STUDENT'S GUIDE TO THE VISIR REMOTE LABORATORY FOR ELECTRICAL EXPERIMENTS

A VISIR laboratory is a computer mediated university laboratory where remote students conduct physical experiments in the same way as in a hands-on laboratory using a PC, iPad, smart phone etc. 24/7. It is always safe to perform experiments in a VISIR laboratory because you, the experimentalist, are separated from the instruments and other equipment. The laboratory staff sets bounds to the experimentalists' actions in order to avoid damage of the equipment. Thus, if something in the laboratory happens to be damaged it is never the experimentalist's fault. If you have at least some experience of components and have tried experimenting on a breadboard you may start experimenting right now in the VISIR laboratory for electrical experiments at Blekinge Institute of Technology (BTH) in Sweden. Please feel free to perform experiments with four resistors[1]. Main differences between a VISIR laboratory for electrical experiments and a hands-on one are summarized in section 1.

Instructional laboratories are indispensable in science and engineering courses. The teacher presents each theory e.g. Kirchhoff's laws and then the students use a simulator to get familiar with the theory. Finally, the students perform physical experiments selected by the teacher in order to verify that the theory is useful in real life. The importance of experimenting is further explained in Appendix A. This guide is written for students who are enrolled in courses, which offer experimentation in a VISIR laboratory for electrical experiments described in Appendix B. The students are supposed to have some prior experience of instruments, components and a solderless breadboard acquired either in a hand-on laboratory or by home experimenting.

VISIR laboratories at universities and schools are integrated into an administrative system adapted to education. For example, experimenting is organized in courses, each of which includes a number of laboratory sessions. Laboratory education organization is summarized in Appendix C. Section 2 describes the administrative procedures at Blekinge Institute of Technology (BTH) in Sweden. The user interface of VISIR laboratories at other universities may be different. Experimenting is described in section 3 but before experimenting, you should study the laboratory instruction manual describing the experiments you will conduct, usually found on the web site of the course. It is possible to organize supervised lab sessions where the students and the teacher are dispersed using a web conferencing platform providing shared screen as is described in section 4. Error messages and restrictions are listed in sections 5 and 6 respectively.

1. Main differences between experimenting hands-on and remotely in a VISIR laboratory

Fig. 1 shows a workbench in a hands-on laboratory for electrical experiments at BTH. Such workbenches are in operation at universities all over the world even if the makes and models of the instruments vary. Presently, it is not possible to display the devices simultaneously in a VISIR laboratory. When you enter, the Breadboard View of the online workbench will be displayed as is shown in Fig. 2. The buttons on the menu bar

---

[1] http://openlabs.bth.se/electronics/demo/ohmslaw

will allow you to select the Breadboard View and other views, one view for each instrument.

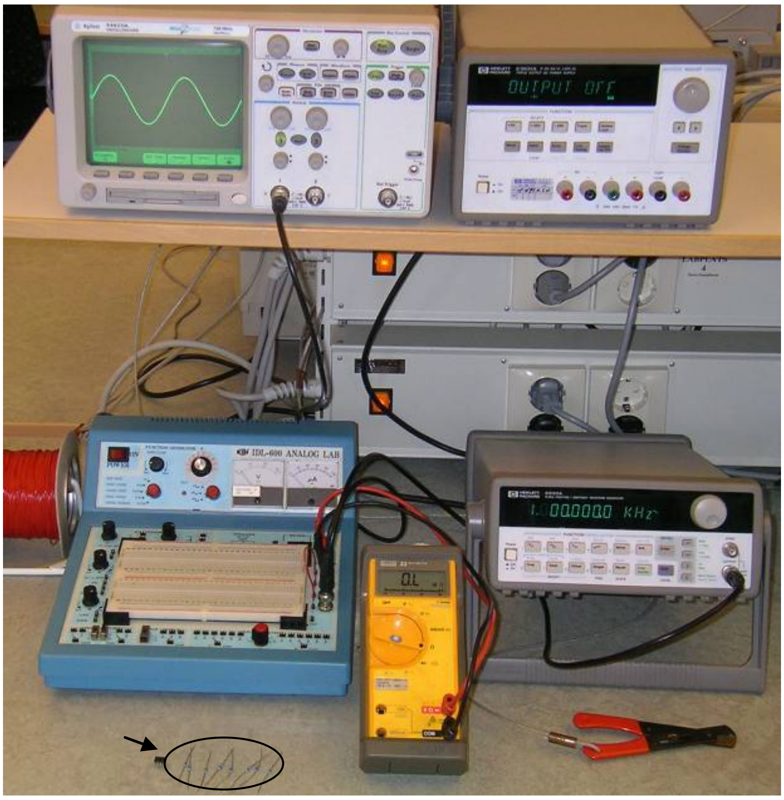


Figure 1. A workbench for electrical experiments in a hands-on laboratory at BTH

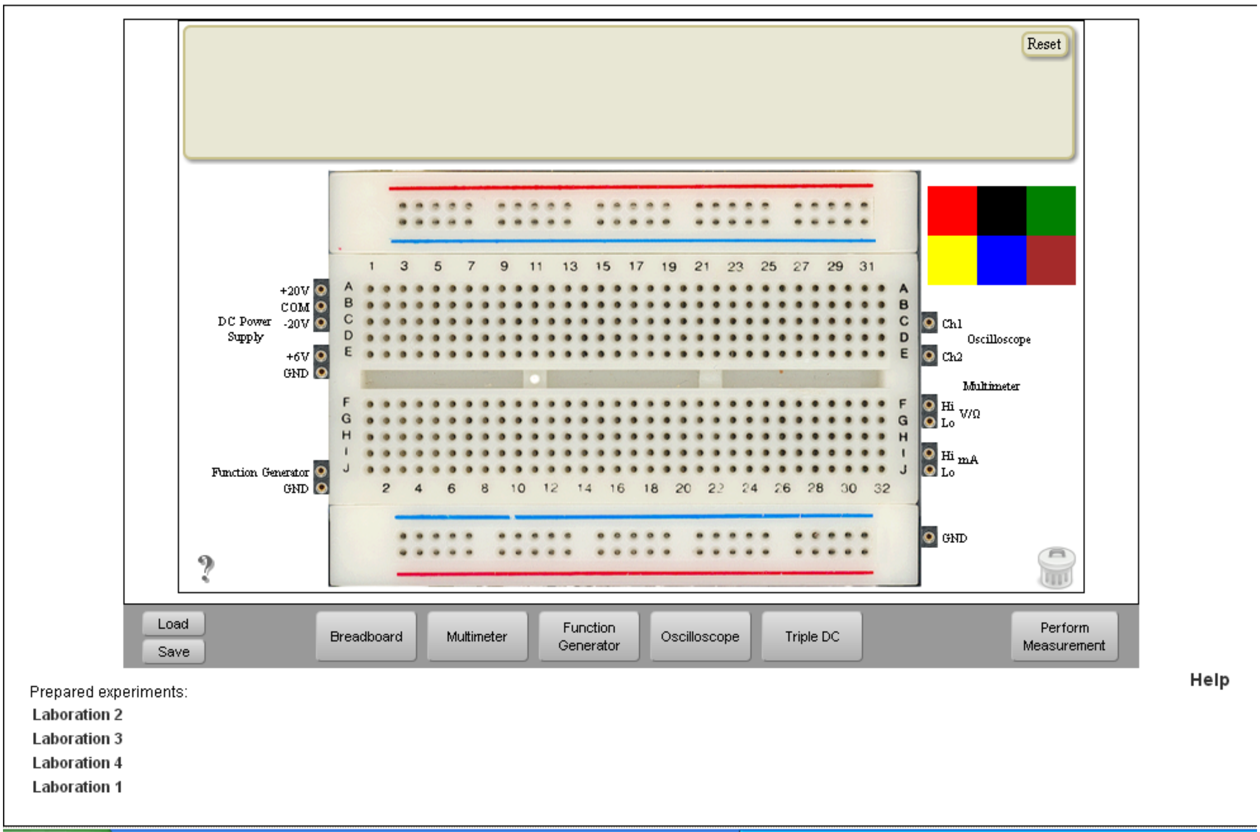


Figure 2. Breadboard View

The *Perform Experiment* button is special for the current VISIR laboratories. Only when you press that button the client software sends a message containing a description of your desired circuit and the instrument settings to the online workbench (server). A flash symbol appears to the right of the button indicating that the experiment request has been sent to the server that creates the desired circuit, performs the measurements requested, and returns the result is returned to your PC if the desired experiment is allowed.

The number of nodes of a circuit possible to wire on the virtual breadboard is limited. For example, in the introductory lab session with four resistors mentioned earlier only five circuit nodes are supported. If you wire a circuit with more than five nodes an error message will be returned. However, circuits with up to 10 nodes are supported in most other sessions.

2. Administrative procedures

You should find a link to the laboratory at your course site[2]. You must log in before you can start experimenting. To get a password the first time you visit, you must activate your account using the email address that you gave when you enrolled in your course. The login screen is shown in Fig. 3.

In Fig. 4 you are logged in as a student. You can only see the courses in which you are enrolled. By selecting a course, you will see the student's course page, Fig.5. Here you can make reservations. "My reservations" lists future time reservations you have made. When a reservation is in progress, it will show up under "My ongoing reservations". The laboratory uses CET (Central European Time). When a teacher has scheduled supervised laboratory sessions (refer to Appendix C), a link "Reserve a seat" will show up, which lets you sign up for a particular session.

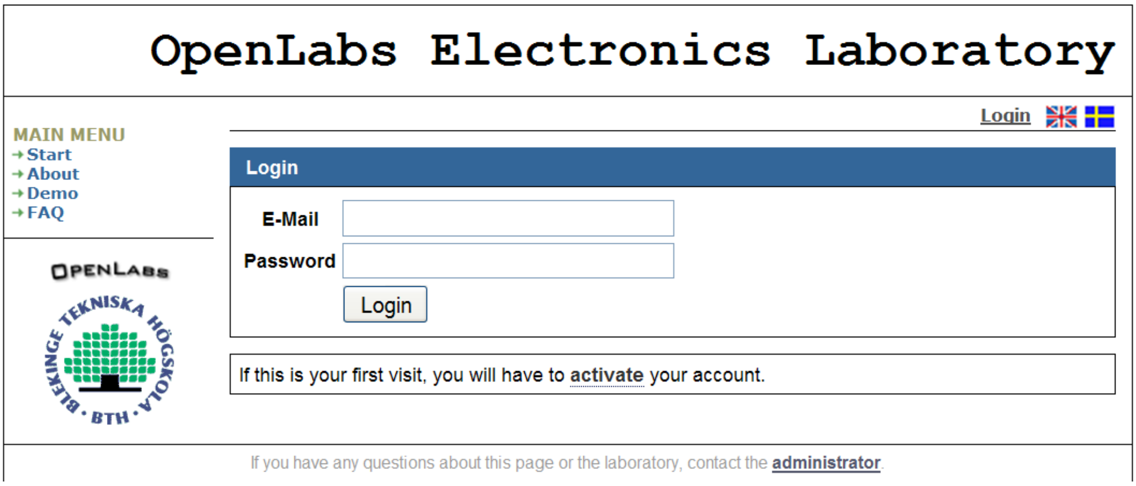


Figure 3. Log in view

[2] If not, the URL of the online workbench is http://openlabs.bth.se/electronics/

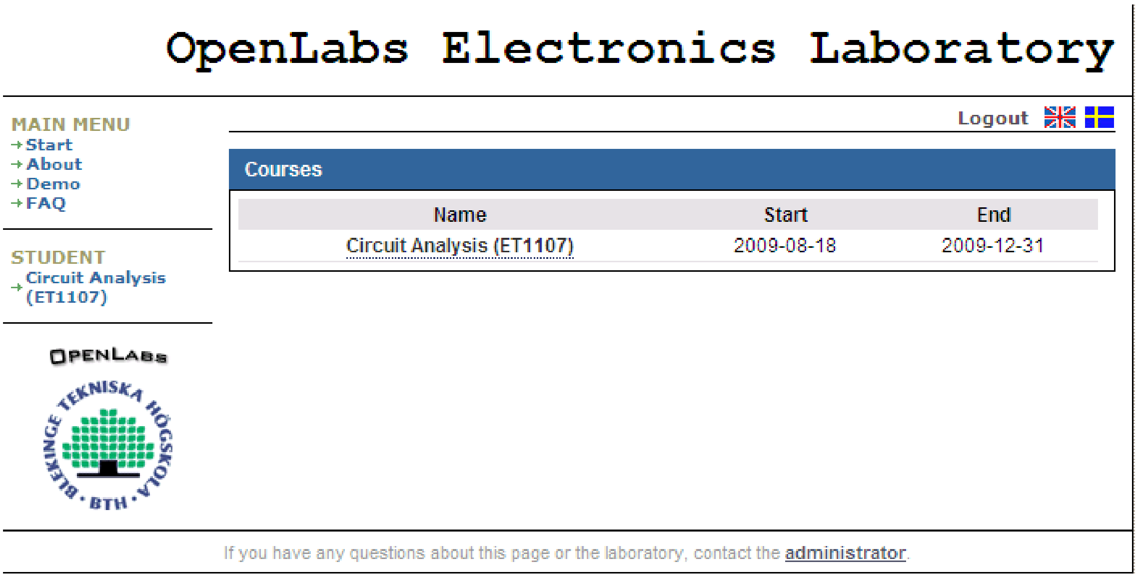


Figure 4. Student's course list

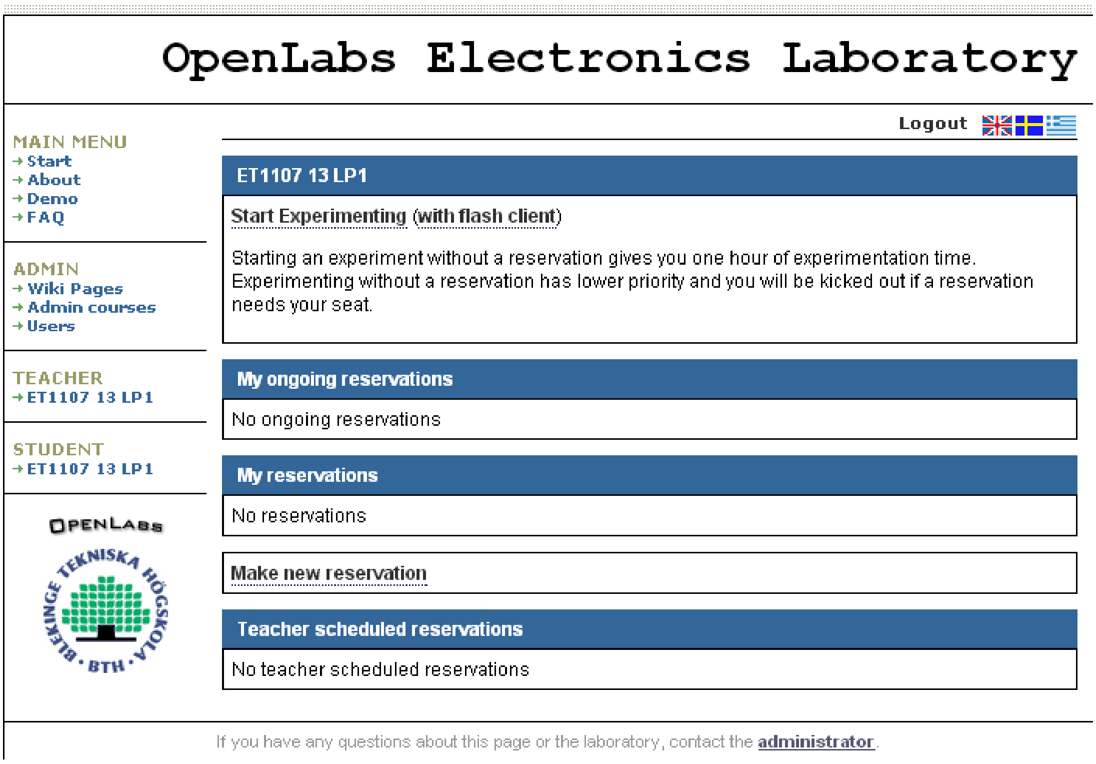


Figure 5. Student's course page

3. Experimenting

Press "Start Experimenting" in Fig. 5 in order to use the HTML5 client. The Breadboard View will be displayed. The names of the laboratory sessions offered will be listed under the heading "Prepared experiments" at the bottom of the view, as is shown in Fig. 2. By selecting a session, the corresponding component set will appear in the component box on the top of the breadboard. Some wiring made by the teacher may also show up on the breadboard. The *Save* button allow you to save your circuit and instrument connections (instrument settings are currently not saved). *Load* will restore previously saved circuits.

A complete circuit is composed of a number of connected components and includes at least one source generating the current. It is complete if it consists of closed loops (meshes) only. The tie points are denoted nodes. You may now begin experimenting by wiring one of the circuits described in the laboratory instruction manual. An example of a complete circuit is shown in Fig. 6. This circuit has three nodes denoted A, B, C and GND (ground = 0 V) and two current loops A, B and GND and B, C and GND. A circuit is not complete if at least one loop is broken.

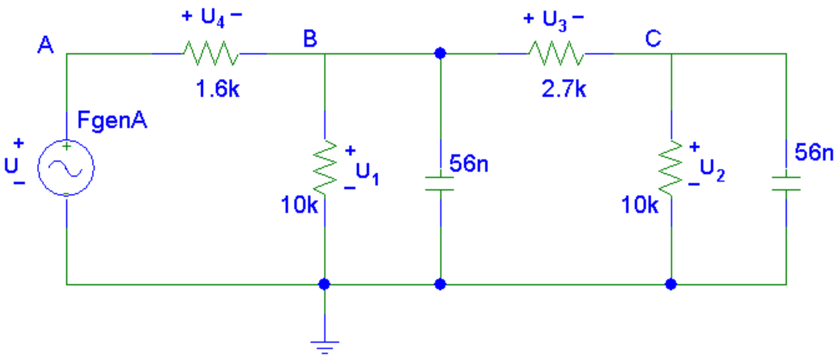


Figure 6. Circuit example

Fig. 7 shows possible circuit nodes on the breadboard i.e. how all the holes for components leads and wire ends are connected beneath the white plastic cover. There are more possible nodes on the breadboard than are supported in the matrix. The matrix supports circuits with up to ten nodes. These ten nodes could be any of the possible nodes on the breadboard.

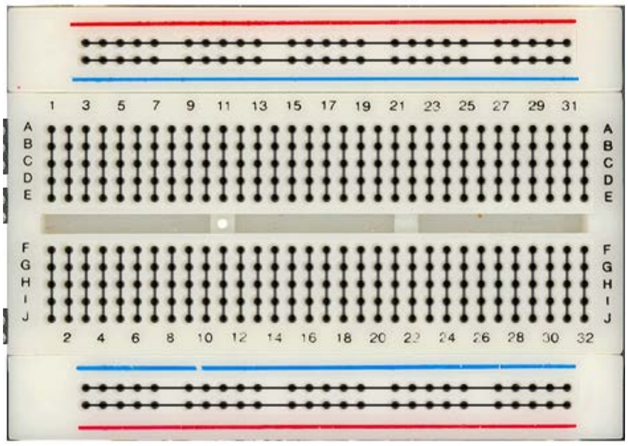


Figure 7. Possible nodes

Six wire colors are provided, Fig. 8. Standard colors are black for GND, red for + and blue for – from the power supply.

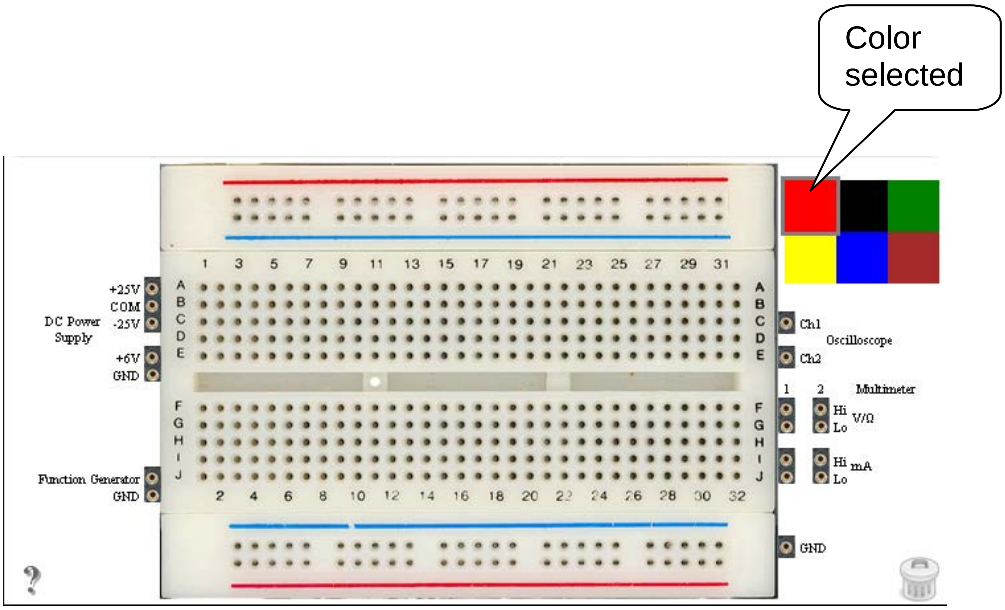


Figure 8. Wire color selection

First select a wire color and then drag the wire from one hole to another, Fig.9. Three circles will appear if you press the wire. You can move the ends using two of the circles. The third one is used to bend the wire. The three holes for wire ends denoted GND outside the breadboard are connected and they are connected to protective earth via the function generator, the 6 V power supply, and the oscilloscope.

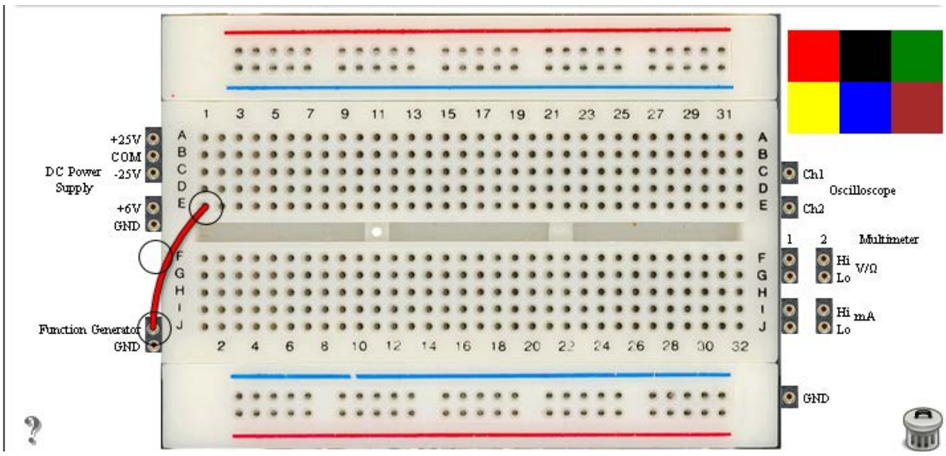


Figure 9. Wiring

The circuit in Fig. 6 is wired on the breadboard in Fig. 10. A recommendation is to place the components in the same order on the breadboard as in the circuit diagram and to use different colors for the wires. The components have only very short and inflexible leads. However, the leads of the physical components installed in the matrix may not be as short. Please note that the circuit in Fig. 6 has only four nodes denoted A, B, C and GND. Physically in the matrix, the low leads of the 10 kΩ resistors and of the capacitors in Fig. 6 are connected to GND in order to use no more nodes than necessary i.e. four. Thus, the black wires in Fig. 10 have no physical correspondence but they make it easier to see that the wired circuit is identical to the circuit diagram.

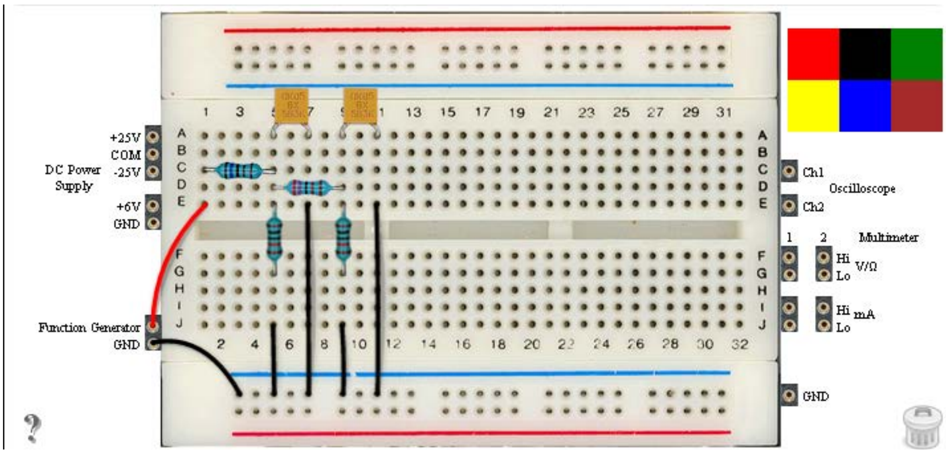


Figure 10. Circuit example wired

Even the wiring in Fig. 11 is a complete circuit if the multi-meter is measuring resistance. The meter is feeding a known current through the resistor i.e. is the source and measures the voltage drop. It calculates the resistance using the volt-ampere method. Please note the resistance obtained will not be correct if a second source is included in the circuit. For example you should not connect the second multi-meter measuring resistance in parallel with the first one measuring resistance too. It would be a second source.

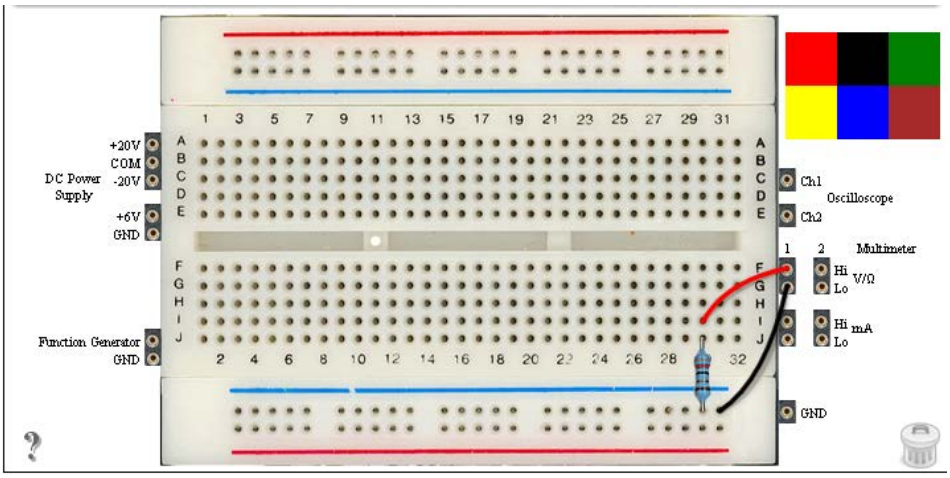


Figure 11. Measuring resistance

Voltage drops is easy to measure. Of course, when connected the voltmeter will add an extra loop but the voltmeter impedance is high and the loop current is negligible compared with the currents of the original circuit.

In order to measure current in a branch of a circuit using an amp-meter you must include it in the branch. However, the amp-meter is low impedance and including it may be hazardous and cause to high currents in the circuit. In the rules of the virtual instructor the teacher must indicate where you are allowed to include the amp-meter. In Fig. 12 the teacher has included jumpers to indicate where it is possible to measure current with the multi-meter. The corresponding circuit wired on the breadboard is shown in the circuit diagram in Fig. 13 where the green wires are the jumpers. Just replace a jumper by the meter successively in order to check Kirchhoff's current law. The yellow wires and the blue one have no physical correspondence.

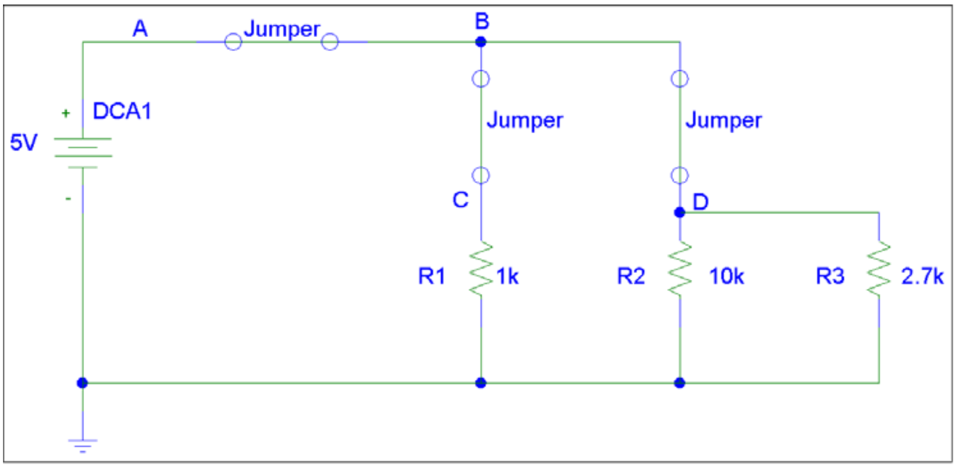


Figure 12. Circuit diagram of a circuit intended for checking Kirchhoff's current law

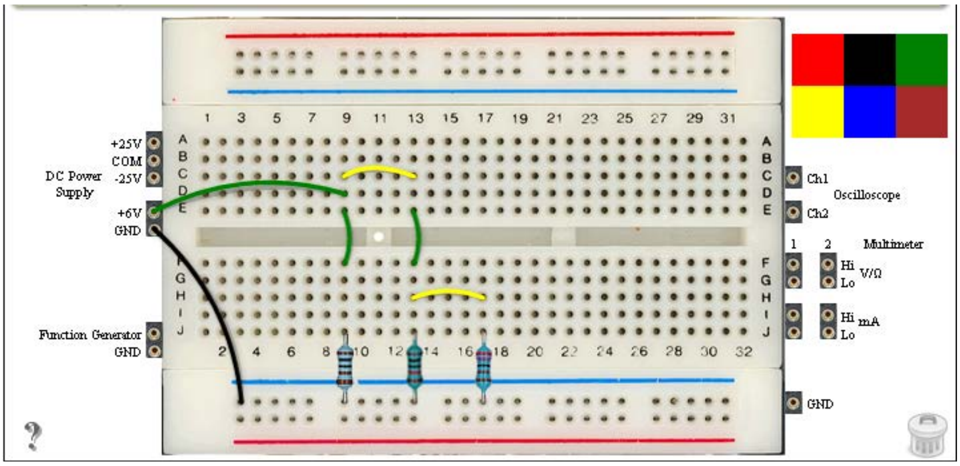


Figure 13. Circuit intended for checking Kirchhoff's current law

4. Collaboration

Adobe Connect or other web conferencing platforms providing screen sharing can be used for supervised lab sessions or used to perform experiments together with others. BTH provides a room in Adobe Connect to be used as a VISIR laboratory open for everybody, https://connect.sunet.se/visir. Fig. 14 shows the host's screen on which a presenter is sharing the presenter's screen. Thus a presenter may demonstrate an experiment and discuss its outcome with the teacher or with other students.

If the bandwidth is not high enough for a web conferencing platform a student can send her circuit using the save/load feature to the teacher and then the teacher could perform the student's experiment and discuss with the student over the phone.

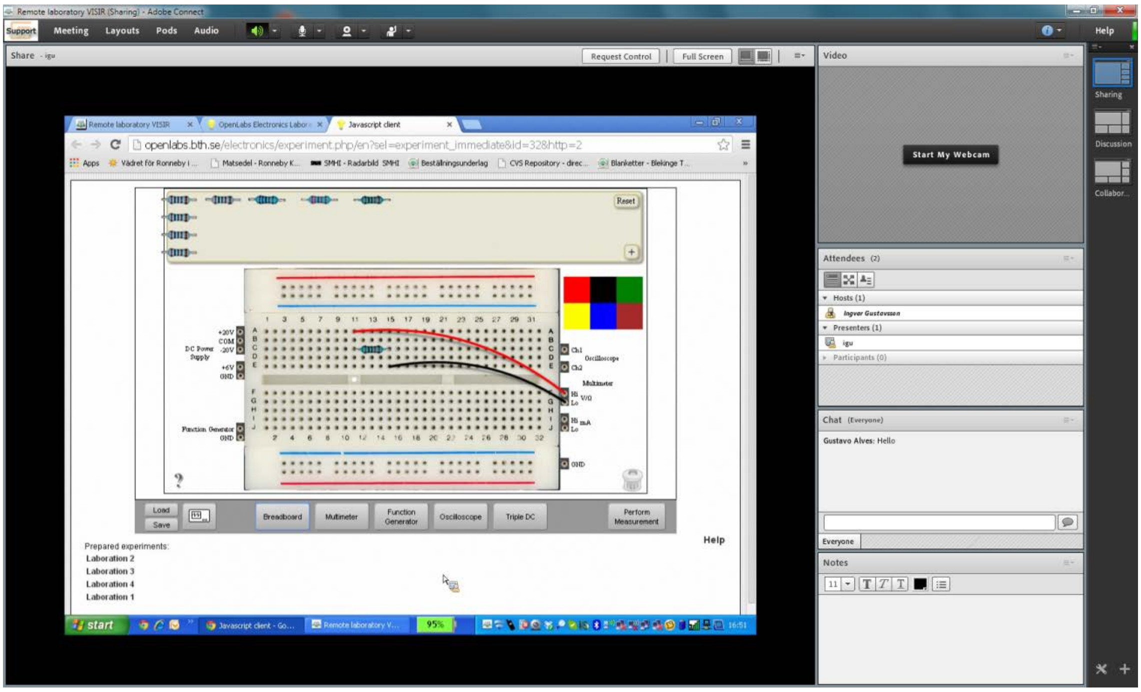


Figure 14. An Adobe Connect room at BTH to be used as a VISIR laboratory

5. Error messages

1. The circuit on the virtual breadboard may be safe but the *Virtual Instructor* has not been instructed to allow it.

6. Restrictions and known errors

1. Measurements are transmitted either directly (on port 2324) or over HTTP (port 80). If the system has been configured so that the user can choose which, the alternative "(over HTTP)" should be visible on the student's course page. Measuring over HTTP can be useful in cases when sitting behind a firewall that does not allow direct communication (on port 2324).
2. Only the Agilent oscilloscope supports *Run Mode*, described in Appendix B.
3. The duration of a single experiment is restricted by limiting the time base of the oscilloscope. The maximum sweep length is 50 ms.
4. When measuring DC voltage with the DMM set to "DC Volts" the result might not be zero even if it should be zero. A low frequency AC signal or noise may be present. Please refer to a NI tutorial[3] A work around is to change the aperture time. The Fluke DMM on the virtual instrument shelf is 3½ digits and the resolution of the physical instrument (NI PXI-4070 or NI PXI-4072) is set to 3½ digits. In this mode, the time period of one measurement is short. It is possible to set the resolution to 5½ digits in the VISIR LabVIEW code. Then the error will disappear but all types of measurements using the DMM - not only "DC Volts" -

[3] http://www.ni.com/white-paper/3226/en#toc3

will take longer time. The teachers are encouraged not to use AC signals whose frequency is not lower than 1 kHz.

5. The *Load* and *Save* buttons are not available in the iPad client.

Feedback are welcome

This guide describes version 4.1 of the online workbench. Please send feedback to Ingvar Gustavsson, ingvar.gustavsson@bth.se.

Appendix A. The importance of physical experiments

For centuries, scientists have formulated hypotheses, theories and mathematical models describing phenomena of nature and have performed physical experiments as well in order to verify them or vice versa. For example, in the nineteenth century the excellent experimentalist, Michael Faraday wrapped two insulated coils of wire around an iron ring, and found that, upon passing a current through one coil, a momentary current was induced in the other coil. In subsequent experiments, he found that, if he moved a magnet through a loop of wire, an electric current flowed in that wire. The current also flowed if the loop was moved over a stationary magnet. His demonstrations established that a changing magnetic field produces an electric field; this relation was modelled mathematically by James Clerk Maxwell as Faraday's law, which subsequently became one of the four Maxwell equations, and which have in turn evolved into the generalization known today as field theory[4]. In the twentieth century computer made it possible to animate models i.e. to simulate phenomena.

Nowadays, professional engineers use simulators when designing prototypes. However, they perform experiments as well for two other reasons. First, in the design process they often "ask" nature when they suspect that a required aspect of a particular model to be used may not be accurate enough. The second reason is to determine if a prototype meets the specification and performs as intended in the environment where the final product is to be used. When students, especially undergraduates, perform experiments, it is not typically to discover a new addition to our knowledge of nature, to extract some data necessary for a design, or to evaluate a new prototype. Each of these functions involves a complex mental process whose result is something that is not expected and available. Students perform experiments to learn laboratory workmanship and to see that the theories presented in the courses are useful descriptions of phenomena of nature.

In most undergraduate science courses, for example, circuit analysis the theory is presented first. The students do some hand calculation exercises. However, the superior tool they use to get familiar with the theories is the simulator. Finally, the students perform a number of physical experiments selected by the teacher in order to confirm that the theory describes phenomena in real life well enough. Even if experimentation and simulation produce similar results these two tools must not be confused. They are like apples and pears and cannot be compared. The result of a simulation originates from the underlying model of the simulator used. How well a simulation reflects a natural phenomenon depends on the model and to what degree it reflects the phenomenon. The result of a physical experiment emanates directly from nature and the accuracy of the result depends mainly on the relevance of the experimental setup, on the accuracy of the measurements performed and on the experimentalist's ability to interpret the data received. For example, an inverting operational amplifier can be simulated in PSpice.

Scientific experimentation may be compared to an interview with nature. The experimentalist asks and nature answers. The delicate action is formulating a useful question and above all it is interpreting the answer. For example, students who want to become engineers able to design goods and services fitting a sustainable society must spend

---

4 http://en.wikipedia.org/wiki/Michael_Faraday

much time in the laboratory performing experiments in order to master this “language of nature”; practice makes perfect. Unfortunately, the hands-on laboratories at most universities are a limited resource and they are open too few hours. Remote laboratories are a supplement available 24/7. For example, in a VISIR laboratory students can learn laboratory workmanship including procedures, methods and other things required to formulate a question and to interpret the answer of nature.

Appendix B. A short introduction to the VISIR Online Laboratory for electrical experiments

Most instruments in an electronics laboratory have a remote control option but the solderless breadboard has not. Remote wiring of circuits requires a wiring manipulator with remote control capabilities. A switching matrix equipped with controllable switches, for example, electro-mechanical relays can serve as such a device. The matrix is the card stack in Fig. 1B showing a VISIR online workbench at BTH. The relays are arranged in a three dimensional pattern together with instrument connectors and component sockets. Components needed for a number of laboratory sessions are installed in the sockets i.e. the matrix is an online component store as well. The PC to the right in the Figure controls the workbench.

The desktop instruments and the handheld multi-meter shown earlier in Fig. 1 in the main text are replaced by PXI instruments in Fig. 1B. PXI[5] (PCI eXtensions for Instrumentation) is an international standard for instrumentation. The PXI chassis and the instruments are manufactured by National Instruments[6]. PXI instruments are PC controlled plug-in boards with tiny front panels fitted only with connectors. Each board is shipped with a virtual front panel i.e. a software module that NI calls Soft Panel to be installed in the PXI system controller PC. The panel module displays the control knobs and buttons found on desktop instruments on the monitor of the controller of the PXI system. Thus, it is possible to use these boards as stand-alone instruments but with reduced functionality. Referring to NI the boards are designed primarily to be included in measurement systems controlled by LabVIEW[7] drivers and not to be used as general purpose instruments. However, NI is improving the Soft Panels and updated modules will be possible to use as general purpose instruments with full functionality. User manuals or online help will be provided. In a VISIR laboratory, the Soft Panels are moved to the experimenter’s PC. Generally speaking, it is possible to combine a particular instrument module (plug-in board) from, for example, NI with the corresponding virtual front panel of another module of the same instrument from another manufacturer, as long as the performance of the hardware matches that of the depicted instrument.

---

[5] http://www.pxisa.org/

[6] http://www.ni.com/

[7] http://www.ni.com/labview/

Figure 1B. The VISIR online workbench at BTH

The VISIR workbench has a *virtual instrument shelf* containing the instrument models implemented so far. The idea is that you should be able to select the instrument model you want to use. Unfortunately, no virtual front panels of the instrument models shown in Fig. 1B are provided by the manufacturers. The virtual front panels of those instruments are photographs of the real front panel of each instrument and the corresponding software modules are written at BTH. All the functions offered by the original instruments depicted on the *virtual instrument shelf* are not implemented so far but the functions required in basic courses are supported.

The virtual breadboard shown earlier in Fig. 2 in the main text is a sort of virtual front panel of the matrix. It is based on a photograph of an ordinary physical solderless breadboard. You control the matrix hardware by wiring on the virtual breadboard using the mouse. The length of the wires on the breadboard has no physical significance. The length of every physical conductor of the matrix connecting any two items (a component socket or an instrument connector) via a relay switch is fixed. The fact that the relays and the components are positioned close together in a 3D pattern minimizes the length of the conductors maximizes the bandwidth of every circuit created. It should be better than the bandwidth of an identical circuit created by a skilled student on a physical breadboard.

Most of the wire holes at the right side of the physical breadboard in Fig. 1B are connected to BNC connectors or banana plugs on the box carrying the breadboard. These connectors are used to connect the instruments. The virtual breadboard and the adjacent holes for wire ends in Fig. 2 mimic the breadboard and its supporting box in Fig.1. However, the BNC connectors and banana plugs shown in Fig 1 are concealed in Fig. 2 but the corresponding connections are shown in the next sections.

It is possible to study most low frequency phenomena at different time scales by selecting appropriate values of the components controlling the time constants. At present, VISIR uses this feature to allow simultaneous access to one workbench by time-sharing. In this way, a VISIR workbench emulates a whole laboratory with many workbenches. You may use all the time you need to wire your circuit and set up the instruments, as this procedure is done locally on your PC. The teachers are encouraged to adapt their experiments to the millisecond scale in order to keep the response time acceptable. At present the maximum sweep of the oscilloscope is limited to 100 ms.

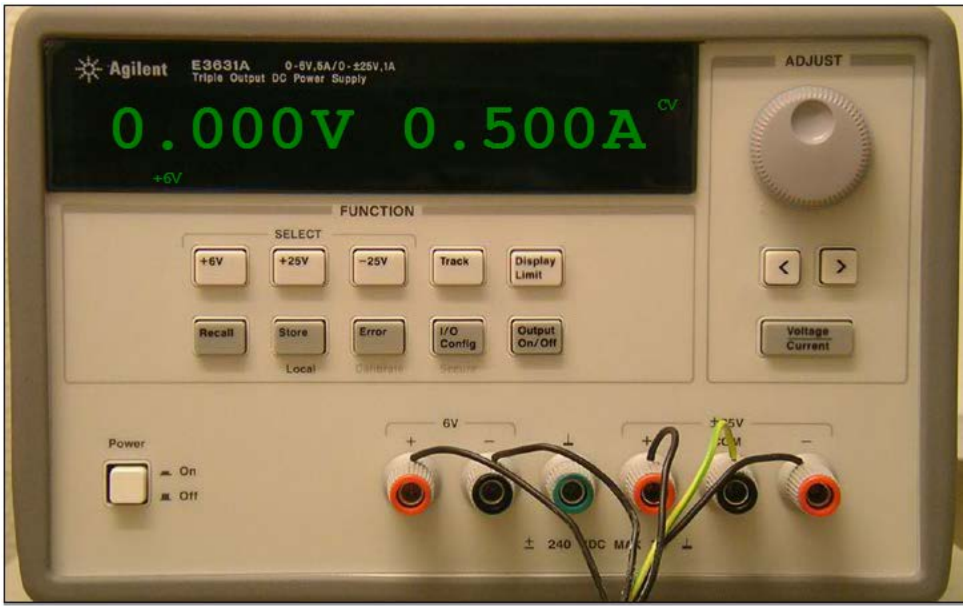
The *Virtual Instructor* checks that the circuit you wire is safe i.e. that neither a component nor an instrument can be damaged. For example, the current allowed in the conductors and relay switches of the matrix is 500 mA. The power rating of the resistors installed in theVISIR laboratories at BTH is 0.6 W. The laboratory staff creates the rules for the *Virtual Instructor* when configuring the matrix. Thus, it is up to the laboratory staff to make sure that no hazardous circuit can be created physically.

In the next sections the virtual front panels are presented together with the corresponding hardware including connection possibilities. The drawings of the tiny physical front panels of the instruments in the PXI chassis in the figures below are copied from the NI documentation. The metal tube of the BNC connectors of the function generator and the oscilloscope are connected to protective earth i.e. they are connected via the mains cord of the PXI chassis. The connecting curved lines between the physical front panels and the wire holes adjacent to the virtual breadboard of the breadboard view in the Figures below represent the conductors of the coaxial cables and banana plug cords connecting the instruments.

DC Power supply

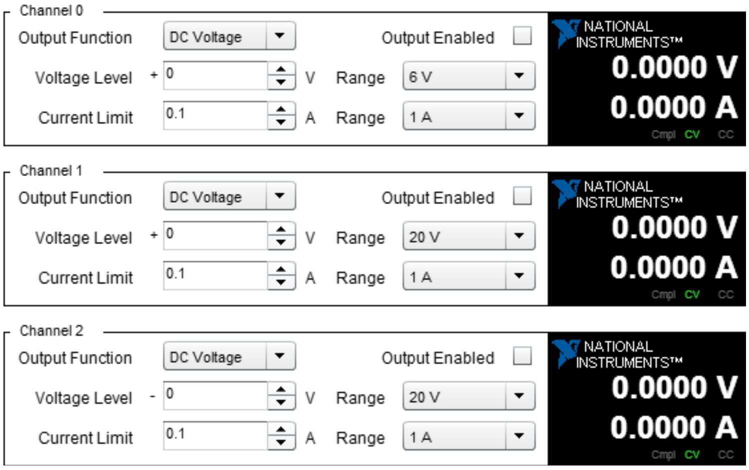
<u>Agilent E3631A</u>

Front panel operation is described in the user guide of the manufacturer, http://cp.literature.agilent.com/litweb/pdf/E3631-90002.pdf.



NI PXI-4110

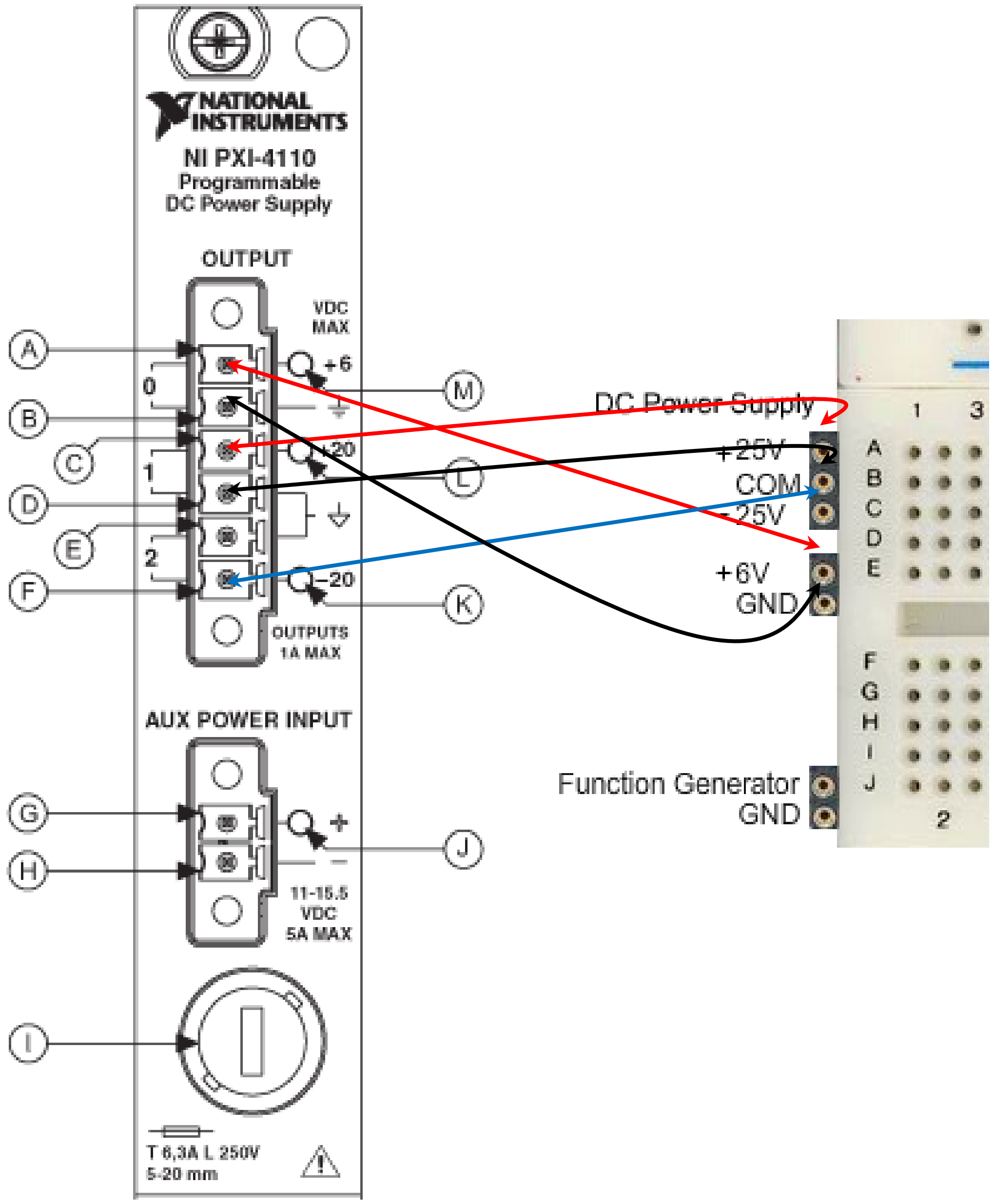
No user guide is available.



NI PXI-4110 specifications:, http://www.ni.com/pdf/manuals/371635f.pdf

Please note that the current floating[8] dual power supply range is ±20 V. The +6 V supply is referenced to Protective earth.

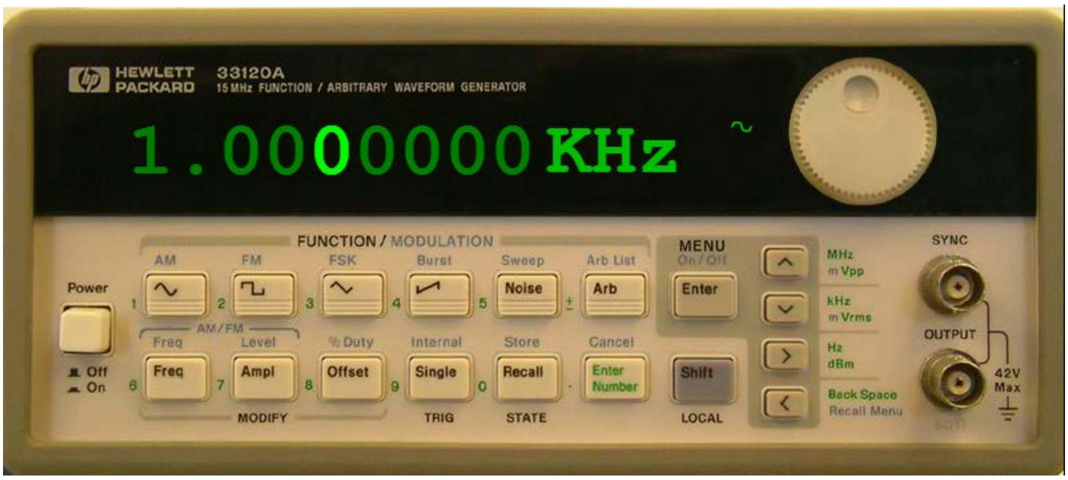
[8] Floating means that the dual power supply outputs are not referenced to any ground only to COM.



Function generator

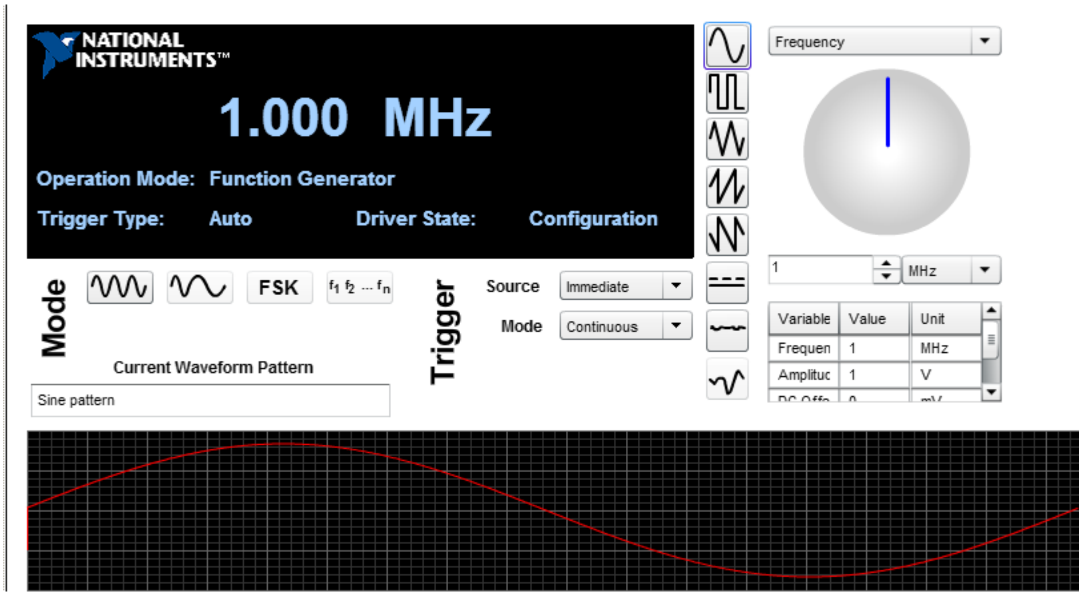
Agilent 33120A

Front panel operation is described in the user guide of the manufacturer, http://www.home.agilent.com/upload/cmc_upload/All/6C0633120A_USERSGUIDE_ENGLISH.pdf?&cc=SE&lc=eng.

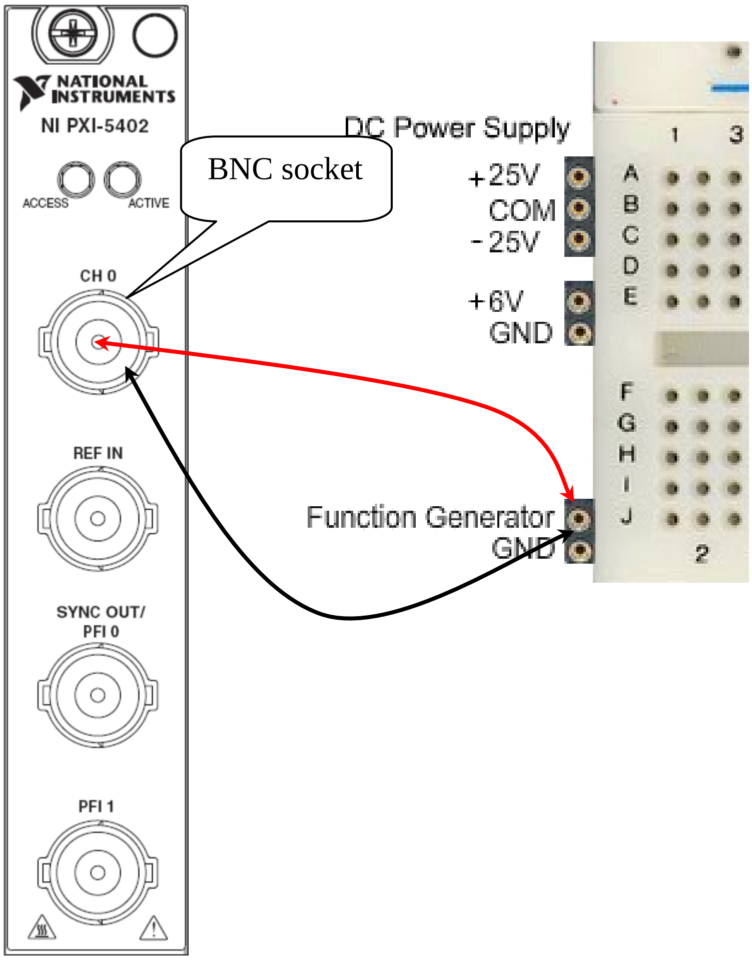


Please note, the displayed amplitude may differ from the output amplitude. Refer to page 281 of the user guide.

<u>NI PXI-5402</u>



NI PXI-5402 specifications, http://www.ni.com/pdf/manuals/371707e.pdf

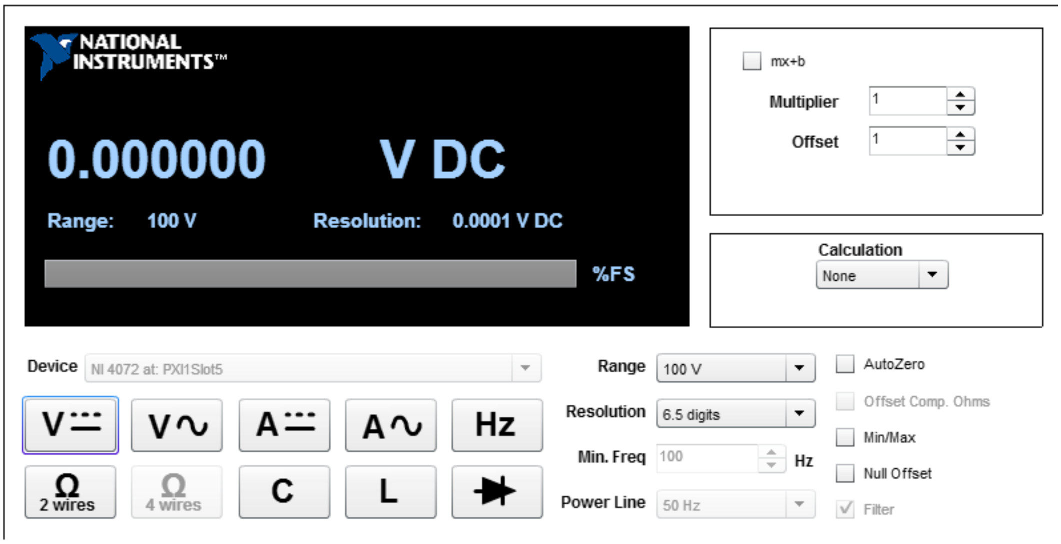


Multimeter

FLUKE 23

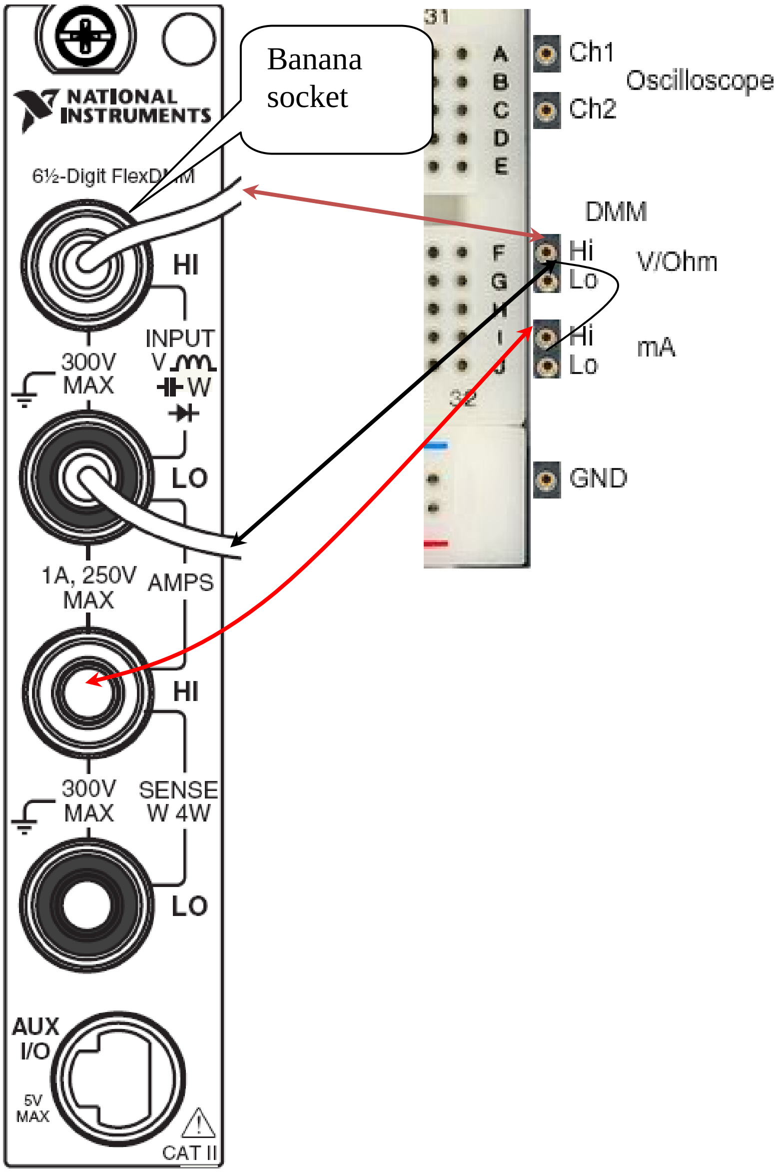
The PXI module resolution is set to 3.5 digits.

NI PXI-4070



NI PXI-4070/72 specifications, http://www.ni.com/pdf/manuals/371304g.pdf

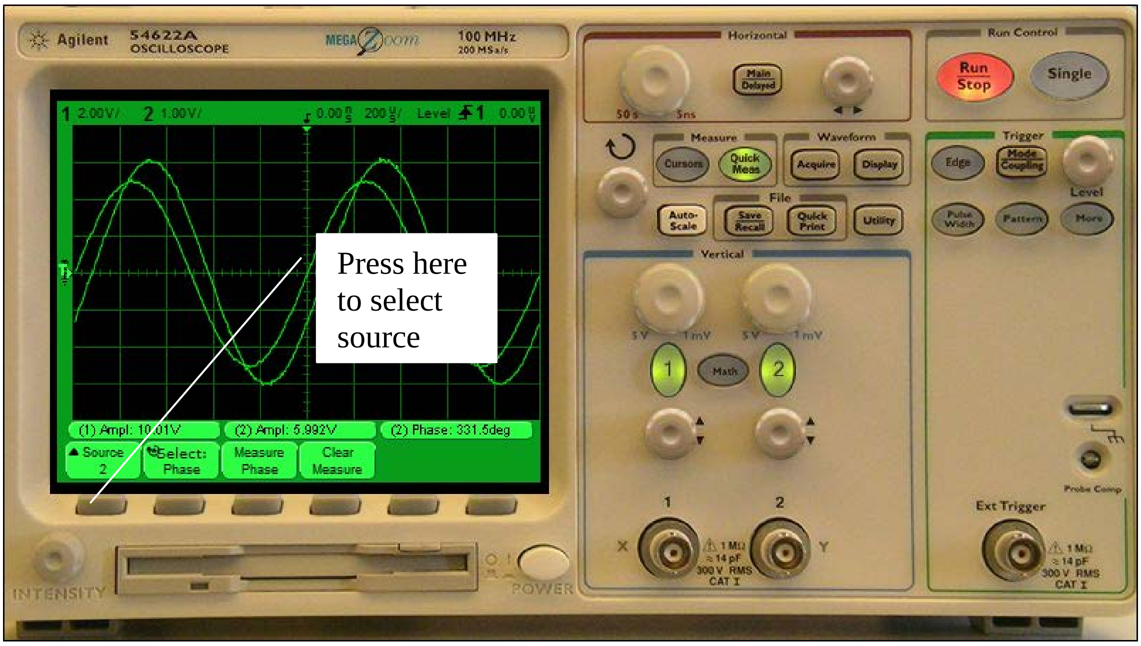
Only two wire mode is supported.



Oscilloscope

Agilent 54622A

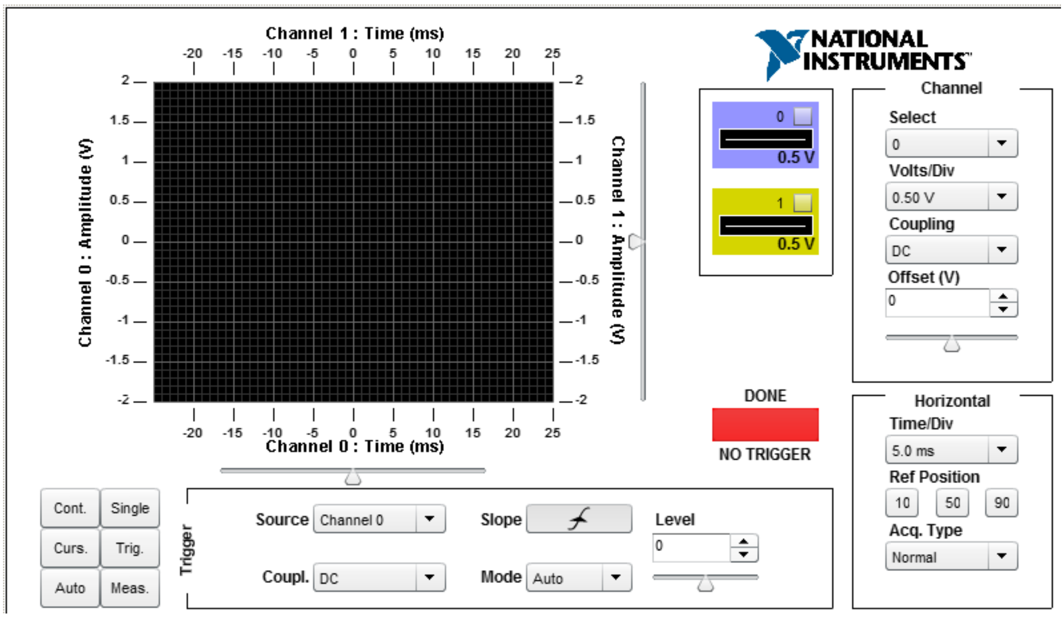
Front panel operation is described in the user guide of the manufacturer, http://cp.literature.agilent.com/litweb/pdf/54622-97036.pdf.



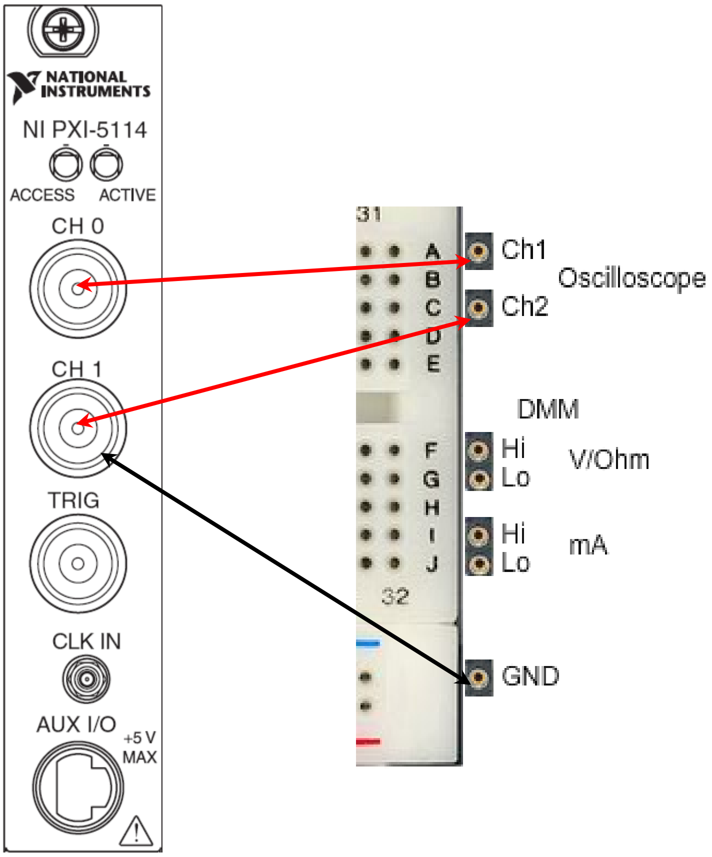
In the Figure it is illustrated how to use the soft keys located below the display.

By default you get only a single acquisition from the oscilloscope when you press the *Perform Experiment* button. However, the workbench supports normal oscilloscope operation i.e. *Run Mode.* In the Figure above the *Run/Stop* button is red meaning continuous acquisitions is stopped. If the administrator allows *Run Mode*, the *Run/Stop* button will be green when you press it. Then *Run Mode* of the oscilloscope will be emulated and you will get continuous acquisitions. Just press the *Run/Stop* button again to stop run mode. Please use *Run Mode* for short periods only. The administrator may not allow run mode as the response time will be longer for other concurrent experiments.

NI PXI-5114



NI PXI-5114 specifications, http://www.ni.com/pdf/manuals/374179e.pdf



Appendix C A short introduction to laboratory education organ-ization

Many courses in engineering education include a laboratory component i.e. practical hands-on *laboratory sessions* supervised by an *instructor*. In each session, the students perform a number of experiments that are described in a *laboratory instruction manual*. Every experiment is designed to verify that a particular model, for example, Kirchhoff's voltage law works in real life.

Most instructional hands-on laboratories for electrical experiments contain a number of identical workbenches and a component store. The laboratories are generally only open during supervised sessions when an instructor is present. No other opportunities for ex-perimenting are provided at least not for novices. Before a student is permitted to enter a hands-on laboratory for the first time, she has to learn the safety rules of the laboratory and to pass a test in order to be aware of the risk of being hurt or of damaging the ex-pensive instruments. Usually two students share one workbench and perform experi-ments together. A supervised laboratory session is only three or four hours.

A VISIR online laboratory is organized in a similar way. It is not locked but you have to login, select a course and a laboratory session. Then the corresponding component set will be displayed. There is a virtual instructor checking that your circuit is harmless before your circuit and your instrument settings will be sent to the hardware. Experimenting in a VISIR laboratory is much the same as in the traditional laboratory, but there are a few differences described earlier.