

## **A remote measurement laboratory using NetLab**

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**ABSTRACT:** Remote laboratories have expanded exponentially in academia worldwide. They offer the utmost flexibility of access for users around the clock, as opposed to real/proximal/physical laboratories, which have scheduling and supervisory limitations and a substantial price tag. Remote laboratories are cost and time effective, and often one bench desk is sufficient to serve many users, and the supervision and maintenance costs are, therefore, limited. The remote laboratory NetLab has been developed and has been in operation at the University of South Australia since 2002. It is a mature system, developed by academic staff and their students. In this article, the authors report on a remote measurements laboratory using the NetLab, for experiments to build up basic student electrical/electronic measurement skills. The users' experiences of the remote measurement laboratory include multi-location and multi-national aspects. The feedback of the students is crucial for the overall assessment, and is discussed in the article.

### **INTRODUCTION**

Masters/graduate diploma level programmes in Australia and elsewhere, e.g. in the area of electrical power systems that are already being offered totally on-line, including exclusively on-line remote laboratories, obviate the need for students to attend real laboratory sessions at all [1].

The remote laboratory NetLab, which has been in operation at the University of South Australia (UniSA) since 2002, is a mature system, perfected and developed over the years by academic staff and generations of BEng, MEng and PhD students [2]. It is robust in terms of reliability and flexible regarding experimental circuit configuration and access availability. The laboratory is by design an open access and a collaborative environment, allowing for experiments to be conducted freely by students/users from different locations, locally and worldwide [3].

The users of the remote measurement laboratory have included Australian students from UniSA campuses at Mawson Lakes and Whyalla, UniSA international students from Singapore and Sri Lanka, students from Open University Australia, students from Blekinge University of Technology in Sweden and recently BEng, MEng and PhD students from Poland's Lublin University of Technology, all being taught remotely from Adelaide. The recent student perceptions of the remote laboratory are included in another paper [4].

### **NETLAB**

NetLab is a remote laboratory for experimentation with real electronic instruments and electrical circuits. A graphical user interface (GUI) represents the actual instruments in the form of virtual instruments. Students can control remotely an oscilloscope, a multimeter and a signal generator and get their readings in real time. When they click a button on an instrument in NetLab, the corresponding real instrument in the laboratory responds in real time in exactly the same way as if the user had physically pressed the button on the front panel. The waveforms displayed on the NetLab oscilloscope are actual measured signals from the real circuit, displayed exactly as they appear on the real oscilloscope. The only delay comes from broadband delay and the refreshment rate of the NetLab server's and user's computer display.

Figure 1 depicts the animated images of the instruments, used in the remote laboratory: digital multimeter, function generator and the oscilloscope. In addition, a camera view of the real equipment is provided, which extends the user's experience of the real experiment and confirms that what the students see on their computer screens is not a simulation. The window visible in Figure 1 on the lower left side is used for communication between the users, and the one on the lower right reports on all actions undertaken by users, such as changing the waveform or the amplitude of the signal generation or changing the camera setting. Details of the NetLab's configuration can be found in Nafalski et al [5].

A high quality *pan, tilt and zoom* Web camera is mounted in the laboratory that allows the NetLab users to observe the real instruments in real time as they operate them (Figure 1 lower right hand); thus, adding to the reality of the experiments.

To access NetLab, users should use the following links: <http://netlab.unisa.edu.au> or <http://netlab2.unisa.edu.au> as there are now two nearly identical systems of NetLab available to anyone in the world who registers to use the self-defined configuration of a circuit to conduct remote measurements.



Figure 1: The NetLab interface showing the instruments and the camera output.

The unique feature of NetLab is the circuit builder that allows users to configure instruments remotely and electrical components that have values that can be changed by turning a knob on the screen. An example of the circuit building connections and the instrument/component shelf to be dragged to the circuit builder to be configured is shown in Figure 2.

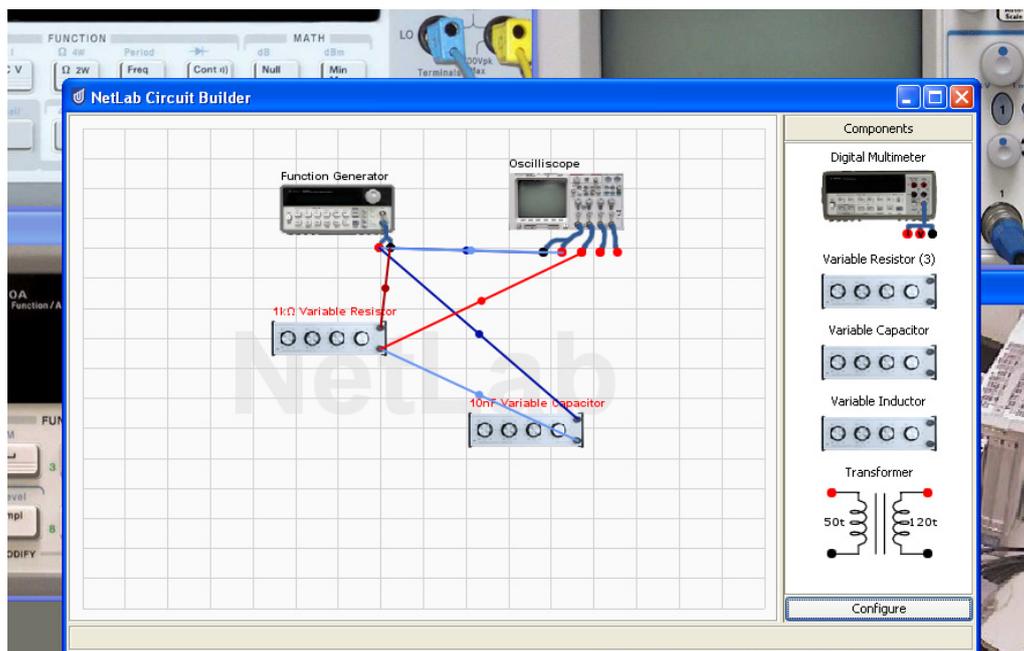


Figure 2: The circuit builder with instruments and variable components.

Users apply via the NetLab booking system to access the remote laboratory; the time is limited to three hours per week, to avoid overbooking by certain users, something that was encountered in the early stages of NetLab, by as much as a whole week being booked out. An example of the current booking system is shown in Figure 3. The time of the booking is visible in a user's local time, for example in Singapore or in Poland.

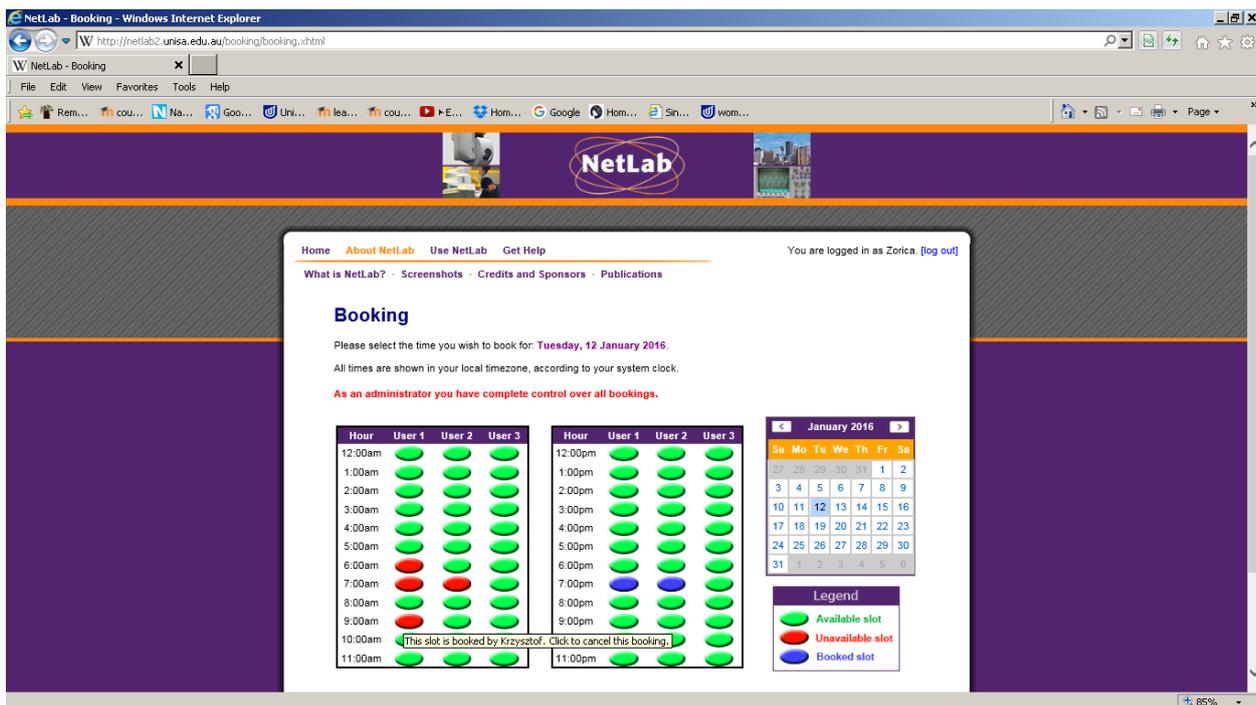


Figure 3: The Netlab booking system.

The physical appearance of the NetLab laboratory is shown in Figure 4. The GUIs of NetLab instruments are created from photographic images of the instruments' front panel. The instrument's GUIs can be enlarged for better readability.

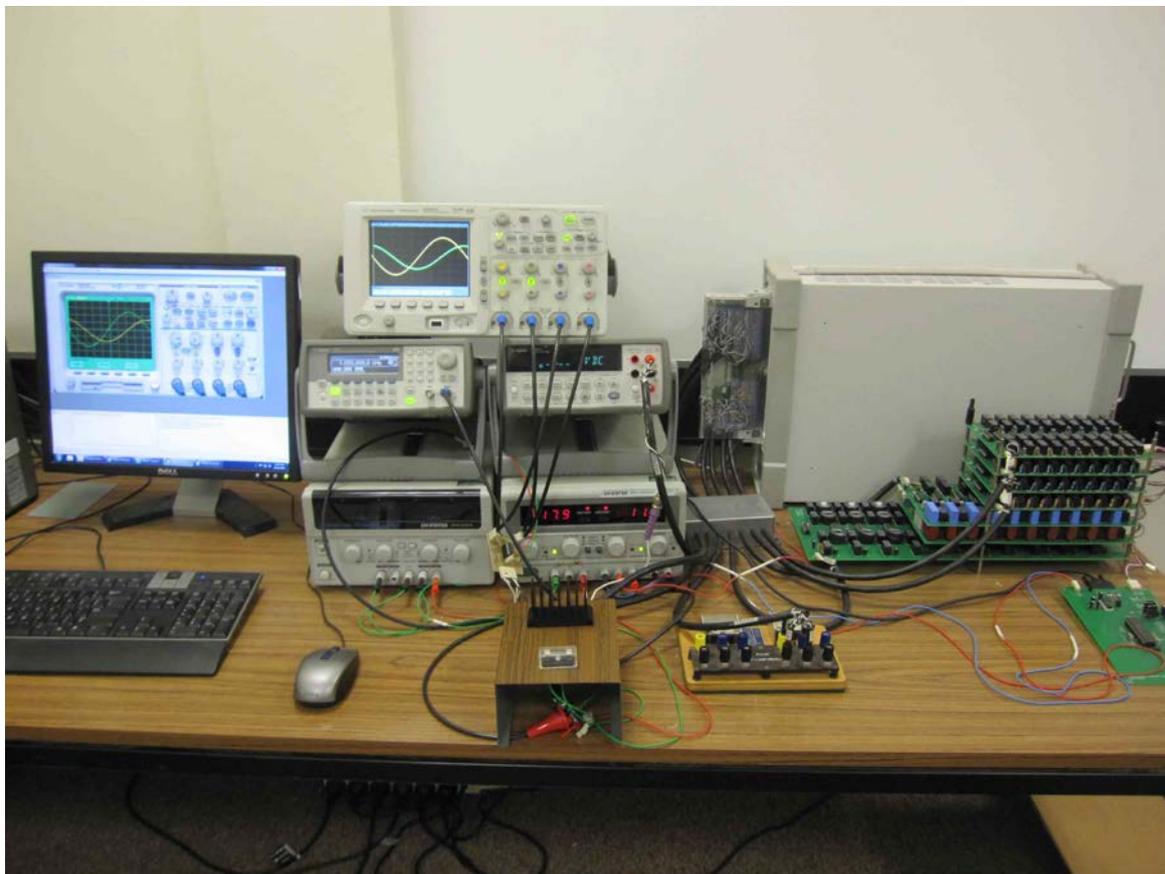


Figure 4. The physical setup and appearance of NetLab2.

The interactive image of the oscilloscope is such that on a standard 17" monitor it has approximately the same size as the real oscilloscope front panel (Figure 4). The grey box in Figure 4 on the right is the Agilent 256x256 relay switching matrix, which can be controlled via the Internet to connect components and instruments.

The PCBs on the right, in front of the switching matrix are the variable R, L, C components controlled remotely through the Internet. The box between the power supply and the switching matrix with cables going in and out is a part of the electromagnetic compatibility (EMC) system designed to mitigate serious EMC interference problems [6].

## THE SCOPE OF THE LABORATORY

In the measurement experiments using the remote laboratory NetLab the students are expected to learn:

- How to use a multimeter, signal generator and oscilloscope;
- How to wire circuits in a circuit builder;
- How to check and measure the parameters of basic components, such as resistors, capacitors, inductors, etc;
- How to determine and measure the parameters of various DC and AC (sinusoidal and square-wave) signals;
- Some advanced use of a digital storage oscilloscope.

Before starting, there are several important things students must be aware of and understand:

- Safety rules and expensive equipment handling principles - although this is a remote environment, students must apply the safety rules used in the real world;
- Rules of using electrical laboratory.

## THE REPORTS

Domestic and international students were requested to submit practical reports to be assessed for the final marks, based on the results of the remote laboratory measurements and the report quality. An excerpt from a remote measurement report prepared by Polish MEng students is shown in the Appendix 1 of this article [7]. The excerpt illustrates the technical and the English language proficiencies of the students.

## THE STUDENT FEEDBACK

Overall, students reported strong satisfaction and acceptance of using the remote laboratory NetLab to perform measurements of electrical/electronic circuits [4]. Surveys to obtain feedback from students on using the remote laboratory NetLab have been carried out many times, including in 2004 (soon after implementation of the NetLab in UniSA courses) and in 2015, the latter one for students enrolled in the course Electrical Circuit Theory offered by the School of Engineering at UniSA. These surveys asked the students to provide feedback on:

- If they find NetLab convenient to use;
- How NetLab compares with working in physical laboratory;
- What features do they like about NetLab;
- Difficulties of using the NetLab.

The survey results indicated that more than half of the students in 2015 had no preference for using NetLab or working in a real laboratory to perform measurements circuit analysis experiments. This is a very positive outcome for the remote laboratory, where only limited supervision is required. In the real laboratory, the students often rely on a supervisor to solve their laboratory problems; in a remote laboratory they have limited access to supervisory help and need to rely on their own knowledge and skills.

The result is a significant improvement in favour of a remote laboratory, compared with the majority of students in 2004 who preferred to work in the real physical laboratory. About 80% of students in 2015 also acknowledged the convenience of using the NetLab, because they can carry out experiment tasks remotely at any time within and outside the university environment without being personally present in the real laboratory.

Another area where NetLab was found useful was the accessibility for obtaining experiment results and capturing experiment figures to be used in the compilation of the practical reports. Some students found that the NetLab environment allowed them to collaborate with other students to perform experiment tasks.

Self-study and revision on measurement and circuit analysis theory were also made possible. Most of the students commended the user interface in NetLab as being easy to use and operate and, hence, it greatly reduced the connection errors compared with the physical laboratory. Another positive piece of feedback about using NetLab was the ability to repeat the experiment tasks to check, verify and perfect results, which is usually not possible in real laboratories.

Some difficulties were reported, for example: booking the preferred time slots and reading experiment results from the screen. Most of the time students were competing to book preferred time slots to use NetLab in peak days (several days before report submission due date) and, hence, securing a booking slot during these time periods was sometimes difficult. The latter problems with the students using laptops, tablets or smart phones with small screen resolution could have resulted in difficulties in reading the display in NetLab.

## CONCLUSIONS

The remote laboratory NetLab at UniSA in Adelaide, Australia has been in operation for 14 years. It is an open access, robust and user-friendly system, perfected over the years. Tens of thousands of users from many countries have accessed and used it for conducting experiments that are part of their compulsory curriculum or for educational/life enriching experiences.

Overall, students showed strong satisfaction and acceptance of using the remote laboratory NetLab to perform circuit measurement and analysis tasks. The flexibility of using NetLab anywhere, anytime, the ability to collaborate with other students from any location in the world, and the easy-to-use graphical user interface to set up circuits, make NetLab a suitable platform for enhancing their electrical and electronics knowledge and skills. NetLab can be the perfect platform for practical classes when students are enrolled in on-line study programmes.

On-line practical experiments have contributed to the increased awareness and hands-on ability of engineering students in using electrical/electronic measurement techniques. They developed skills that are important for their future studies and their careers in modern industrial environments.

## REFERENCES

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## APENDIX 1

Lublin University of Technology, Poland - excerpt of a student practical report [7].

### Section 3: Procedures and Methods of the Experiments

#### 1. Exercise 3

The main purpose of this exercise is to generate and measure of 50 Hz sinusoidal wave frequency. To achieve good results a user has to accomplish the following steps:

1. Make a connection between the digital multimeter and function generator in the NetLab circuit builder.

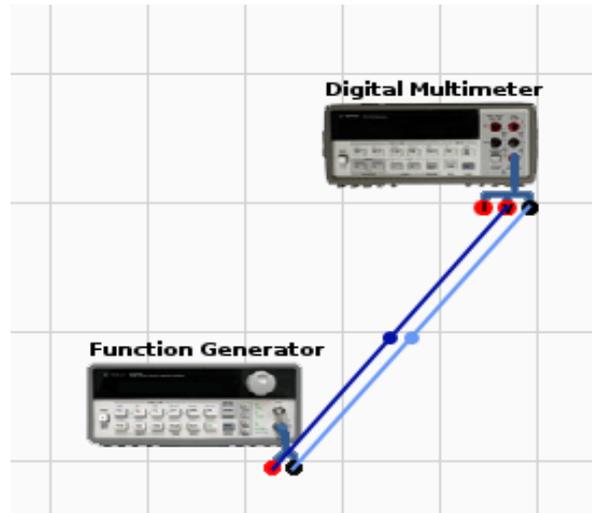


Figure 3.1: Connection between the digital multimeter and function generator in the NetLab circuit builder (Source: own).

2. Set the circuit by pressing the *Configure* button.
3. Turn on the digital multimeter and function generator windows on the toolbar's menu and power them on.
4. Set-up the frequencies and enter properly the value (i.e. 50 Hz).
5. Set-up the amplitude at 1 Vp-p.
6. Change the voltage for AC voltage on the multimeter window by pressing the *AC* button.
7. Read the measurements in the table and repeat points 4 to 6 as many times as you like.

#### 2. Exercise 4

Exercise 4 is similar to Exercise 3, but the main purpose of this exercise is to generate of 3.5 kHz square wave frequency instead of sinusoidal. To achieve good results in this exercise a user has to accomplish the following steps:

1. Change a waveform to square form in the signal generator by pressing the *Square form* button.
2. Set-up proper frequencies and amplitude (i.e. 3.5 kHz and 5Vp-p).
3. Select the *AC* button on the multimeter window.
4. Press the *Single* button to read the value of the voltage.
5. Repeat points 2 to 4 and write the measurements in the table.

#### 3. Exercise 5

The main purpose of Exercise 5 is to introduce the oscilloscope's functionality to a user. To achieve that purpose a user has to follow the steps below:

1. Select the oscilloscope's window from the instrument menu.
2. Turn the oscilloscope on by pressing the *Power* button.
3. Turn on the channels by pressing buttons with numbers 1 to 4 - the buttons will glow after selection.
4. Set channels coupling at different stages - channel 1 - AC, channel 2 - DC and channel 3 - ground input connection.
5. Press the *BW* button to help to reduce the unwanted high frequency noise at each channel.
6. At channel 4 press the *Invert* button.
7. Press twice any channel to deselect the channel.

This exercise shows the fundamental functionality of the oscilloscope.