Session 2426

The Use of Home Experimentation Kits for Distance Students in First-Year Undergraduate Electronics

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Abstract

Laboratory and practical classes are an important part of the education of students in electronics and electrical engineering. "Hands-on" experience is critical for any engineer working in these fields in particular. For many years, delivering engineering practicals to distance-education students has been a tremendous challenge for universities. For a number of years now, students enrolled in the common first-year electronics course by distance mode at Deakin University have received a home experimentation kit. Using the kit and a laboratory manual, students are required to complete a number of experiments based on components included in the kit. The kit supports a full range of practical activities for digital electronics, and a more limited range of activities for analog electronics. With the kit, off-campus students are supplied software for simulating AC electronic circuits, such as amplifiers and rectifiers. In this report we examine the past use of this kit and software, review anecdotal student experiences with the package, and propose changes to it and to other curriculum resources, aiming to enhance the use of the kit by distance students. Key curriculum resources planned are a web-based 'companion' for the components in and the use of the kit, and two additions to the kit itself: a battery powered function generator, and a PC-based oscilloscope.

Introduction

Practical education through hands-on activities is an essential part of any engineering curriculum. "Book Learning" alone is quite insufficient for the student who is training to be a modern engineer. In the field of electronics and electrical engineering this is especially so. Electronics is one of the most hands-on fields in engineering. The ability to build and test electronic circuits and devices is just as important as the ability to design them. For the student who is new to electronics, the practical skills that he needs to learn include the operation and characteristics of various linear and non-linear devices, such as power supplies, rectifiers, resistors, capacitors, inductors, diodes, transistors, op amps, logic gates, and flip flops. The student needs to learn the effective use of breadboards, circuit layout, how to test his circuits, and how to use common test equipment, including multimeters, AC function generators, logic probes and oscilloscopes. In a conventional university electronics course, the practical skills in basic electronics are normally taught by means of on-campus lab classes, with real test equipment, in the presence of a lab instructor, with students working in small groups.

The past 25 years or so have seen the rise of distance education and the "open university," where students are given the opportunity to take courses in part or completely at home.[1] This at least partially eliminates the need for the student to attend classes during normal working hours. It thus extends the opportunity for a university education to students who work full time, are unable to leave home (due to a disability, for example), and those who are stationed interstate or even overseas from the home campus.

In teaching engineering to distance-education students, the problem arises in providing them with training in the practical skills they will need as engineers.[2,3] This is especially true in electronics, a most practical engineering discipline. The most obvious solution is for the engineering school to run evening or weekend practical classes, or perhaps intensive on-campus residential schools one or twice a year. This solution requires students to have some on-campus component of their course. For local students, this is not usually a great problem. However, regular on-campus lab sessions prove expensive and burdensome for those students who live far away from the home campus. For students posted overseas, on-campus attendance at lab classes is virtually impossible.

Deakin University teaches numerous off-campus students who live locally, interstate, and overseas.[4] In developing its undergraduate engineering courses, including electronics, the University needed a means to deliver practical education to off-campus students. The University has applied numerous strategies in delivering laboratory activities for distance education, including week-end practical classes, Internet-controlled experiments,[5-10] simulations,[11-13] at-home activities or projects, where the student obtains his own materials,[14] and experimental kits issued to students.[15,16] To satisfy this need in the case of first-year electronics, we have developed an electronics-experiments kit (figure 1) and corresponding lab manual. With the kit, the off-campus student may learn practical, first-year electronics at home. The kit contains a breadboard, battery pack, jumper wires, and components so that the student may perform a number of exercises at home (table 1).

The prescribed experiments include a complete set of activities in basic digital electronics, and a limited set of activities in analog electronics. Those exercises that require a function generator and an oscilloscope are performed by means of additional software for electronics simulation. The exact procedure of some analog experiments is allowed to be flexible, depending on what resources are available to each individual student. The activities are designed to allow the student who has no electronics test equipment to complete the exercises at home.

The experiments

The lab manual is divided onto two parts: digital (part A) and analog (part B). Table 2 shows the activities to be completed with each part. Each activity presents an essential lesson in electronics: observing electronics theory in practice, building actual circuits, and testing them.

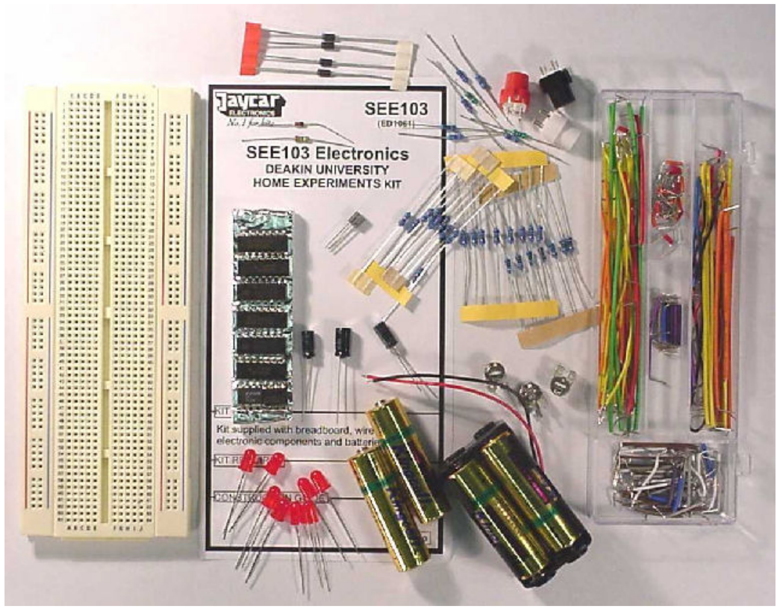


Figure 1: Deakin University kit for first-year electronics.

1 × battery pack	1 × 1.5 MΩ resistor
4 × AA batteries	1 × 500 Ω trim pot
1 × battery lead	1 × 2.2 kΩ resistor
1 × breadboard (80 mm × 55 mm)	1 × 22 kΩ resistor
1 × wire jumper set	1 × 1 kΩ trim pot
8 × LED (red, 5 mm)	1 × 1 MΩ trim pot
4 × 1N4001 diodes	1 × 2 MΩ trim pot
1 × OA91 germanium diode	1 × BC547 transistor
1 × 100 Ω resistor	1 × 100 microfarad capacitor
7 × 180 Ω resistor	1 × 1 μF capacitor
4 × 220 Ω resistor	1 × 10 μF capacitor
2 × 510 Ω resistor	3 × momentary action switch
8 × 1 kΩ resistor	1 × 74HC00 IC NAND gates
1 × 4.7 kΩ resistor	1 × 74HC02 IC NOR gates
2 × 10 kΩ resistor	1 × 74HC08 IC AND gates
1 × 43 kΩ resistor	1 × 74HC32 IC OR gates
1 × 51 kΩ resistor	1 × 74HC86 IC Exclusive-OR gates
1 × 100 kΩ resistor	1 × 74HC73 IC JK flip flops
1 × 470 kΩ resistor	1 × 741 op amp
1 × 1 MΩ resistor	1 × NE555 timer

Table 1: Contents of the home-experiments kit.

Exercise	Activity
A1	Introduction to the breadboard and the transistor
A2	Basics of logic gates
A3	Universality of NAND and NOR gates
A4	Equivalence of Boolean expressions
A5	Half and full adders
A6	Combinational logic circuits
A7	Flip flops
B1	Introduction to diodes
B2	Applications of diodes and rectifiers
B3	Introductions to bipolar transistors
B4	Op amps – open-loop operation
B5	Op amps – closed-loop operation

Table 2: Lab exercises assigned in first-year electronics.

The first digital exercise is designed to introduce students to breadboards by means of simple circuits: an LED and series resistor, a standard NPN transistor, and a 6-volt battery pack (four AA batteries in series), figure 2. Students learn how to find their way around the breadboard and use the trim pot to control the current flow into the base of the transistor. The transistor in turn controls the current flow and thus brightness of the LED. The next four exercises give the student experience in using various logic gates and Boolean operations AND, OR, NOT, NAND and NOR. These operations are then applied to show various logic expressions, combinational logic circuits, and very basic digital arithmetic. These activities are performed only by means of the kit. The on-off status of the LED's indicates the logic levels associated with the various circuits. Students record their results in the form of truth tables.

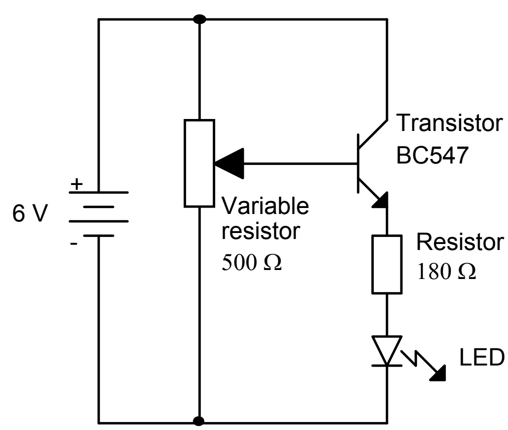


Figure 2: A simple circuit to introduce the breadboard to the student.

The analog experiments introduce the student to the basic analog devices diodes, bi-polar transistors, and op amps. Each type of activity has both a DC component and an AC component. For these activities, the students fall into one of three groups: students who have no access to electronic test equipment, students who have access to a basic multimeter, and students who have access to multimeters, function generators, and oscilloscopes.

The lab procedures are flexible enough to cater for all three groups. On-campus students of course have access to all necessary test equipment, and thus perform all the experiments in real life. Only a small number of off-campus students have access to all the needed test equipment and thus perform all the exercises hands-on. To accommodate the majority of off-campus students, over the years we have provided the students with electronics-simulation software.[17] Students then simulate the AC components of their analog experiments on a PC.

The lab course

The lab exercises run in the context of the Deakin University course SEE103, first-year electronics. The pre-requisite for this course is introductory physics, which covers the basics of DC electric circuits, but not AC circuits. SEE103 is divided into three modules:

- Digital systems – four weeks
- DC network theorems and AC circuits – three weeks
- Analog electronics and devices – six weeks.

The student breakdown is typically ¾ on-campus, ¼ off-campus, with a total enrolment of around 90 students.

On-campus and off-campus students perform the same lab exercises and they all use the kits. On-campus students attend six scheduled three-hour lab classes, work in pairs, and have an instructor present. Off-campus students perform the experiments at home in their own time. Both groups of students submit written reports on their experimental work and results. To assist with describing their experimental procedures, students sketch breadboard diagrams of their actual circuits, starting with the template shown in figure 3. A typical, completed breadboard diagram for a specific exercise would appear similar to that given in the lab manual for the first logic-gate experiment, figure 4.

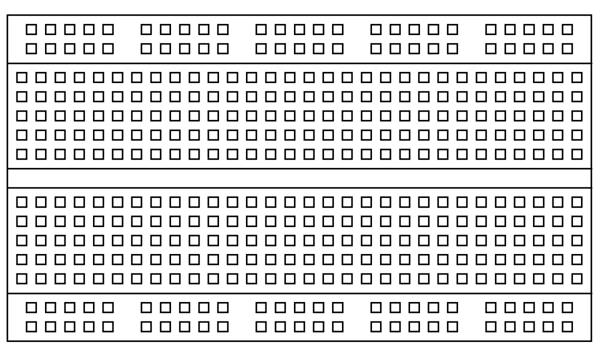
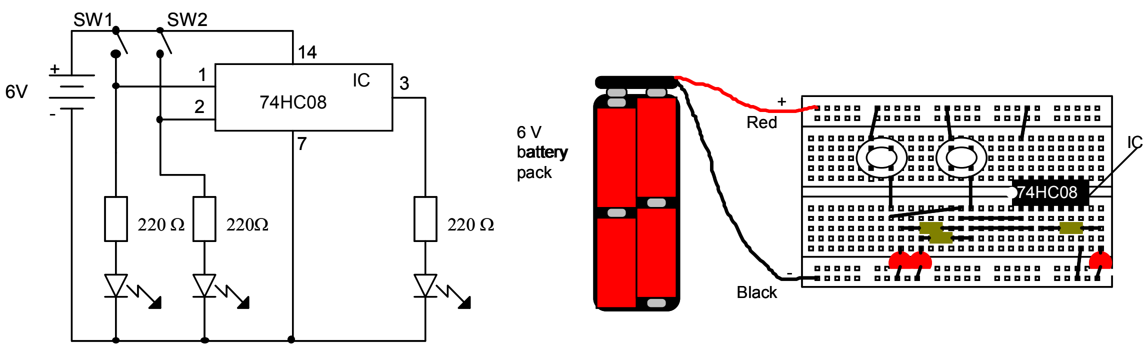


Figure 3: Breadboard template that students use when sketching the actual circuits they assemble and test.



(a) (b)

Figure 4: Use of breadboard diagrams (b) to demonstrate how a logic circuit (a) is assembled.

In a lab report, the digital results are listed as truth tables. The analog results take the form of data tables and plots of voltage versus time (input and output) for those circuits having AC inputs. In 2003, a few off-campus students included digital photographs of their assembled and operating breadboard layouts (figure 5). This is the first time digital photographs appeared in student lab reports for SEE103. It demonstrates that off-campus students can show a good deal of ingenuity and flexibility when working on practical activities at home. It also shows that advances in technology in the home are helping to increase the quality of students' work. Those students who performed computer simulations for the AC components of their labs simply printed out the simulation results from the computer and pasted appropriate figures into their reports. Also in 2003, Deakin provided one on-campus lab session on a Saturday for local off-campus students, mainly for the analog experiments. It was well received by the dozen students who attended. Other off-campus students who had difficulties with their lab work (including one in Canada) received assistance from the lecturer by telephone, email, and fax.

Evaluation of the kits and the lab program

Deakin University Engineering has been using kits and simulators for off-campus lab exercises for the past eight years. As a whole, SEE103 is evaluated and the end of each academic year. Anecdotal evidence from these evaluations indicates that the off-campus students are in general satisfied with the kits themselves. Once the components are identified and they understand how the breadboard works, most students find the digital experiments straightforward. On the other hand, the analog exercises tend to be more difficult for students, and performing the simulations is usually a problem for everyone. Simulations add an extra burden on off-campus students. They need to install the software and learn how to use the simulator, prior to doing the exercises themselves. Some off-campus students have used their own simulation software instead of that supplied by Deakin. The lecturer has allowed this flexibility so long as the exercised are performed correctly. Student comments over the years also suggest the need for additional tutorial notes on the use of the kits.

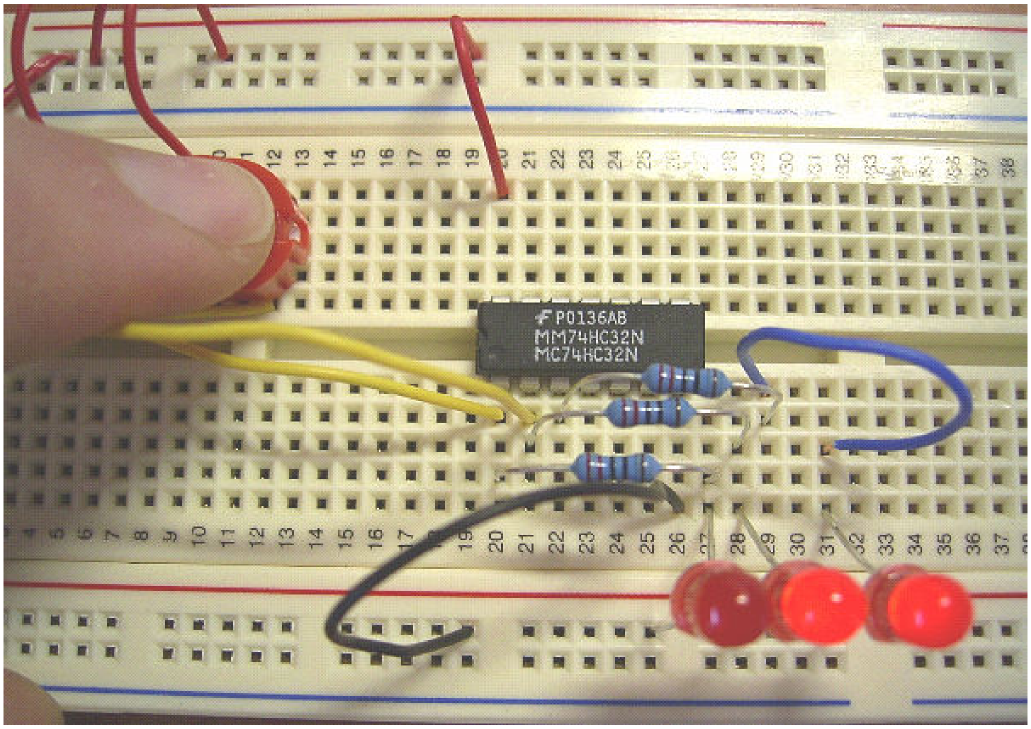


Figure 5: Testing of a digital OR circuit, from a student's lab report.

Lab instructors grade all the students' reports on a scale from one to ten, ten being the top score. Separate grades are recorded under the two headings Digital and Analog. The reports are checked for completeness of the experimental work, the results, the structure of the reports, and use of English. Table 3 shows the average scores on each type of report for the past six years.

Year	Total on-campus assessed	Total off-campus assessed	Average on-campus Digital score	Average off-campus Digital score	Average on-campus Analog score	Average off-campus Analog score
1998	54	22	5.7	5.5	5.3	5.5
1999	73	27	6.6	7.1	6.1	5.5
2000	88	24	8.1	8.8	6.2	5.3
2001	87	20	7.1	6.7	6.2	5.8
2002	68	22	6.6	6.4	6.0	5.3
2003	70	29	8.1	8.0	6.9	6.0

Table 3: Average lab-report grades for on-campus and off-campus students over the years 1998-2003. The maximum possible score is ten.

The average on-campus scores are in general, higher than the average off-campus scores, but not always. In addition, the digital scores are usually higher than the corresponding analog scores, confirming the extra difficulty students face when performing analog exercises as compared with digital exercises. On-campus students have the advantage in this case that they have the assistance of lab instructors, where as off-campus students do not. The one on-campus lab session held on a Saturday in 2003 may have contributed to the increase in off-campus analog scores for that year. It is clear that improvements can be made in the teaching of the lab exercises.

At the end of 2003, to better judge the needs of students, the authors sent a questionnaire to the off-campus students in SEE103, specifically asking for their views on the practical program and the kits, and for suggestions on further improvements. An initial study of the returned questionnaires suggests a number of points:

- Most students thought that the digital exercises were less difficult than the analog exercises.
- Some students had difficulty identifying specific components in the kit. Of those students who used the simulator in the analog experiments, no one found them straightforward.
- When asked whether they would prefer doing the exercises on-campus rather than at home with a kit, the responses were split evenly between yes and no. Presumably local students prefer to attend an on-campus lab session and those who live far away prefer to work through the experiments at home.
- Most students welcomed the idea of creating a website specifically for helping students with their kits.
- Most students welcomed the idea of replacing the simulations with real-life exercises.

Future Developments

SEE103 is currently being revised for semester two, 2004. Two key improvements are under development. One is the production of a tutorial, companion website for the kits. It will contain photographs of all the components in the kit, further instructions on reading data sheets and color codes, and photographs of select circuits to help the student get started. We also intend to replace the simulations with real-life exercises. This will involve two additions to the kits. One is a battery-powered function generator. The other is a simple device and associated software to allow a PC to operate as an oscilloscope. Such devices will allow students to perform the AC components of their lab exercises by means of the household PC.[18] We also intend for these devices to be used in later-year electronics courses, where for example, amplifiers and analog filters are taught more extensively. The use of simulations will remain, however, in our more advanced second-year courses in analog and digital electronics. Another improvement planned is the introduction of a discussion page on the course website, where students can post questions, suggestions, and other items for the benefit of all students. All these additions will enhance the hands-on nature of the course for off-campus students.

Conclusion

The education and training of students in basic electronics require a significant amount of hands-on lab work. Providing this sort of instruction through distance education has always been a challenge. Deakin University has addressed this problem through the use of an electronics kit mailed out to all off-campus students enrolled in first-year electronics. Evaluations of student performance and comments indicate that the use of kits for digital exercises is relatively straightforward, but their use in analog exercises tends to be more difficult. Further development is needed, especially in the case where AC signals are to be generated and measured. To improve the delivery of electronics education for off-campus studies, we propose to develop a web site 'companion' for the kits, and additional hardware devices to allow students to perform real AC experiments at home.

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Biography

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