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An instrumentation laboratory for first year students

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ABSTRACT: The availability of advanced instrumentation and computer-based sensing technologies, analogue-to-digital conversion techniques and data processing have influenced the way laboratory components of engineering and science programmes are implemented at universities worldwide. At the University of South Australia, a continuous development of facilities for first year students has taken place. Computerised measurement experiments developed for the first year engineering students have been reported before. This article outlines the instrumentation and measurement laboratory experiments involving modern laboratory instruments, leading to developing a good laboratory practice and writing professional experiment reports. The article describes the instrumentation experiments developed for this purpose and details experiences of their use in teaching the first year electrical engineering course.

INTRODUCTION

There is a unanimous agreement among educators that laboratory experience is an irreplaceable part of engineering, science and technology education. The laboratory helps to test conceptual knowledge, typically working in groups, students interact with the equipment - often faulty or with faulty connections, explore trial and error approaches and analyse, interpret and report meaningfully the measurement data and the experiment results. The recent publications highlight the importance of physical/real laboratories, as well as the growing utilisation of virtual and remote laboratories in this area of education [1-3].

A virtual laboratory provides a simulated environment, either locally or on-line. This approach is flexible in terms of time and often with remote access, experiments can be conducted step by step and often started again from a specified point. It is a low cost interactive laboratory version, increasingly also simulating user inflicted errors in the experiment. Remote laboratories combine real and virtual laboratories as the experiments are conducted via the Internet on real equipment through a simulated, virtual graphical user interface. Comparison of the three types of laboratories is given in Table 1.

Table 1: Comparative list of advantages and disadvantages of real, virtual and remote laboratories [4][5].

Laboratory type	Advantages	Disadvantages
Real	Realistic data	Time and place restrictions
	Interaction with real equipment	Requires scheduling
	Collaborative work	Expensive
	Interaction with supervisor	Supervision required
Virtual	Good for concept explanation	Idealised data
	No time and place restrictions	Lack of collaboration
	Interactive medium	No interaction with real equipment
	Simulation plus photo	
	Low cost	
Remote	Interaction with real equipment	Only *tele presence* in the laboratory
	Possible collaborative work	
	Realistic data	
	No time and place restrictions	
	Photo or live Webcam - virtual presence	
	Low/medium cost	

At the University of South Australia (UniSA) staff regularly review programmes and courses to keep up with the newest developments in the available technology both in engineering and education. The first year electrical engineering courses have been modified on average every 4-5 years during the past two decades. In that period, the first year course that introduces students to fundamentals of electrical engineering and technology went through a number of revisions and name changes; from Circuits and Devices 1 (1993), followed by Electricity and Electronics (1997), then, Introduction to Electrical Engineering (2001), Electrical and Energy Systems (2006) and ending in a revised version of Electricity and Electronics (2013) offered with an amended and improved content and implementation [6][7].

The laboratory parts of these fundamental courses were also often amended. In 2004 conventional experiments were replaced with a project based laboratory [7]. This approach although successful became unsustainable due to a substantial support required for the students. The laboratory was reshaped again in 2012. In the first part of it, the instrumentation and measurement, students practiced the circuit wiring and learned how to use contemporary electronic laboratory instruments. The second part introduced students to sensors, data acquisition and computerised measurements [8][9]. In both parts students developed their teamwork skills and technical report writing proficiency.

This article discusses some of the equipment and instrumentation experiments developed for the first year course in electrical engineering for electrical and mechanical engineering students, the assessment and summarises student perceptions in the conclusions section.

THE INSTRUMENTATION AND MEASUREMENT LABORATORY

The laboratory setup and implementation was based on the developed Practical Guide [10] that contained the following sections listed in the Table of Contents:

The Instruments

The characteristics of instruments are given in Section I of the above list. The instruments used in the laboratory are:

- Bench-top Digital Auto-ranging True RMS Multimeter Uni-Trend UT803, DIGITECH instrument was used as backup;
- Signal Generator Goodwill GW GAG-809;
- Digital Storage Oscilloscope RIGOL DS1062CA (Figure 1).

Figure 1: Digital storage oscilloscope RIGOL DS1062CA.

The oscilloscope was the most complicated and comprehensive instrument in this laboratory. It had the following major characteristics important for the exercises:

- Dual channel, 60MHz, 2GSa/s (Gigasamples per second) real time sampling rate (single channel).
- Vertical Sensitivity/Resolution: 2mV/div-10V/div, 8 bits.
- Time range: 500ms/div - 50s/div.
- Automatic measurements: Vpp, Vmax, Vmin, Vrms, frequency, period, rise time, fall time, positive/negative width, positive/negative duty cycle, etc.
- Input coupling: DC, AC, ground.
- USB storage and printing; support of CSV (comma-separated values) text format file for storing data and BMP (Bitmap) graphic format file for storing raster images.

Implementation

The implementation of the instrumentation and measurement laboratory will be illustrated on two examples; Exercise 3: DC Voltage Measurement and Exercise 16: Current and Power Measurement in DC Circuits.

In Exercise 3, the students received the following guidance:

- Plug the probes into the COM and V terminals, observing colours/polarity.
- Rotate the selector switch to position V≂.
- Press the SELECT button and choose Auto Range/DC mode.
- Switch ON the bench-top power supply unit and adjust the output voltage to be 5V.
- Connect the probes to the DC source and observe the measured value. Write it in the table below.
- Compare the values of the voltage, indicated on the screen of the power supply unit, and the measured one. Comment on any differences in the values.

DC Voltage	Source (Power supply)	Measured
Volts (V)		
Comments:		

The Exercise 16 was more complicated:

- Connect the provided resistors in series to the DC power supply using the breadboard - Figure 2. Refer to the Appendix for additional help how to use the breadboard. The blue wire is connected to the Ground/negative terminal, the red wire is connected to the positive terminal and the white wire is connected to the centre point of the voltage divider.
- Identify the values of the resistors and write them in the table below.
- Adjust the voltage of the power supply to 10V. Check it with the multimeter.
- Measure the voltage drop over each of the resistors and write it down.
- Now you have to measure the current through the resistors. Connect the multimeter in a manner you think is appropriate for current measurement. Describe how you did that.
- Write down the measured current. Comment on the value of the current for resistor R_1 and for resistor R_2.
- Calculate the power consumption of each of the resistors with the formulae:

$$P = \frac{V}{I} = \frac{V^2}{R} = RI^2$$

- Comment, which of the expressions in the formulae did you use and why.

Resistor R_1 value =		Resistor R_2 value =	
Voltage drop, V		Voltage drop, V	
Current, mA		Current, mA	
Power consumption, mW		Power consumption, mW	
Comments:			

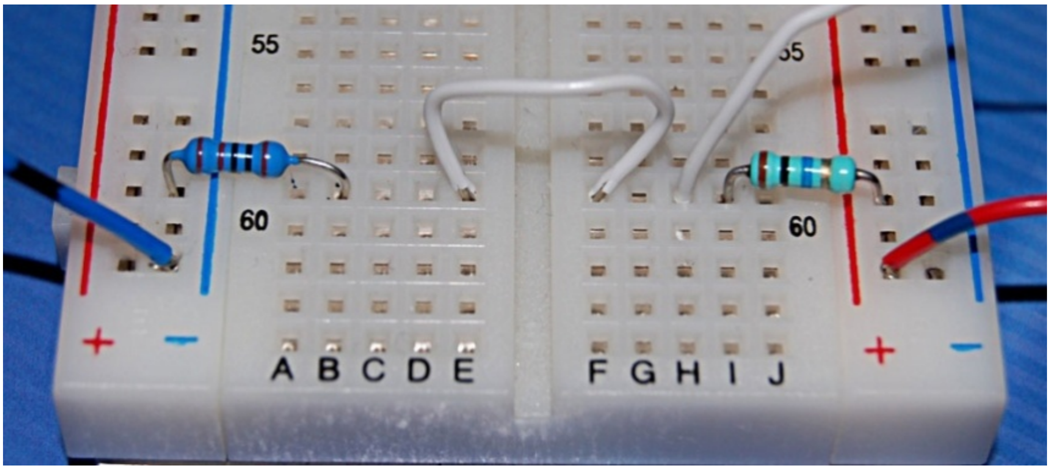

Figure 2: The solderless breadboard with connected resistors.

It was soon realised that the scope of the exercises is too large for average students within six contact hours in the laboratory. Therefore, 30% of the exercises were made non-compulsory and available for bonus marks to ambitious students, who could complete the additional exercises in their own time. About 15% of students of the cohort chose to do this.

THE ASSESSMENT

The assessment in the Electrical and Energy Systems course included 10 tutorial quizzes (20%), instrumentation and measurement practical report (15%) based on 3x2 hours sessions in the laboratory, computer measurement practical report (25%) based on 5x2 hours laboratory sessions and the final examination (40%).

The students were provided with a template for the report that included six sections: abstract, introduction, procedures and methods, experimental results, observations and discussions, conclusions and recommendations and, finally, appendices, references, etc.

The report marking scheme was structured as follows:

1.	Introduction	10%
2.	Conclusion and recommendation	10%
3.	Procedure	30%
4.	Experiment results and discussions	50%
	Total	100%

There was a differentiation between the so-called *easy* exercises e.g. 5, 8, 11, 14 and *hard* ones e.g. 9, 15, 17, in assessed item *3. Procedure,* easy exercises could attract 9 marks and hard 21 marks out of 30. In *4. Experiment results and discussion,* easy and hard exercises could attract a similar proportion of 50% of marks.

CONCLUSIONS

The learning objectives of the experiments were: acquisition of fundamental knowledge and skills in electronic measurements and using bench top instruments. The learning activities to achieve the above objectives included preparation for laboratory experiments, participation in performing the supervised laboratory experiments in teams and writing semi-professional laboratory reports.

Students appreciated the experiments and the electronic instrumentation/computerised measurement approach, which was reflected by their overall satisfaction in the course experience questionnaire of 60% on the scale between -100% to 100% (a very good result) compared with the satisfaction of only 10% when these experiments were not used [9].

The exposure of engineering students to the modern instrumentation and measurement techniques is essential when preparing the graduates of engineering disciplines for the digital age.

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