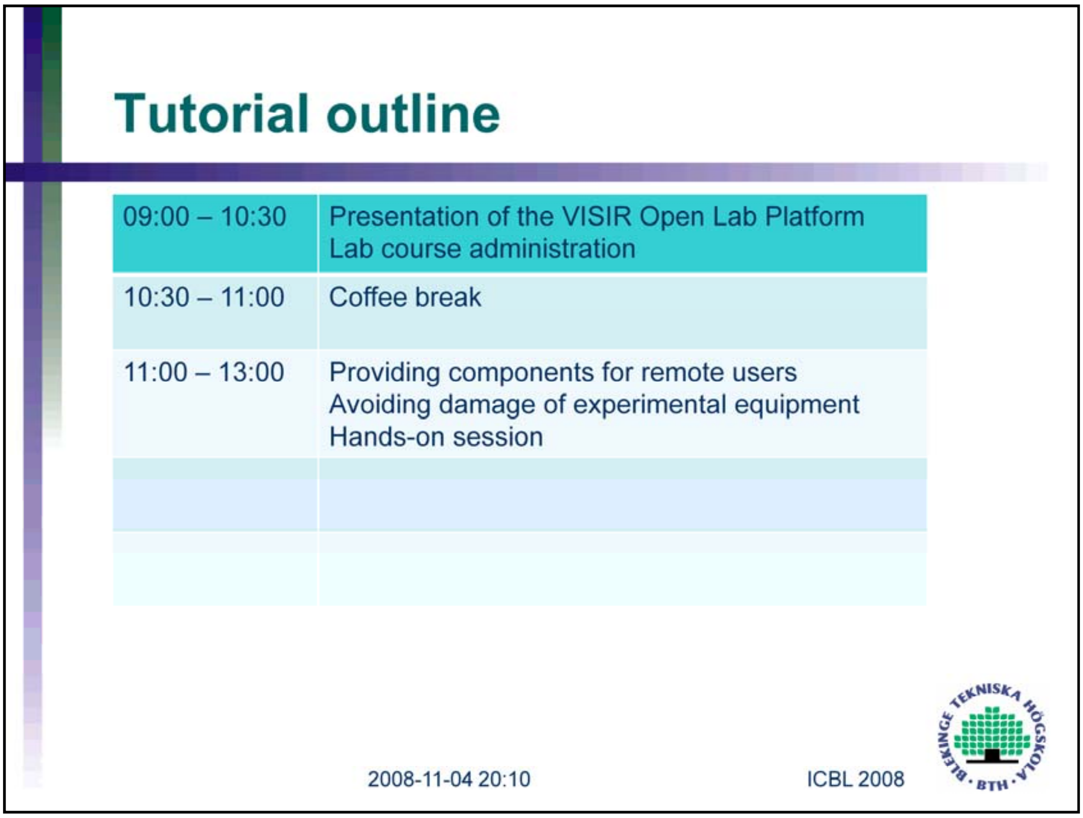
A local electronics laboratory can be opened for remote access using the VISIR Open Lab Platform. This is a way to open the laboratory for students on campus and off campus 24/7 without any risk for themselves or the experimental equipment. The VISIR Open Lab Platform is a server/client application enabling learners to perform physical electrical experiments described in lab instruction manuals over the internet using a web browser. Virtual front panels and a virtual breadboard displayed on the client PCs are used to control the physical equipment connected to the server. The server is a time shared online workbench giving the learners the impression that they are working in a real laboratory. Such a workbench supplements a local laboratory equipped with workbenches comprising oscilloscope, function generator, DMM, triple power supply, and a solderless breadboard.

Apart from Blekinge Institute of Technology in Sweden, where the platform has been created two universities, University of Deusto in Spain and FH Campus Wien in Austria, have already implemented copies of the workbench and use hem in their regular education. Other universities are ready to start. Thus, the workbench is being used at universities but it is perfect for schools and for vocational education as well. It is easy for teachers to introduce their own existing lab assignments. A modem connection and a web browser with Flash player are sufficient for the learner.

The software required to set up such a workbench was published approximately a year ago under a GNU GPL licence. Apart from a standard PC the hardware required to join the VISIR Group and implement a workbench is a PXI chassis with instruments from National Instruments and a switching matrix. The components to be used by the learners are to be provided by the teachers and installed in the matrix. Universities, schools and other teaching organizations are invited to participate and open their local laboratories for remote access in order to be able to produce engineers with a solid and documented lab experience but without significantly increased cost per student.



The last part will be the hands-on session where an open laboratory brought to the tutorial room will be available for the participants to test via WLAN using their own laptops.

Outline of the presentation of the VISIR Open Lab Platform

- Introduction and background to VISIR
- Demonstration of an existing VISIR Lab
- The aim and goal of the VISIR project
- Overview of the Open Lab platform
- How to join the VISIR project
- Conclusions and further development

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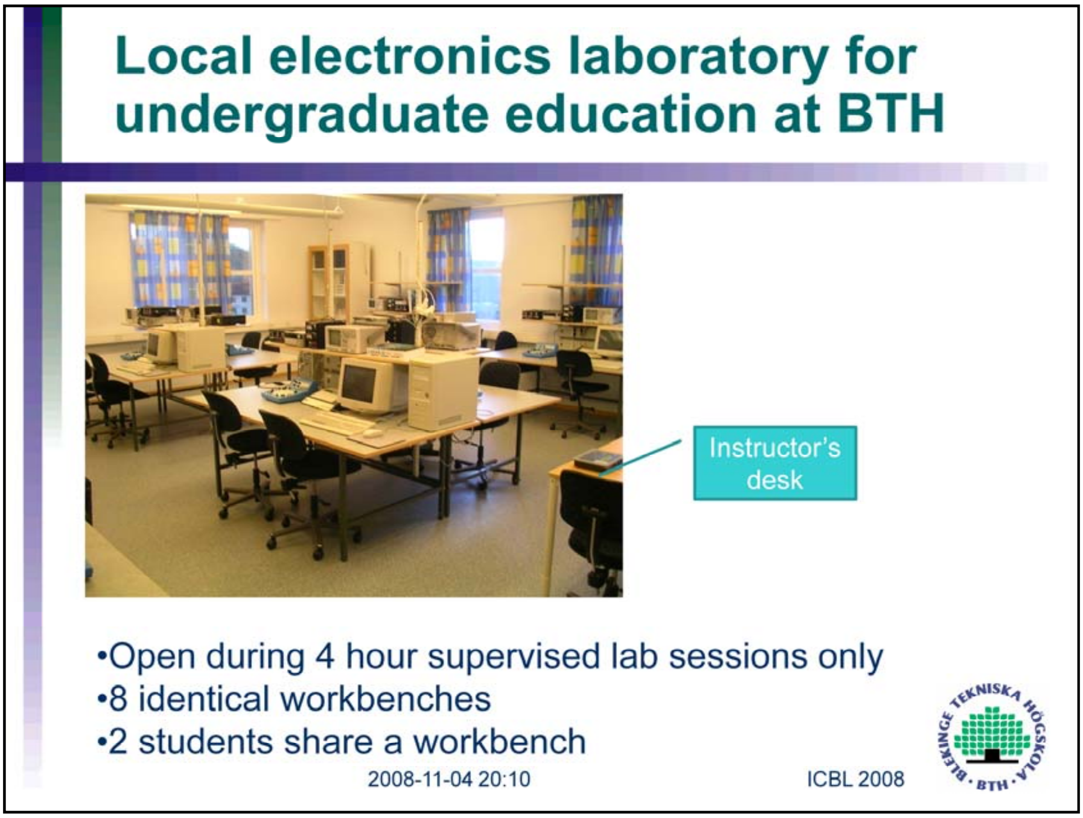
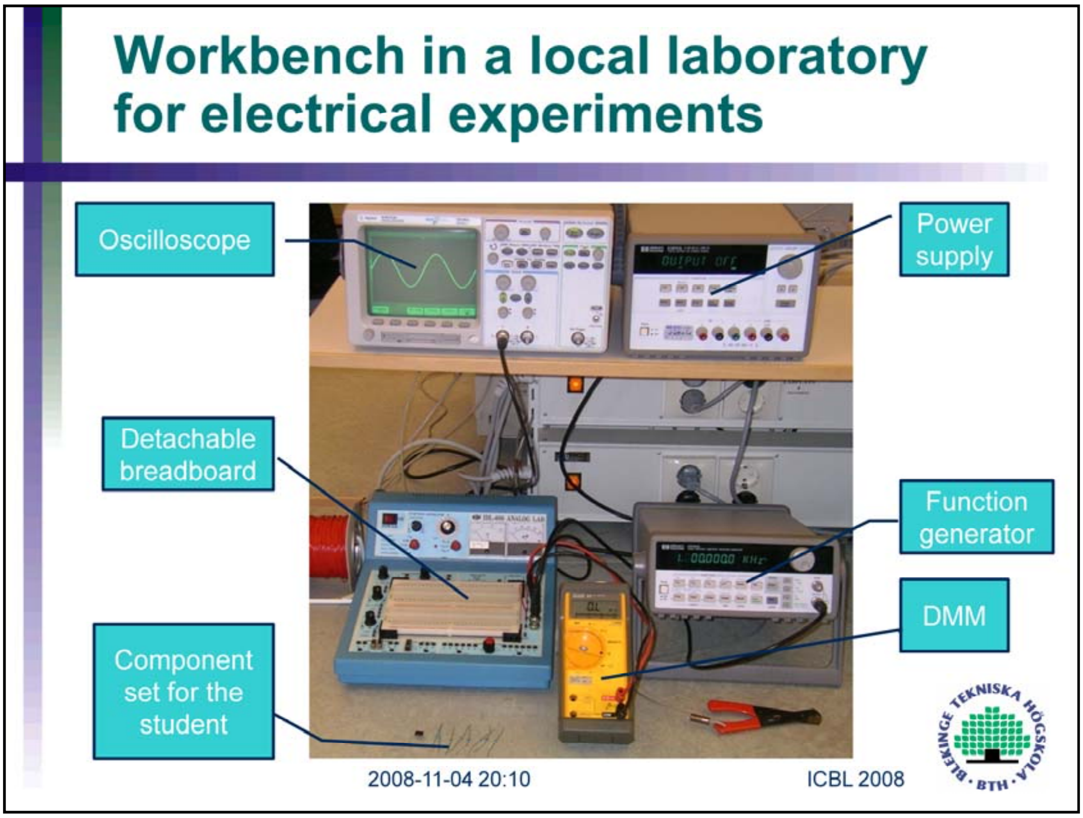
BLEKINGE TEKNISKA HÖGSKOLA · BTH ·

Outline of the first part of the tutorial.

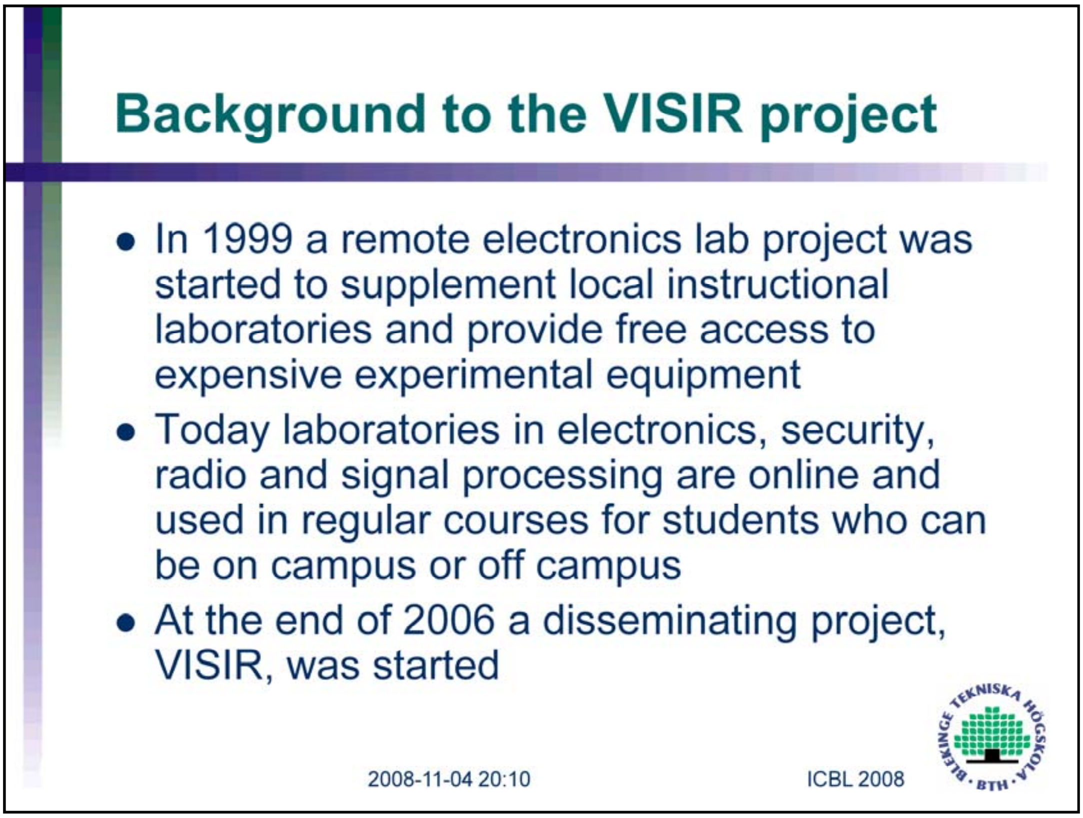


In a *local laboratory* the experimenters are located close to the experiment and control the instruments and other experimental equipment directly using their fingers. The photo shows a laboratory for electrical experiments in undergraduate engineering education at BTH. It is open during supervised lab session only. The lab sessions are four hours. One instructor is supervising 16 students in a lab session. Sometimes there are a few more students than 16. Workbenches containing the same equipment mean that all the students can perform the same experiments synchronously.



The workbenches contain oscilloscope, DMM, function generator, power supply, and a solderless breadboard. The breadboard is detachable from the box carrying it. The cables from the instruments connect to sockets on this box and these sockets connect in turn to holes for wires making it easier to connect the instruments to a circuit wired on the breadboard.

Before a lab session starts the instructor distributes to every student team in front of a workbench a component set to be used for the experiments.

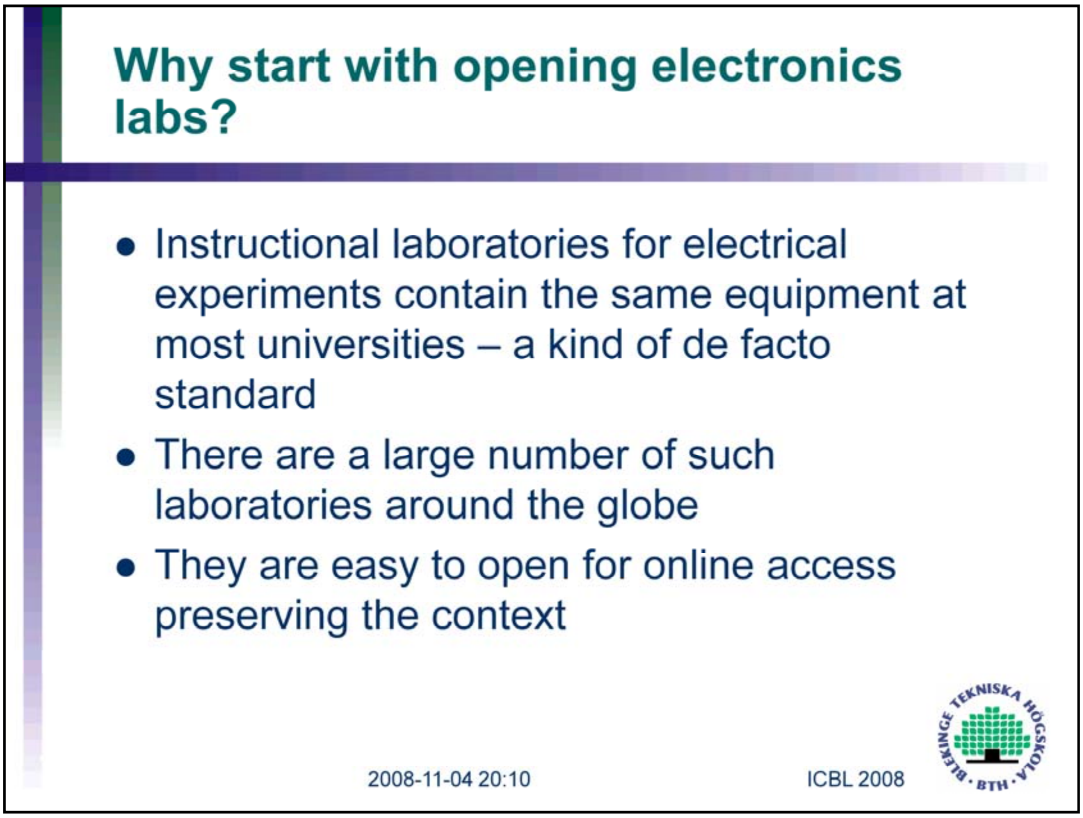


When I returned to the academic world in 1994 I saw that reduced funding had forced institutions to decrease the number of physical experiments considerably compared to the situation when I was a student 30 years earlier. In some courses experiments had been replaced by simulations. However, laboratory work is indispensable to see the differences between mathematical models of natural phenomena and nature itself. You might say that laboratory work is a conversation directly with nature and that experiments are the language of nature.

In 1999 I started our lab project to provide more physical experiments for our students. The intension was providing free access to the laboratory over the Internet in order to offer students an even better education than thirty years ago.

Today laboratories in electronics, security, radio, and in signal processing are online at BTH and used in regular courses for students who can be on campus or off campus.

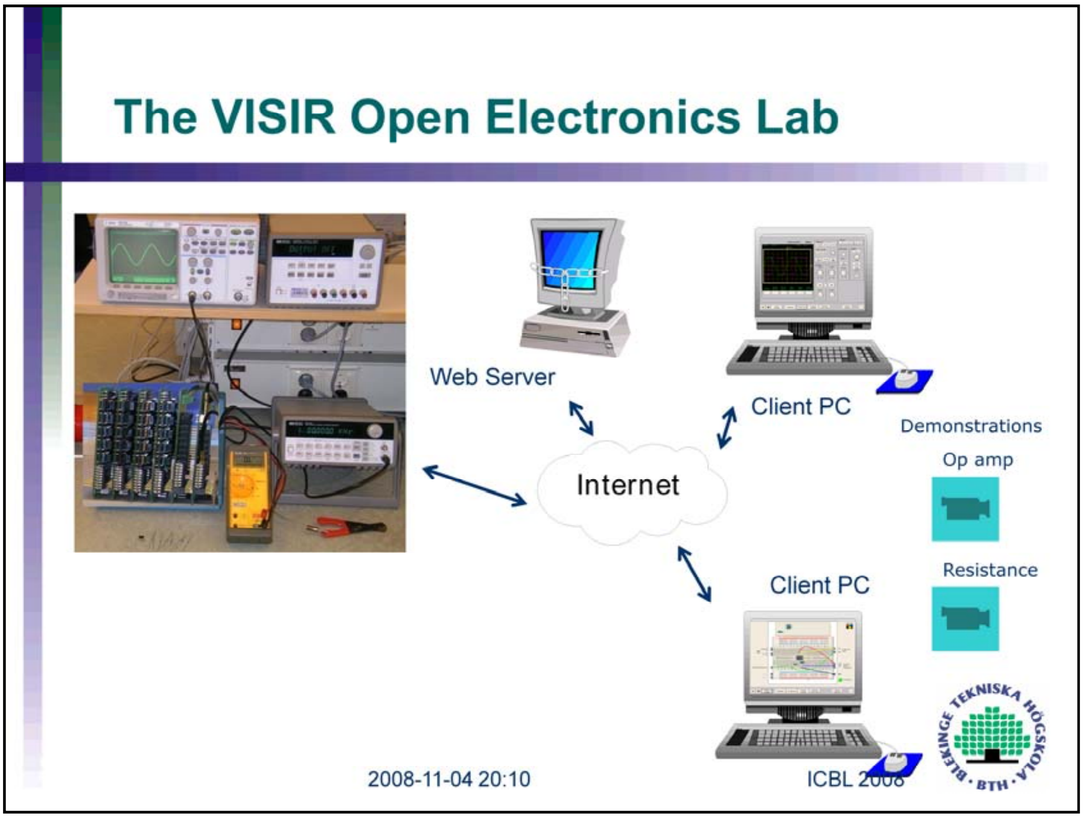
At the end of 2006 a disseminating project, VISIR, was stareted. So far, University of Deusto and FH Campus Wien have joined the consortium and set up VISIR laboratories of their own.



Laboratories for electrical experiments contain the same equipment at most universities even if the instrument model or brand may vary.

Such laboratories are not only used by electrical majors but also in, for example, machine engineering education and in schools for vocational training. Thus there are many learners who needs experimental training.

They are easy to open for online access preserving the context as will be shown in the next slide.

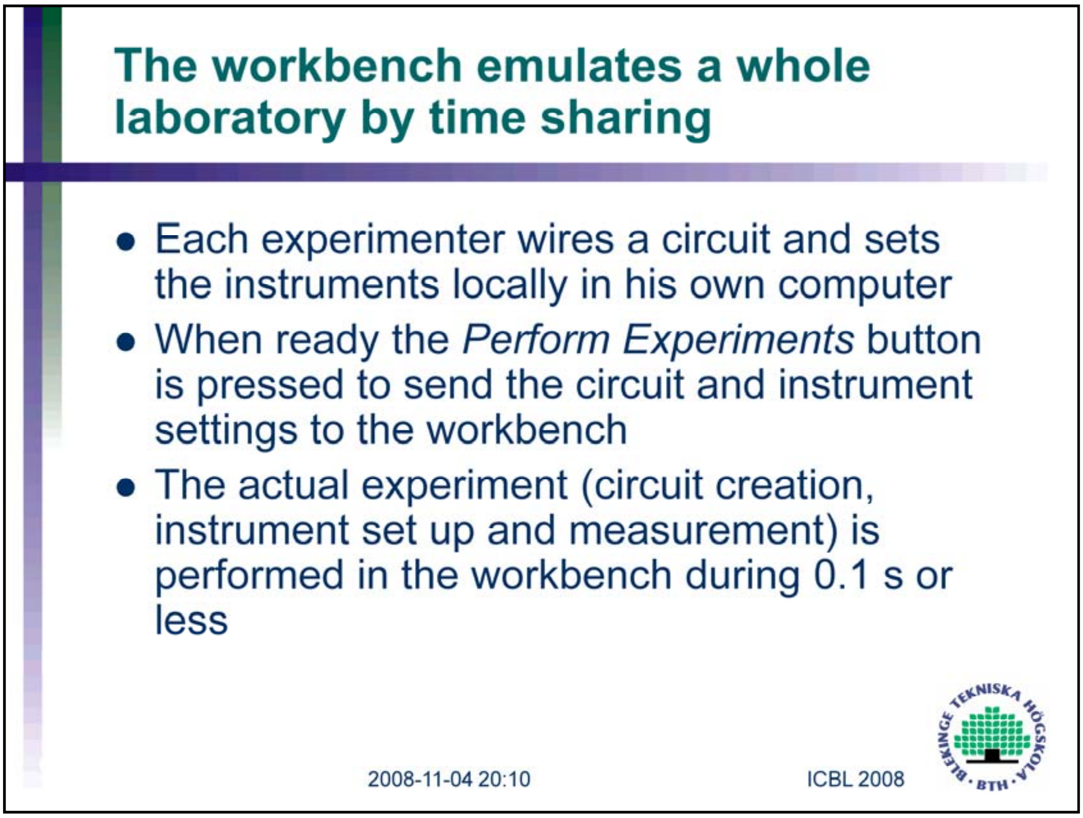


Here is the workbench again. Most electronic instrument can be controlled remotely but the breadboard can not. It must be replaced by a device for circuit wiring possible to control remotely e.g. a switching matrix equipped with electro-mechanical relays, sockets for components, and instrument connectors.

The workbench can now be controlled from client machines over the Internet.

The client software is downloaded from a web server. The client computers show photos of the front panels of the instruments or the breadboard.

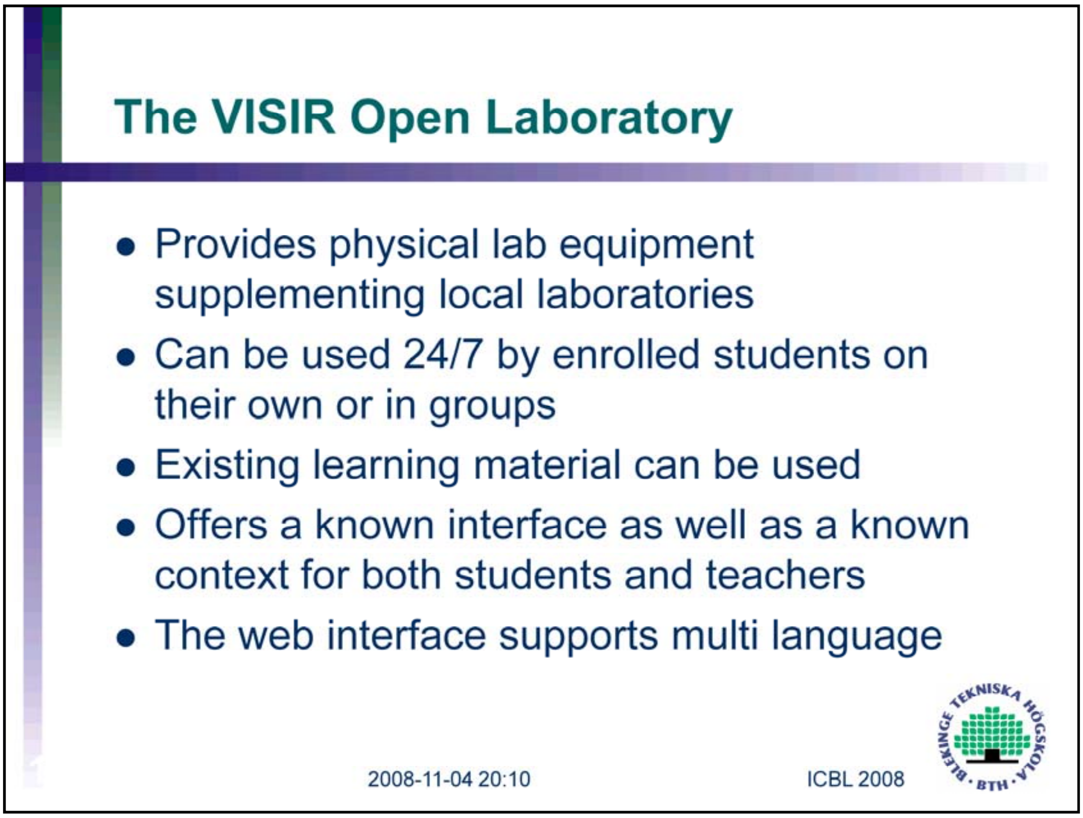
The demonstrations are Camtasia video clips. The op amp clip starts with an almost completed inverting op amp circuit to save time but two wires remain. These two wires are added and the instruments are set. When the circuit and the settings are ready the experimenter presses the Perform Experiment button to send them to the server. The workbench creates the circuit, set the instruments, activates the circuit and performs the measurements requested. Finally the result is returned to the client computer and the oscilloscope traces are displayed.



In electronics, it is possible to perform the same experiment in different time scales by selecting the values of the components controlling the time constants properly. This “feature” is used in the VISIR electronics laboratory to allow simultaneous access by time sharing. A single workbench can replace a whole laboratory with many workbenches.

The maximum duration of a single experiment i.e. circuit creation and measurement procedure is currently set to 0.1 second to get a reasonable response time even with a large number of experimenters.

The experiments are set up locally in each client computer. Only by pressing a *Perform Experiment* button the experimenter sends a message containing a description of the desired circuit and the instrument settings to the workbench. If the workbench is not occupied, the experiment is performed in a predefined order, and the result or an error message is returned to the requesting client computer. Otherwise, the request is queued.

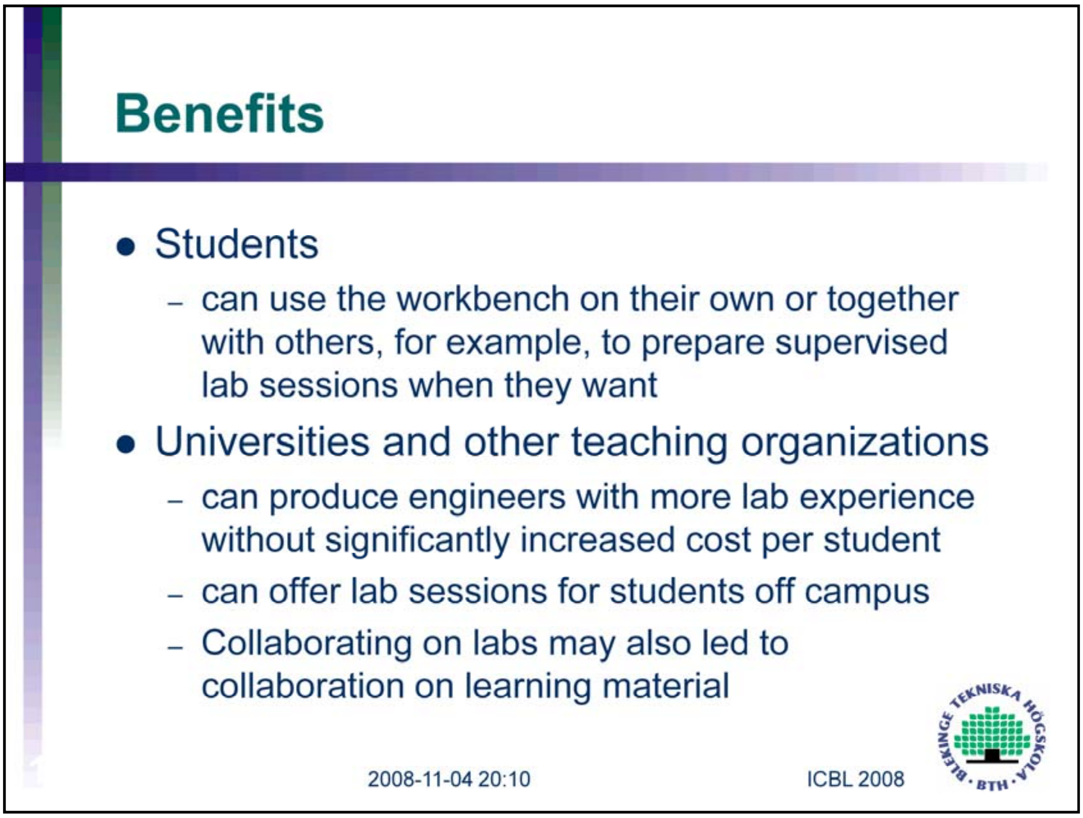


When supervised lab sessions are going on the laboratory is closed for remote experimenters.

Currently the web interface supports English and Swedish.

The VISIR software distribution

- A public subversion repository with all software modules are available (http://svn.openlabs.bth.se/trac/)
- Members of the VISIR group will be granted write access to branches in the repository
- Write to the trunk is limited and will require code review
- The Trac software project management system (http://trac.edgewall.org) is used



Nowadays, students want extended accessibility to learning resources and increased freedom to organize their learning activities, which is also one of the main objectives of the Bologna Process. Students can prepare supervised lab sessions and perform the experiments at home, knowing that the equipment in the traditional laboratory looks and behaves the same. They can also repeat experiments afterwards! Inexperienced or less confident students requiring more time, appreciate these possibilities. A student wanting, for example, to master the oscilloscope, can practice in the privacy of his/her own home.

Benefits cont.

- The local lab sessions can be more effective because
  - The students can learn trivial things such triggering the oscilloscope on their own
  - The local lab sessions can be dedicated to more complicated things such as EMC problems

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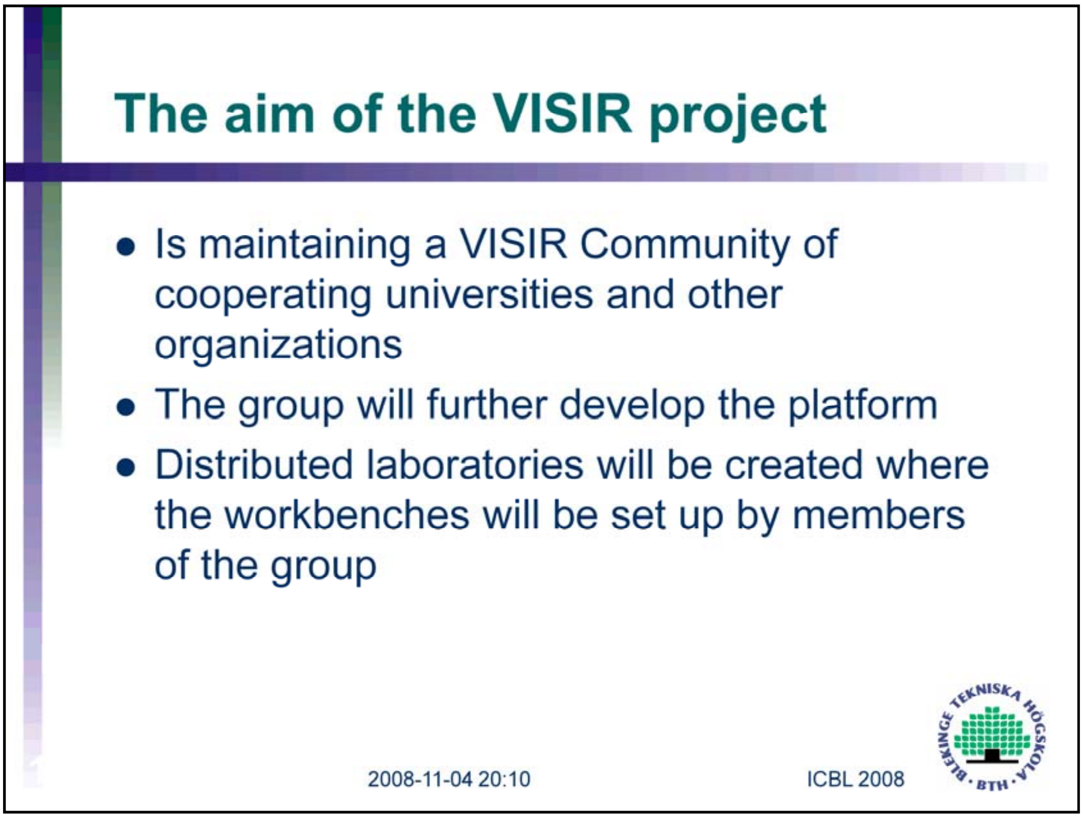
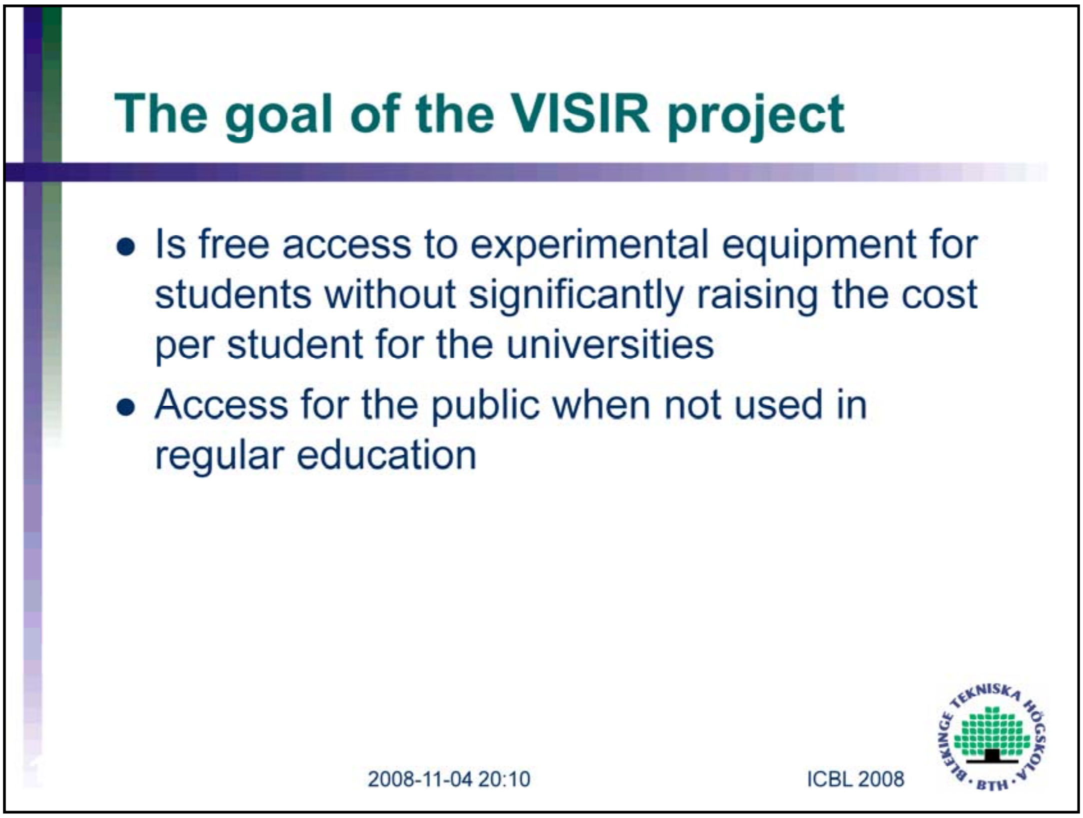
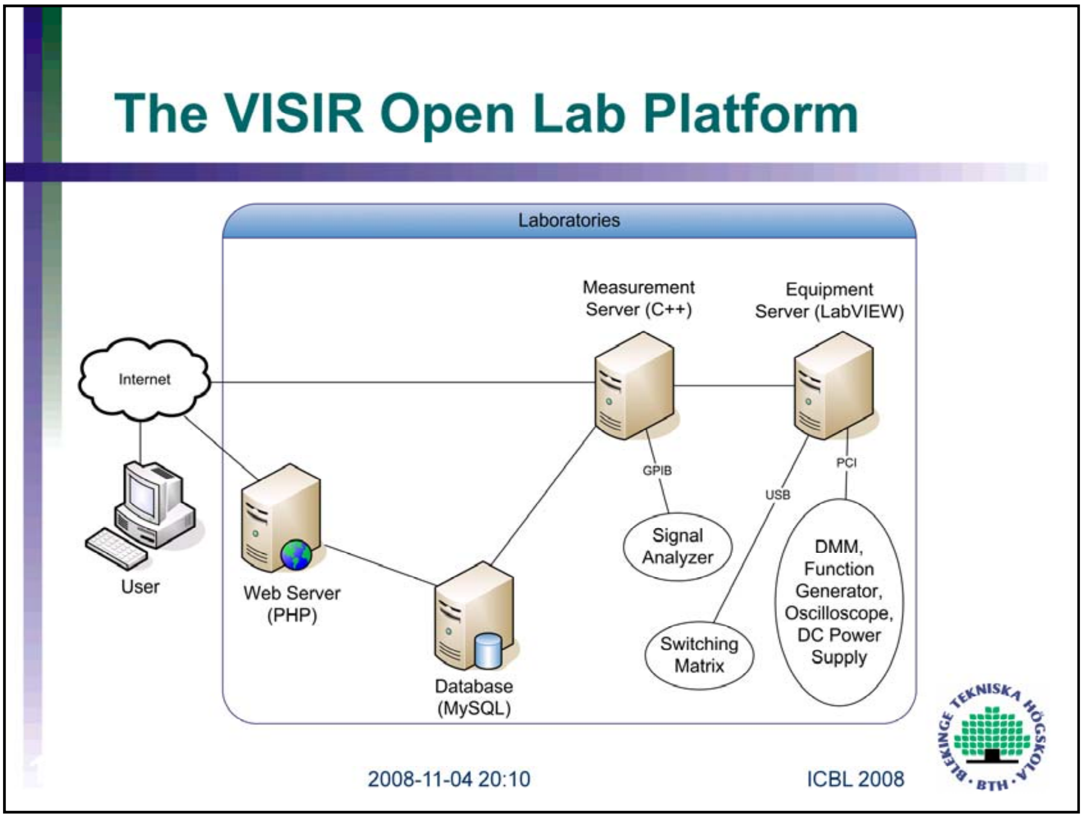


The aim of the VISIR project is to maintain a large group of cooperating universities and other organizations, a VISIR Community, creating/modifying software modules for online laboratories using open source technologies and setting up online lab workbenches. BTH will act as a hub for the development and maintain a server from which the current version of the software can be downloaded.



The overall goal of the VISIR project is aimed at increasing access to experimental equipment in many areas for students, without raising the running cost per student significantly for the universities. The means are online laboratories created by universities in cooperation and supported by instrument vendors. The ultimate goal of the research at BTH is ubiquitous physical experimental resources, accessible 24/7 for everyone, gender neutral, as a means of inspiring and encouraging children, young people and others to study engineering and become good professionals or to be used as a means of life-long learning.



The laboratories are composed of four distinct parts – Experiment client, Web Interface, database, and lab equipment. The Equipment Server hosts the instruments in the electronics laboratory.

The Web Interface manages resources and keeps track of when and by whom the laboratory is used.

The lab equipment is more than the workbench for electrical experiments. It includes the signal processing laboratory as well.

Lab course administration

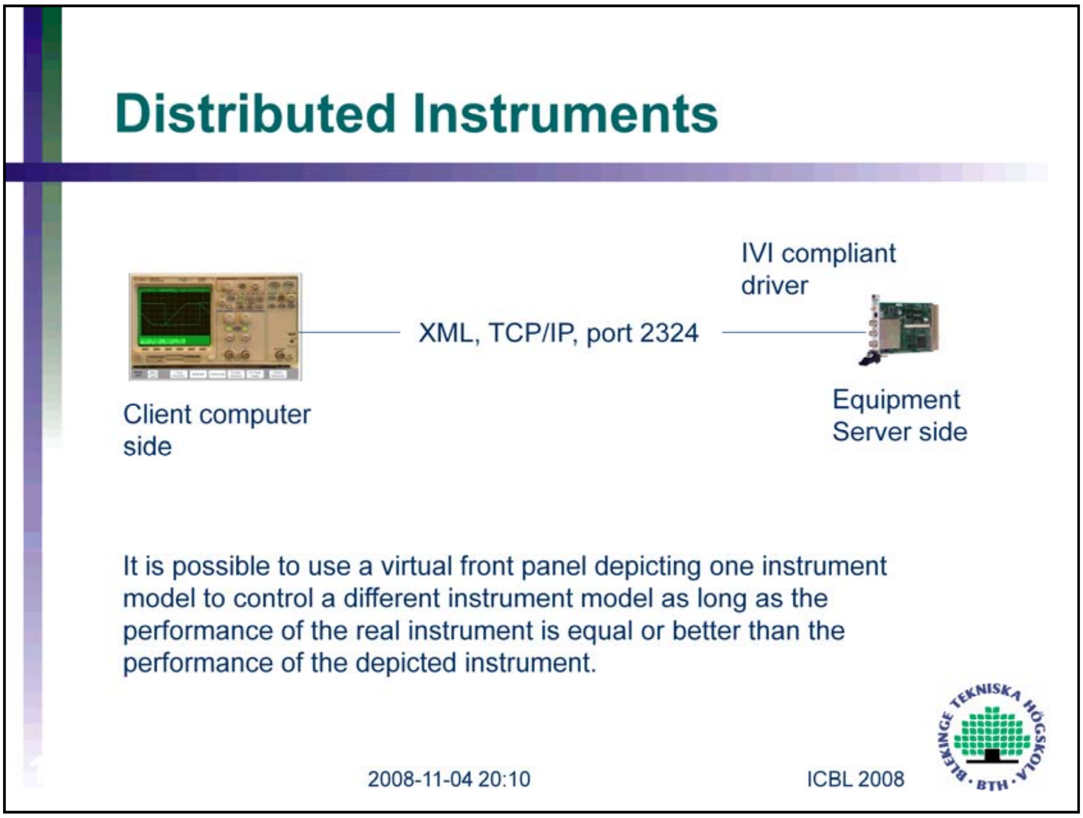
- Different roles such as administrator, teacher and student are defined and they have different access rights
- Time reservation for lab sessions as well as for students' own experiments are provided
- The web interface is used to introduce courses, lab sessions, personal accounts

This is the online workbench. Where are the desktop instrument displayed on the client screen? They are replaced by PXI boards. PXI is a standard for instrumentation. The important thing is that the performance of the boards are equal or better than the performance of the desktop instruments.

The PC is the workbench controller. The switching matrix is the card stack on the top of the PXI chassis. The components to be used in test circuits are installed in the matrix in sockets near the edge of some of the boards.

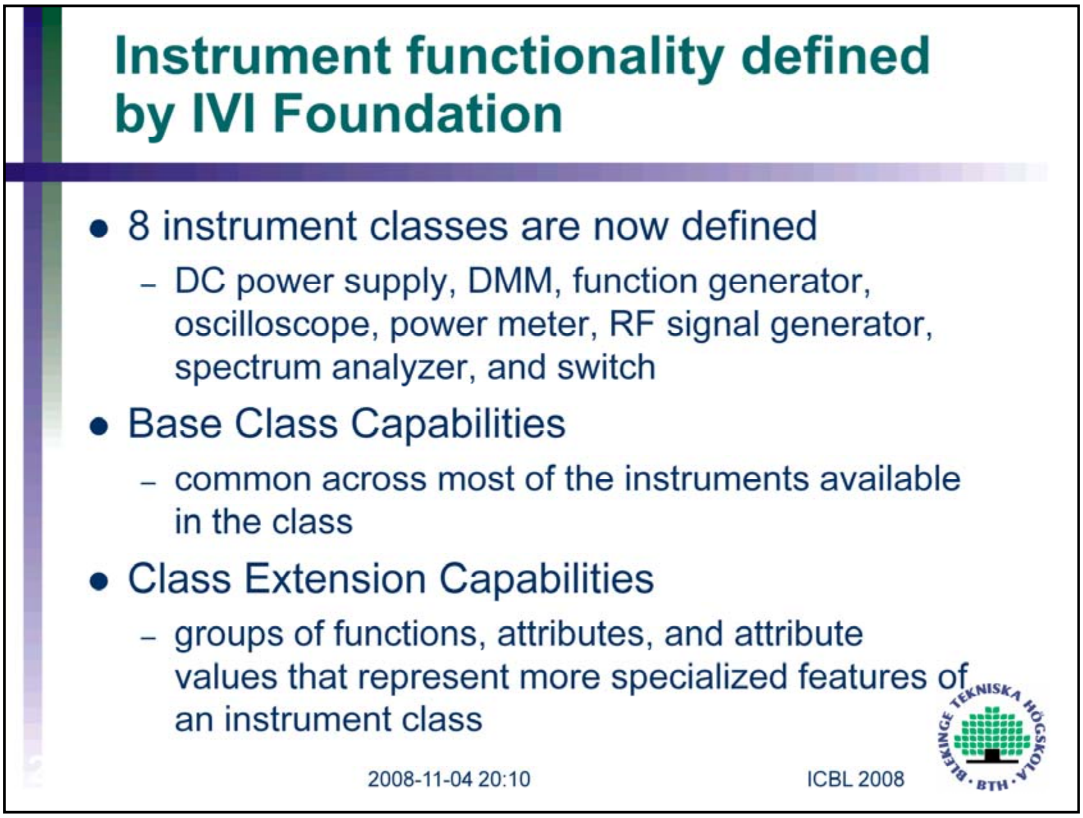
The PXI chassis is NI PXI-1033. The instruments are from left to right function generator NI PXI-5402, dual channel oscilloscope NI PXI-5112, DC power supply NI PXI-4110 with APS-4100, and DMM NI PXI-4070. This equipment is manufactured by National Instruments.

Remotely controllable instruments are standard equipment so are switch boards equipped with electro-mechanical relays. Such switch boards was used in the early versions of the matrix. However, to be compatible with a breadboard in terms of bandwidth the relays and the components must be located close together.

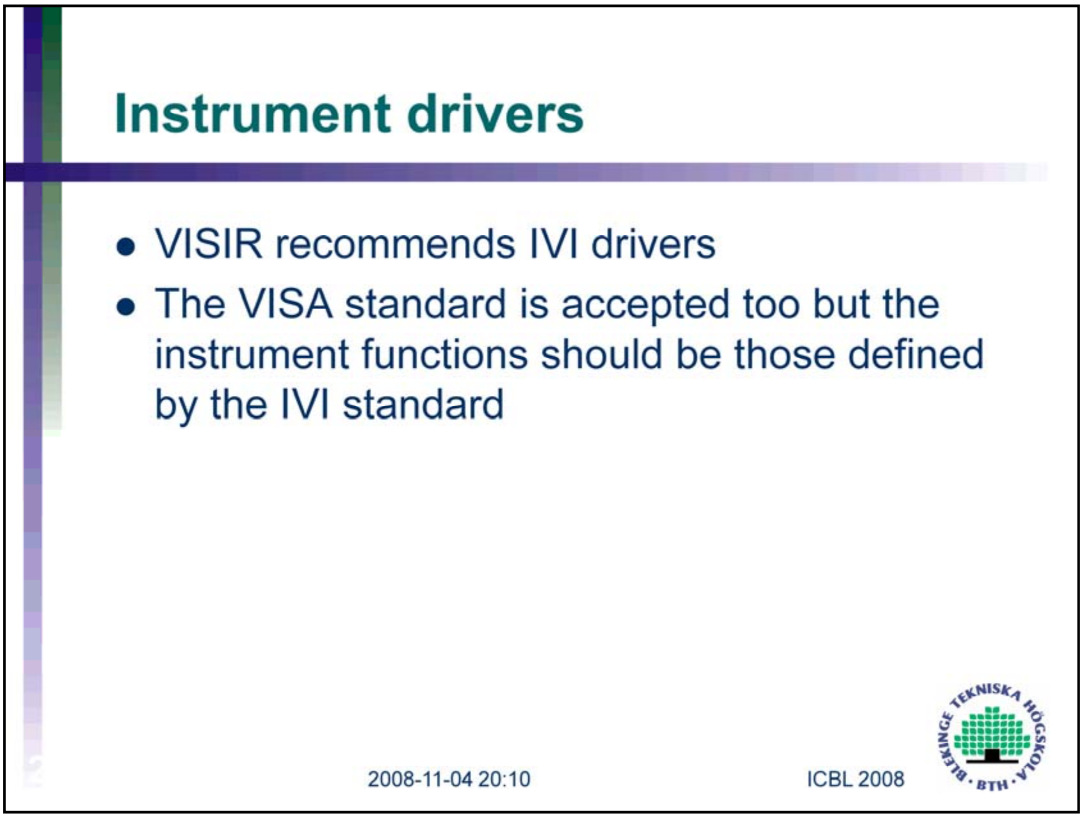


Each virtual front panel controls an instrument board and receives the results of the measurements made.

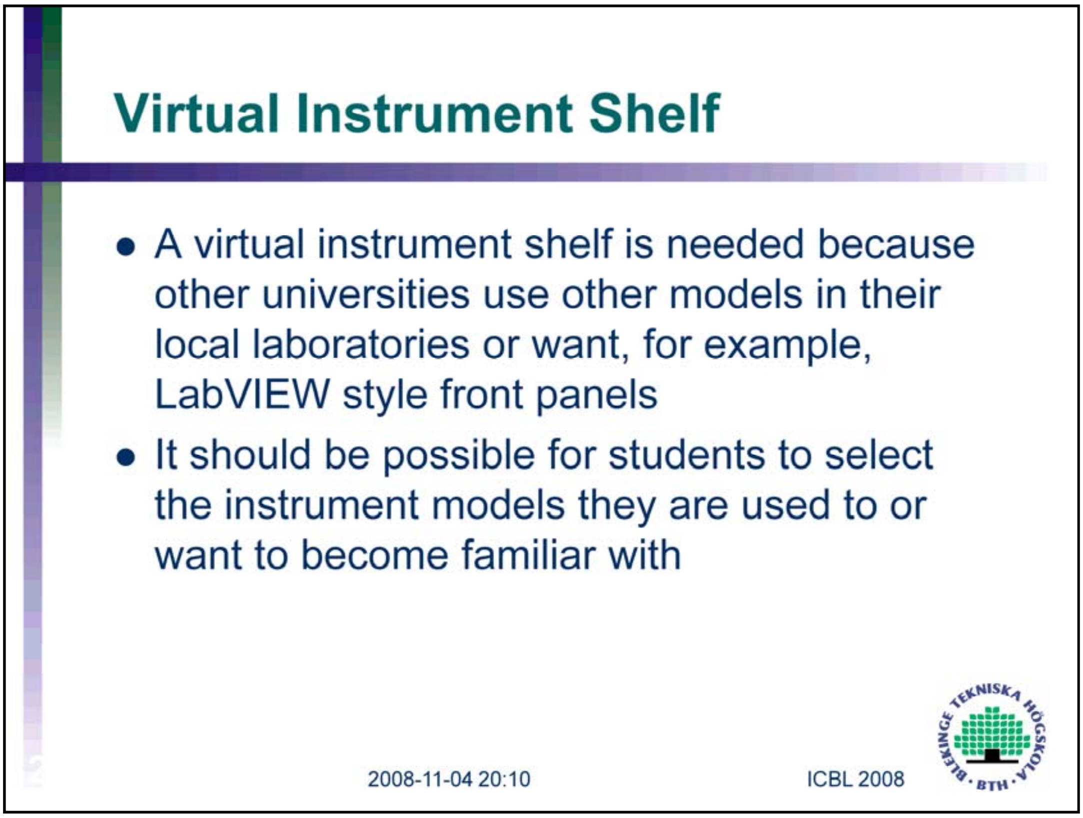
The IVI Foundation, http://www.ivifoundation.org/, is a group of end-user companies, system integrators, and instrument vendors, working together to define standard instrument programming interfaces. The IVI standards define open driver architecture, a set of instrument classes, and shared software components. To enable interchangeability, the foundation creates IVI class specifications that define the base class capabilities and class extension capabilities. The drivers for the instruments in the PXI box are IVI compliant.



Instrument I/O is a well-studied domain with established industrial standards. Most commercial products follow the Virtual Instrument System Architecture (VISA) or the Interchangeable Virtual Instrument (IVI) standards. The IVI foundation creates instrument class specifications. There are currently eight classes, defined as DC power supply, Digital multi-meter (DMM), Function generator, Oscilloscope, Power meter, RF signal generator, Spectrum analyzer, and Switch. Within each class, a base capability group and multiple extension capability groups are defined. Base capabilities are the functions of an instrument class that are common to most of the instruments available in the class. For an oscilloscope, for example, this means edge triggering only. Other triggering methods are defined as extension capabilities.

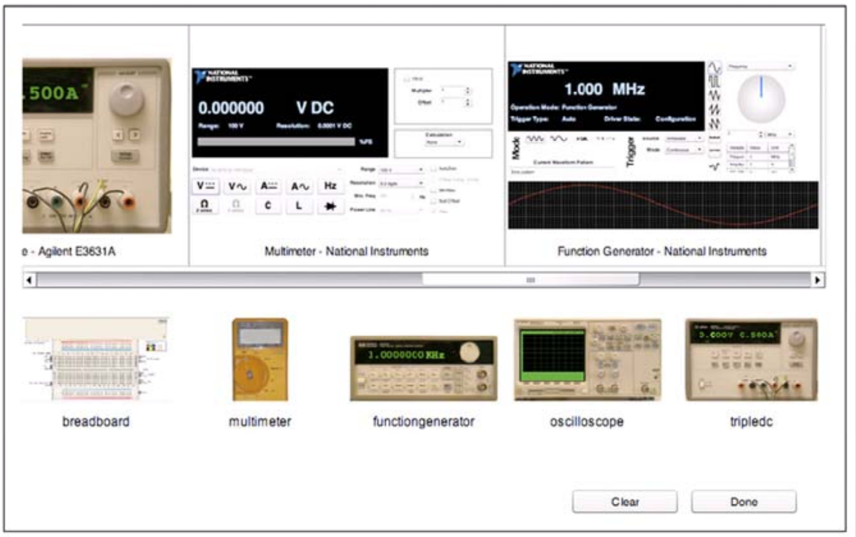


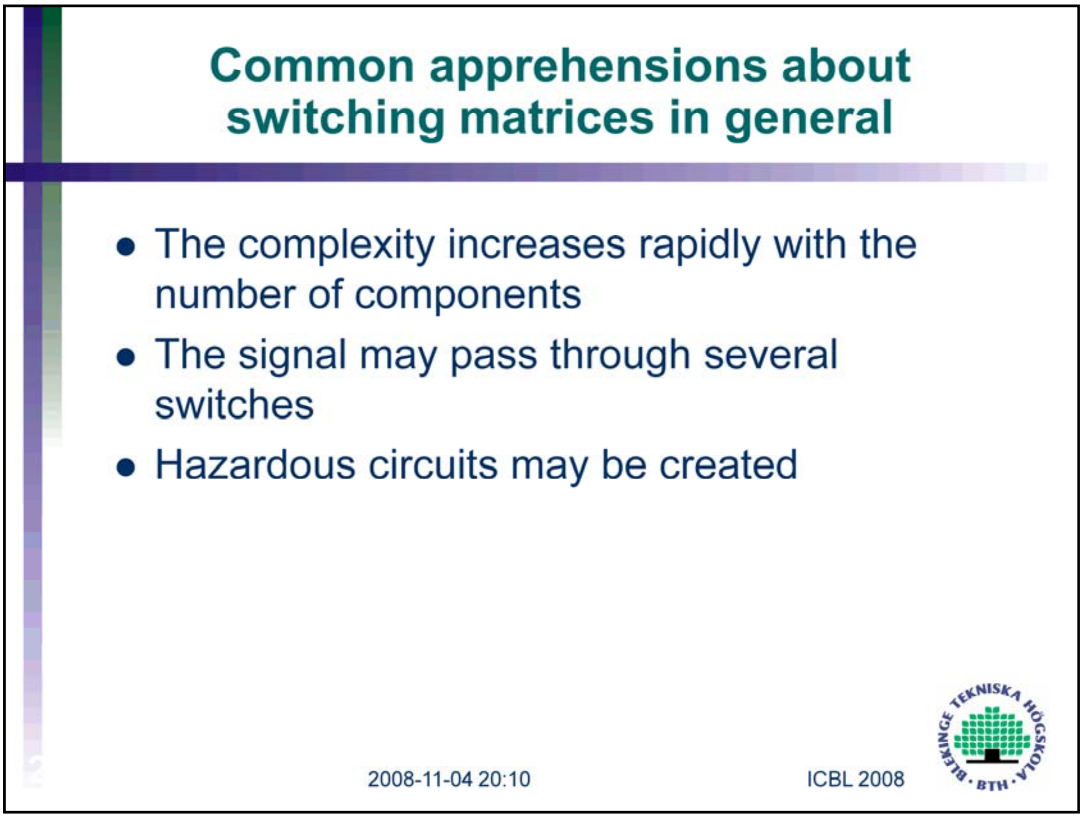
It is not necessary to use IVI drivers, but to enable interchangeability between grid nodes VISIR recommends functions and attributes defined by the IVI Foundation to be used to describe the capabilities of the lab hardware. In this way it should be possible to create a standardized approach which is easy to adopt.



To be able to preserve the context from the local laboratory the front panels of the instruments should look the same. In the local laboratories of BTH there are desktop instruments from Agilent Technologies and the virtual front panels are photos of the physical panels. Other universities and other teaching organizations have other instruments in their labs. Thus, universities having other instrument models should add new virtual front panels. A template will be provided.

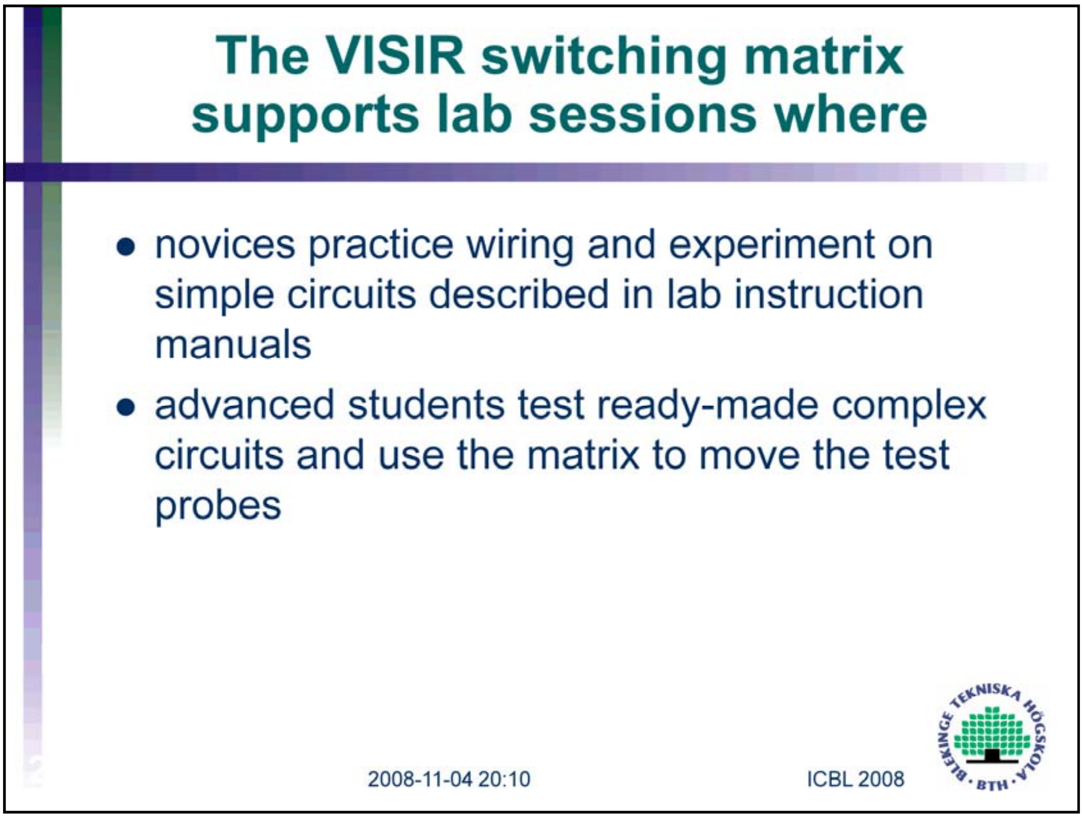
Example of Virtual Instrument shelf





The number of circuits possible to wire on a breadboard is limited primarily by the number of components provided. This number is great even with a modest number of components and a corresponding matrix would be large. However, lab sessions in undergraduate education is not about free experimenting where all circuits should be supported. Please see next slide.

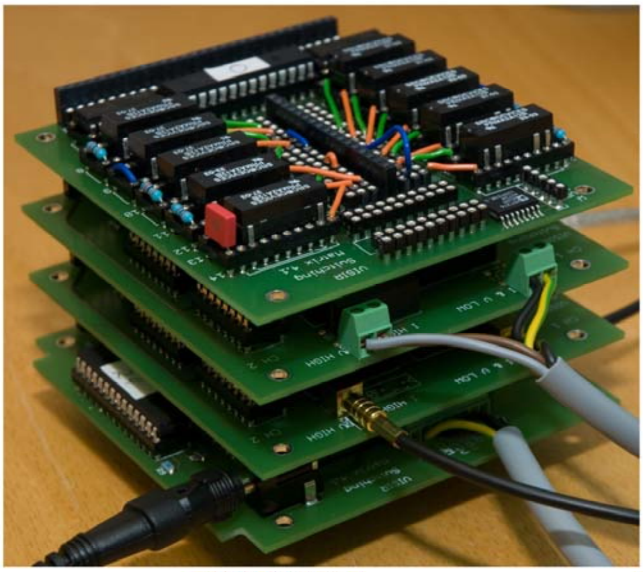
To be compatible with a breadboard only electro-mechanical relays should be used.



In undergraduate lab exercises the students are expected to wire only simple circuits that are described in lab instruction manuals. Some other circuits possible to wire with the components provided by the instructor may be hazardous and should not be created. Trying to perform destructive experiments should cause an error message from the virtual instructor. Thus, the flexibility of a breadboard is not required.

In more advanced courses the students experiment with larger circuits. These students want the circuits to be prefabricated and ready to test. The virtual breadboard and switching matrix combination is still useful. The ready-made circuit to be tested can be, for example, a circuit board or a circuit wired on a conventional breadboard. The ready-made circuit should be positioned adjacent to the switching matrix. In both cases the test points are wired to the switching matrix by the teacher. This circuit under test can, for example, be represented in the virtual component box as a 16 pin IC-chip where the pins are the test points or maybe source connections. These pin numbers should be found in the circuit drawing of the ready-made circuit. If the sources of the workbench are used to feed the ready-made circuit, the virtual instructor can supervise their voltages. Of course, combinations of the cases are also possible.

The switching matrix is a card stack



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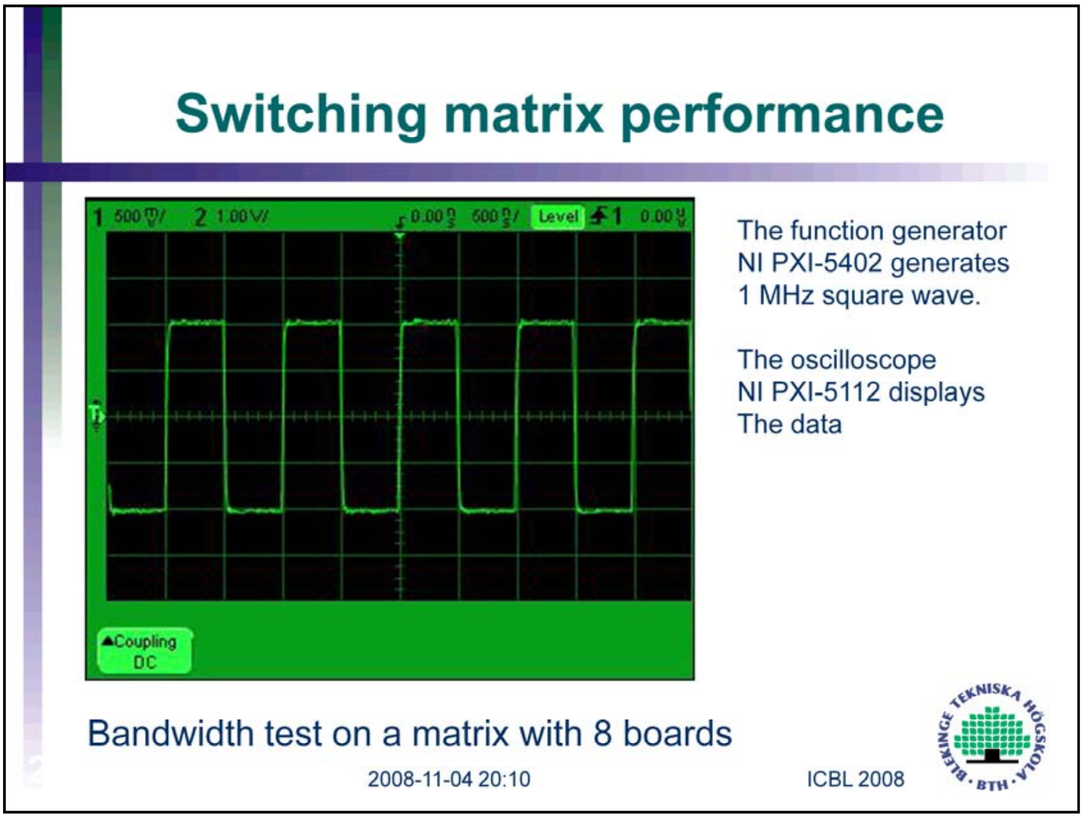
The switching matrix is a stack of boards. The relays are arranged in a three dimensional matrix pattern together with instrument connectors and component sockets. The number of online components can be increased by adding more boards.

The dimensions of the boards are PC/104 which is a well-known standard for embedded systems, http://www.pc104.org/. However, the location and the size of the connectors passing through the boards are different from the standard.



The switching matrix is designed for low frequency experiments. The layout of the board strips, the wiring on the component boards, and the number of boards in the stack limits the bandwidth of the switching matrix. The result of a test of the bandwidth of the switching matrix in the workbench at BTH equipped with eight boards is shown in the slide. The function generator, NI PXI-5402, is connected to the oscilloscope, NI PXI-5112, using this matrix. A 1 MHz square wave signal is displayed on the oscilloscope. The figure in the slide is a screen dump from a client PC. The oscilloscope trace is still a square wave.

How to join the VISIR group and set up a workbench

- Download the software and instructions published at http://svn.openlabs.bth.se/trac
- Buy the PXI hardware from National Instruments
- The switching matrix is commercially available

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Competences required to implement a VISIR online workbench

- Experience of analog electronics, PXI, and LabVIEW
- IT experience (Web, PHP, MySQL, XML, C++, FLASH etc.)

Further development of the VISIR platform

- Additional virtual front panels depicting instrument models used in the VISIR community
- Interface to a learning management system such as Moodle
- Adding new tools for communication between people in the laboratory
- A VISIR grid laboratory based on web services