruments and the breadboard they have already used in the local laboratory. The physical breadboard has been replaced by a circuit-wiring robot, i.e. a switching relay matrix which is remotely controllable. A consortium chaired by BTH will be formed to expand and disseminate our unique electronics laboratory internationally within the framework of a proposed project known as VISIR (Virtual Instrument Systems in Reality). Universities and other organizations will be invited to participate in the development and dissemination together with BTH as part of the VISIR project.

This paper focuses on how this current version of the open laboratory can be shared among universities around the world. The laboratory has been presented earlier but a short description in the next section highlights some significant features for sharing. Reference [9] is a detailed description of the laboratory. The role of the instructor is different from face-to-face supervision and it is discussed in the third section. The authorization and time reservation system in the fourth section is being updated. The final section before the conclusions is short descriptions of the current lab sessions ready for delivery in the open laboratory.

OPEN ELECTRONICS LABORATORY

The BTH open laboratory is a client/server application; the Internet is used as the communication infrastructure. The

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laboratory is fitted with two equipment servers. Apart from the host PC each server comprises an oscilloscope, a function generator, a multi-meter, a triple DC power supply, a circuit-wiring robot, and components which are selected by the teachers who have written the lab instruction manuals for the courses supported. The first server which is used in regular courses and by guest users is always online. However, it is unattended and may go down at any time. Should this happen during a holiday, it may take some time to bring it back online again. The second one is identical and is usually used for the research activities but also as a backup for the ordinary server. The time-sharing scheme used allows simultaneous access. Only a modem and a web browser with a Flash player 7 or a later version are required to access the experimental resources. The address of the home page of the laboratory is <http://distanslabserver.its.bth.se/>.

A local instructional electronics laboratory for undergraduate education at BTH has eight identical lab stations allowing a number of students to perform experiments simultaneously 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 1. Many laboratories for undergraduate electrical engineering education at other universities have similar equipment. The power supply, the function generator, and the oscilloscope are all manufactured by Agilent Technologies and can be remotely controlled through GPIB (General Purpose Interface Bus). However, not all of these devices are suited to this application, and the multi-meter from FLUKE has no remote option. To open the laboratory, the function generator, the multi-meter, and the oscilloscope have been replaced by computer-based instruments with an equivalent or superior performance. Such instruments are composed of a plug-in board fitted with a tiny physical panel containing connectors only and a software module in the host computer. This module displays a virtual front panel containing control knobs and buttons on the host computer screen; here the user can use the mouse to rotate the knobs and perform the instrument settings. In this application the virtual front panels are displayed on the screens of remote client computers instead, and the panels are photographs of the front panels of the desktop instruments. As an example, the oscilloscope virtual front panel is shown in Figure 2. The user manuals can be downloaded from the web sites of the manufacturers. The instruments and the host computer are mounted in a PXI (PCI Extensions for Instrumentation) chassis, Figure 3. This equipment is manufactured by National Instruments.

The fact that the depicted front panels are separate from the hardware enables us to combine a front panel of an instrument from one manufacturer with the hardware from another provided that the performance of the hardware matches that of the depicted instrument. The current laboratory supports only instrument models used at BTH. Other universities have different models, and a virtual equipment shelf containing other instruments from different manufacturers will be added. The performance of the hardware provided matches most instrument models used in

undergraduate education. Only those features required in undergraduate education are currently implemented in the instruments.

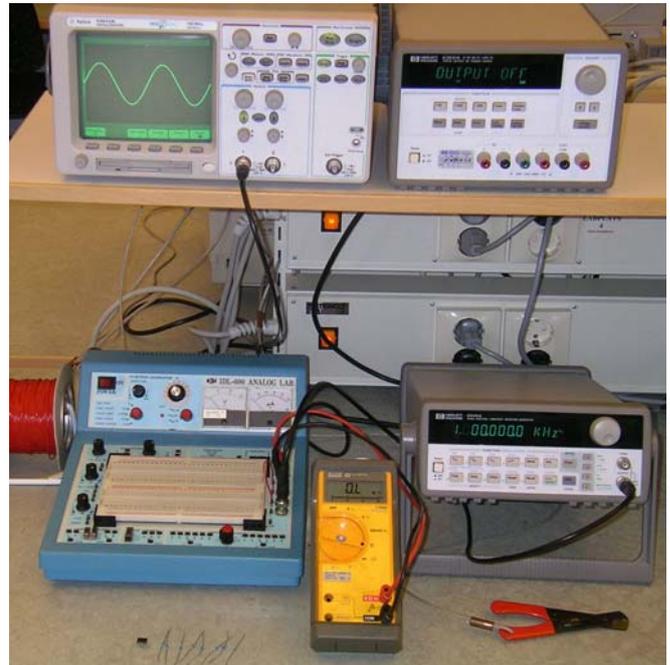


FIGURE 1
LAB STATION IN A LOCAL ELECTRONICS LABORATORY AT BTH.

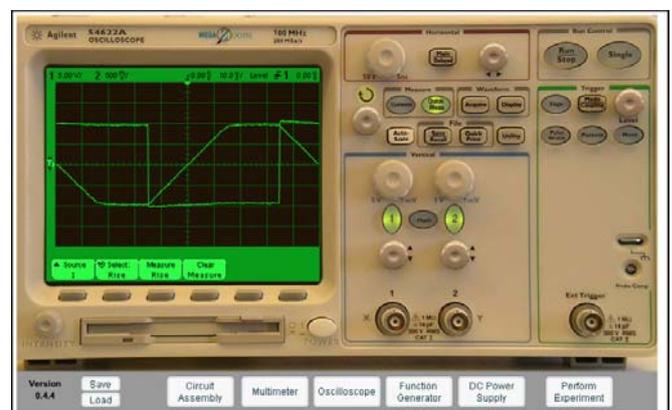


FIGURE 2
OSCILLOSCOPE DISPLAYED ON A CLIENT COMPUTER SCREEN.

It is not possible for students to manipulate the components and wire a circuit with their fingers remotely. A type of circuit-wiring robot, e.g., a relay switching matrix must be used. The complexity of such a matrix increases with the number of circuit nodes provided. If a desired circuit has N nodes and if the user wishes to add one resistor, there are $N \cdot (N-1) / 2$ branches into which it can be introduced. There are 120 possibilities for 16 nodes. The BTH laboratory, however, is designed for undergraduate education where such flexibility is not necessary. The circuits to be formed in lab sessions contain a limited number of components and are not

particularly complex, i.e. they usually have only one input and one output and a signal flow from left to right; some circuits must be excluded for safety reasons.

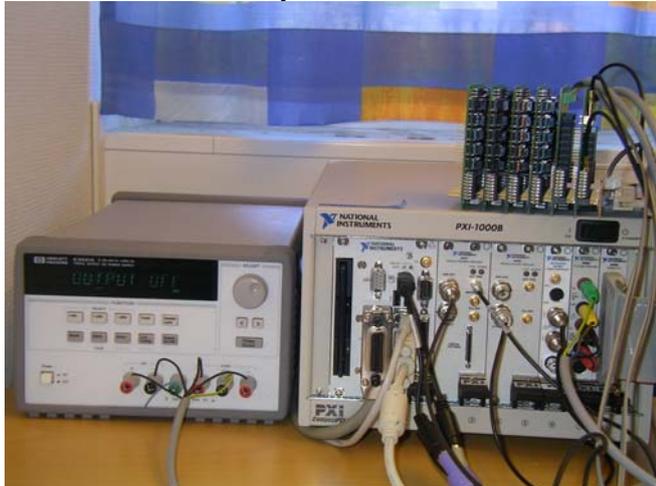


FIGURE 3
EQUIPMENT SERVER.

The circuit-wiring robot is the card stack on the top of the PXI chassis in Figure 3. It is possible to wire a circuit with up to 16 nodes by engaging a number of relays in the current matrix. The card stack contains two types of board: one for components and one for connecting instruments. A component board comprises 10 sockets for components with two leads, two 20-pin IC sockets for components with more pins than two, and 10 double-pole single-throw relays. One oscilloscope and two function generators or a multi-meter can be connected to an instrument connection board. The nodes passing all boards can be connected to sources, instruments, and/or components mounted in the sockets via relay switches. However, the instruments can only be connected to seven of the nodes denoted A – F and 0. The ground terminals of the function generator and the oscilloscope are hardwired to node 0, which is denoted GND on the breadboard. The function generator output can be connected to node A only. There is currently only one function generator per equipment server.

The matrix capacity in terms of the number of online components can be increased by stacking more component boards. The card stack in Figure 3 belongs to the first equipment server. It accommodates components sets required for five lab sessions. The matrix is still only half filled. If the relay switches controlling the sources and all the components in the current matrix of the first equipment server were closed a large circuit would be created. The corresponding circuit diagram is shown in Figure 4. However, the closed relay switches are omitted in the figure to make the diagram less complex. Thus all circuits which can be created with the components mounted in the current matrix are sub-circuits of the circuit in Figure 4. The corresponding circuit for the second server is shown in Figure 5. The latter configuration is intended for experiments on analog filters. The sole purpose for showing these diagrams is to specify for teachers all the

circuits possible to create using the components presently mounted in the matrices. Still more components can be added and the matrix pattern i.e. the wiring can easily be changed by the laboratory staff. Photographs of the components and rules for how to use them are stored in a database. As in a local laboratory, a specific set of components is provided for the student teams in each lab session. This set is a subset created by the teacher from the online components and it is displayed in a component box on the client computer screens.

HUMAN AND VIRTUAL INSTRUCTORS

In a session in a local laboratory an instructor checks each circuit formed to avoid possible damage. If the circuit is safe, the student or the student team is allowed to continue by activating the source. However, in the open laboratory unknown users are allowed to start lab sessions and perform experiments in private. Inexperienced people could create harmful experiments e.g. overload a resistor. It would, of course, be fatal if a resistor were to burn as the equipment is normally left unattended. Users would in all probability observe strange results in subsequent experiments involving the destroyed component. Thus a virtual instructor, a software algorithm, checking the desired circuits before the voltage source is activated is required in the open laboratory. If a circuit is rejected an error message will be generated. Students participating in supervised lab sessions could either be present in the lab room or by remote control. Usually all participants are distant learning students. Mixed sessions have not been tested yet. The instructor can guide the participants or they can help each other using modern means of communication such as Microsoft Windows Messenger.

In the open laboratory the human instructor can skip checking the circuits and concentrate on tutoring because the virtual instructor is always in action. On the other hand the teacher designing the rules for the virtual instructor needs a lot of creativity and imagination to avoid harmful circuits. It is also important that harmless mistakes are permitted. However the number of possibilities is limited because the number of components is not so many and the matrix pattern is not complicated. It is also possible to restrict the source voltage level and select the values of the components properly to minimize the risk. High impedance levels, for example, limit the current levels in the circuit. Such precautions can be made without negative effects on the experiments. In later project courses students should experience, for example, the effect of destroyed components and that it is easy to burn yourself on the soldering iron.

AUTHORIZATION AND TIME RESERVATION SYSTEM

The laboratory is always open with the exception of regular service intervals. Lab instruction manuals, lists of online components, and other documentation associated with the lab sessions listed in the open laboratory are free to read. However, there is an authorization and time reservation system and every user must log on to a lab session to perform experiments. In most courses there are a number of lab sessions, for example, a session on DC circuits, a session on

AC circuits etc. and each session is usually repeated a number of times to allow all enrolled students to participate. A team of users can work together in front of a client computer but only

one of them is logged on and is known to the system. The following actors are defined in the system starting with them having the most restricted access.

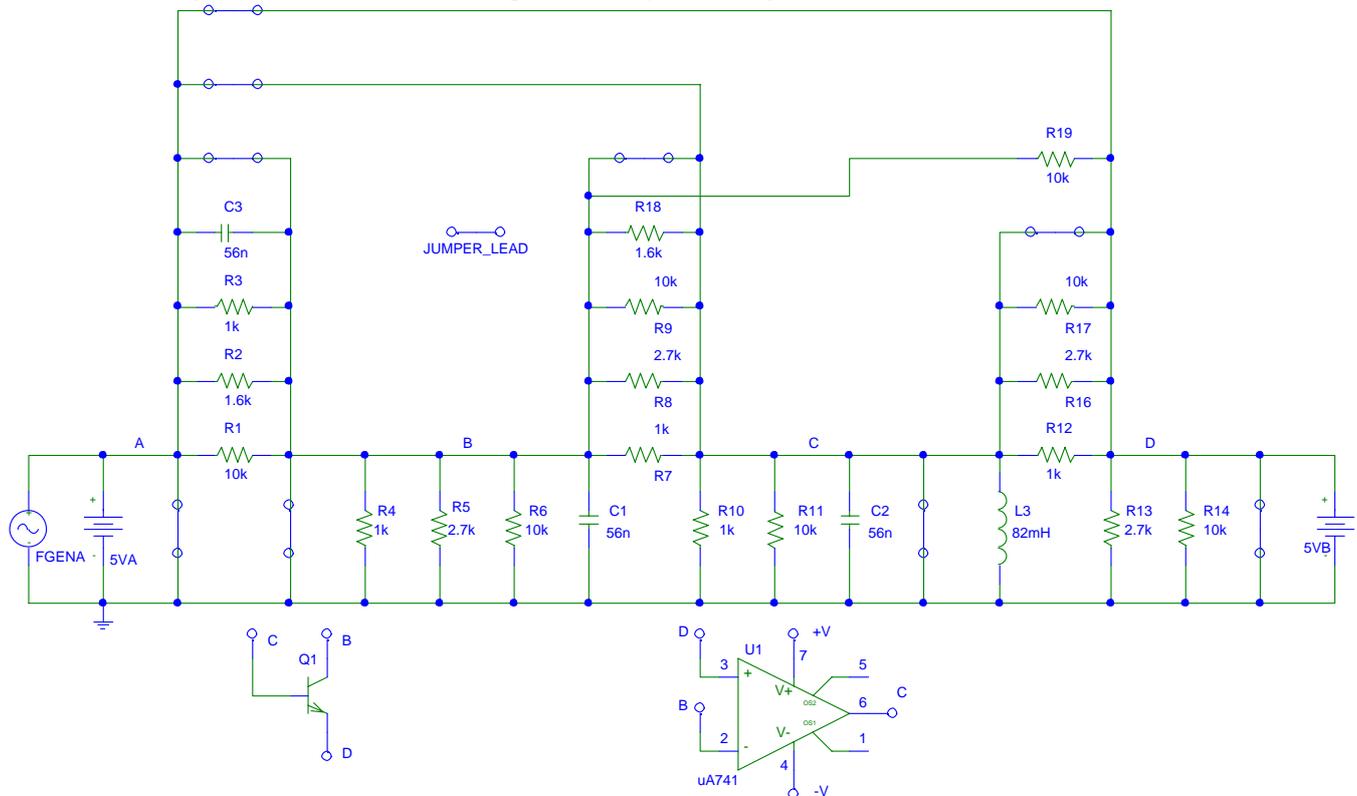


FIGURE 4
CIRCUIT DIAGRAM OF THE SWITCHING MATRIX BELONGING TO THE FIRST EQUIPMENT SERVER.

- **Guest users** are unregistered users. They are permitted to log on and to start lab sessions of a special guest course and to perform experiments in private or together with others when the laboratory is not fully occupied. Currently the length of a session for guest users is 30 minutes. The session starts when the breadboard shows up on the computer screen.
- **Students** registered on a course are permitted to log on and to start any of the lab sessions of that course during the whole course period when no supervised session is taking place. Every student enrolled in a course is also permitted to make seat reservations for participation in each supervised session of the course on a first come, first served basis. Currently the results of the experiments performed are reported in the same way as in the traditional laboratory.
- **Instructors** are registered on the courses containing lab sessions which they are supervising. They have the same access rights as students but are also allowed to log on to supervise sessions without making seat reservations.
- **Teachers** responsible for the courses are permitted to log on to input log on ids for instructors and for

students enrolled in their courses and make time reservations for each lab session indicating the number of participants. If a desired lab session is missing in the laboratory the staff must first introduce it. Other teachers engaged in the course are considered to be instructors.

- **Laboratory staff** is managing the laboratory.

All courses providing lab sessions in the open laboratory are listed in the authorization and time reservation system. The lab staff updates this list of course events in cooperation with the teachers. Entries for each course are:

- Name of the course
- Start and end date. The course event is open for the teacher, instructors, and students during the course period only.
- Maximum number of students and instructors
- Log in id of the teacher of the course
- A list of lab session time reservations made by the teacher
- A list of log in ids of students and instructors are created by the teacher.

- If the instruments and the lab sessions already available in the open laboratory are sufficient and the laboratory is not fully occupied then it is easy to define a course event. Only a course name, start and end date of the course time period, maximum number of students, and the main teacher's email address are required.
- If a teacher wants his or her own lab sessions and the required components already are online and all connection possibilities needed are there then the teacher must provide links to the lab instruction manual and to the list of components to display on the client screens for the new lab sessions.
- If new components are needed they must be mounted in the matrix. Photographs of them and rules for how the users are permitted to use them must be entered in the laboratory database.
- If a new instrument model is required and the hardware in the laboratory is sufficient then a new software module must be added.

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