An AC Signal-Generator and PC-Oscilloscope Test Package for Distance Students in 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. For a number of years now, students enrolled in the common first-year electronics unit by distance mode at Deakin University have received a home experimentation kit. The kit supports a full complement of experiments in digital electronics, and a partial set of analog experiments. Exercises containing AC investigations, such as amplifiers and AC circuits, require either on-campus attendance or at-home computer simulations. The limitation is the need for the student to have access to AC signal generators and oscilloscopes. In this study, we propose a low-cost AC experimental package to be issued to off-campus students, complementing the electronics kits currently in use. A single circuit board contains a simple AC signal generator and oscilloscope input. The device is capable of producing sine, square and triangular waves up to 860 kHz, and output voltages up to 7 volts peak to peak. The oscilloscope package employs the sound card of a PC and a software package to allow PC measurements of real AC signals. In addition to allowing students to perform their specific AC exercises at home, the package will also be useful for electronics studies at later years.

Introduction

Traditional teaching in science and engineering involves lectures, demonstrations, tutorials and problem-solving classes, essay and report writing, project work, and laboratory classes. The specific learning processes comprise coarse-grained knowledge (an overview of the material to be learned), fine-grained knowledge (details), cognitive skills development, and application of the acquired knowledge, where one looks to identify misconceptions or fill gaps left from earlier learning. The development of cognitive skills requires examples, tutorials, and practical experimentation. Once the student is able to manipulate, control and modify the experiment, and use the necessary tools, he can shift into the final application stage of learning.[1]

Practical education through hands-on activities is an essential part of any engineering curriculum. This is because engineering in particular demands the development of both a conceptual and procedural understanding that can only be achieved through practical work. If the student controls the experiment, instruments, and processes, then he will obtain the knowledge more quickly and thoroughly. In the very practical field of electronics, this is especially true. One’s ability to build and test electronic circuits and devices is just as important as the ability to design them. Thus the traditional electronics curriculum requires extensive laboratory classes for the student, who gains skills in the use of components, test equipment, building circuits, and trouble-shooting.

With the modern trend towards globalisation comes the same trend in engineering education. There has been a growing need to provide engineering education to students who are unable to attend traditional lecture and lab classes during normal business hours, or who are physically remote from the home campus. We have thus seen over the past 25 years or so the development of distance education, where students have the opportunity to enrol in engineering courses from home or the workplace.[2] Innovation in distance education has taken place over four distinct phases:[3,4]

1. The use of written material as the cornerstone of education delivery. Tutors and lecturers play a key role in the learning process.
2. By the late 1970's and early 1980's, technology was being used to deliver education, through audio and video tapes, and telephone. This added depth to the educational material by being able to demonstrate key concepts.
3. Multi-media development. In this period the PC became the main tool for delivering educational material. This has led to computer-aided learning packages that allow visualisation of dynamic systems, and the ability to provide the same information in multiple ways.
4. The "telematics-teaching" stage. This is the current trend, where advanced IT and telecommunications are taking education delivery to the next level.

For engineering education, the problem exists of providing practical education through distance learning.[5,6] No where is this need more evident than in electronics education, a very practical engineering discipline. This was first addressed by requiring students to attend lab classes in the evening or on weekends. But on-campus attendance at lab classes generally excludes those students who live far away from campus. One could argue that on-campus attendance allows off-campus students necessary contact with lecturers and fellow students, an essential component in one's education as an engineer. However, on-campus attendance at weekend lab classes or perhaps in residential schools allows the student to have at best one or two days experience in specific laboratories, such as electronics. Students need to have on-going access to test equipment and facilities to gain experience and confidence in electronics.

This need has been addressed through computer simulations.[7,8] Simulations in electronics education have several advantages. They are a cost-effective and efficient way to teach complex, dynamic systems. They allow one to control experimental parameters, which may be greater than what is available in the laboratory, without the danger of safety hazards, and without the possibility of damaging components or test equipment. Students also have continued access to the simulators on their computers at home or workplace. However, there are a number of disadvantages to the use of simulators to teach electronics.[9] Simulators only simulate electronic circuits. They do not teach. Valuable and significant study time is spent by the student learning how to program and drive the simulator. Any problems the student has with using the software will divert attention away from the primary objectives of the exercise. Students can also obtain a false sense of completion. If they are unaware of what the outcome of a simulation should be, they may accept the wrong results as the right ones. Finally, a key disadvantage of the sole use of simulators is that the student loses valuable practical experience that is critical in learning electronics. Many students are aware of this, and it has resulted in some students believing that they have not actually done anything practical.

The educational problems left unsolved by simulations can be overcome by distance students performing the experiments by remote control.[10-12] This provides increased flexibility for both the student and the educator. It also can give the student an appreciation for networking technologies, the use of the Internet, and automatic control systems. It also encourages collaboration between institutions, as one with such facilities could offer them to another's students that lack them. A number of universities offer remote control of electronics experiments.[13,14] The drawback of such activities is that the experimental set-up and associated servers and websites will require constant maintenance by a dedicated technician. Appropriate safeguards need to incorporated to insure that the equipment cannot be damaged by incorrect input or instrument settings. The instructor also needs to stress that students are using real equipment in real time. Finally such practical devices usually only offer a small set of specific experiments, with little or no room for the student to begin investigations of one's own, such as modifying the circuit or trying new designs.

Another approach to providing practical electronics education to distance students is through electronics kits posted to students at the start of semester. Deakin University has provided such a kit to off-campus students for many years.[15] Using a laboratory manual, students are required to complete a number of experiments with the components included in the kit. The kit contains a breadboard, battery pack, various digital IC's (logic gates, flip flops, and a 555 timer), an op-amp, a transistor, diodes, LED's and various passive components. The kit supports a full range of practical activities for digital electronics, and a more limited range of activities for analog electronics. In addition to the kit, off-campus students have been supplied with software for simulating AC electronic circuits, such as amplifiers and rectifiers.[16] This is the kit's chief limitation. It easily allows students to gain experience in building and testing DC circuits, but does not support the development and testing of AC circuits. As AC circuits are an important component of any electronics course, a need therefore exists to provide distance students with the means to build and test simple AC circuits at home, without the need to access or purchase oscilloscopes and signal generators.

To fulfil this need, two key items are necessary in addition to the breadboard, multi-meter, jumper wires, and box of components: One is a simple, low-cost AC signal generator, preferably operated by batteries. The other is an oscilloscope, possibly from software and signals input to a PC. Table 1 shows the design requirements for both devices.

Commercial electronics suppliers are beginning to offer low-cost signal-generator kits, which students could build themselves. One such kit is by Velleman.[17] It is powered by a single nine-volt battery, produces sine, square, and triangular waves, and outputs a single frequency of 1000 Hz. Such a kit requires assembly by students, and has the single-frequency limitation, which excludes many important electronics experiments, such as frequency response. It has the chief advantage of low cost (around $A10). Other educators have proposed employing the sound card on a PC as a source of audio signals for practical activities. Some have also developed packages whereby the PC soundcard is both an audio signal generator and oscilloscope input.[18]

Numerous commercial systems are available to use a PC as an oscilloscope, Softdsp[19] and Scope4pc[20] being two examples. The most advanced educational package that we have seen is the Pandora Box, an instrumentation package that includes a power supply, signal generator, and two-channel oscilloscope.[21] The package is mains-powered and is driven by Labview software. The complete package for one workstation costs around $US 200.

Signal Generator	Oscilloscope
Easy to use.	Easy to use.
Stand-alone unit.	Inputs to a PC.
Battery powered.	Software driven.
Provides positive and negative output voltages.	Has built-in circuitry to protect the sound card from DC and high voltages.
Voltage amplitude variable up to ± the battery voltage.	Can measure frequencies up to about 15 kHz.
Supports sine, triangular and square waves.	Operates on hardware common to most PC’s.
Variable frequency up to around 15 kHz.	Input to a sound card.
Low cost.	Low cost.

Table 1: Requirements of the signal generator and oscilloscope kit.

Package Design and Results

Our package consists in a battery-powered AC signal generator the produces sine, square, and triangular waves of varying amplitude and frequency; and an oscilloscope package that employs the sound card of a PC. The hardware is mounted on a single circuit board, includes both the signal generator and oscilloscope inputs, and obtains power from two standard 9-volt batteries. Freely-available software is installed on the PC for the oscilloscope operation.

The signal generator is based on the EXAR XR-2206 function-generator IC.[22] It offers all the desired functions listed in table 1, including cost and a favourable power-dissipation rating. The entire signal-generator employs this IC and a number of passive circuit components mounted on a surface-mount board. Figure 1 shows the circuit schematic. Testing of a prototype reveals that the signal generator produces good output signals with minimal distortion for a frequency range 1 Hz – 860 kHz, and an amplitude range 0–7 volts peak-to-peak. The use of two 9-volt batteries allows the output voltage to swing around zero. This allows the student to perform full-rectifier experiments, which might not be possible with a single-supply rail device.

For the oscilloscope component, we selected the Dazyweb Laboratories DS2002 Oscilloscope software package.[23] This program has a most realistic graphical user interface (figure 2), and is a key advantage of this software over competing packages. One disadvantage of the soundcard for voltage-time data acquisition is that soundcards do not have much in the way of input protection. Therefore, to make sure that the student does not inadvertently destroy a soundcard by accidentally introducing a signal that the card is not designed to receive, we added an isolation circuit to the oscilloscope input to protect the input port of the card (figure 3).

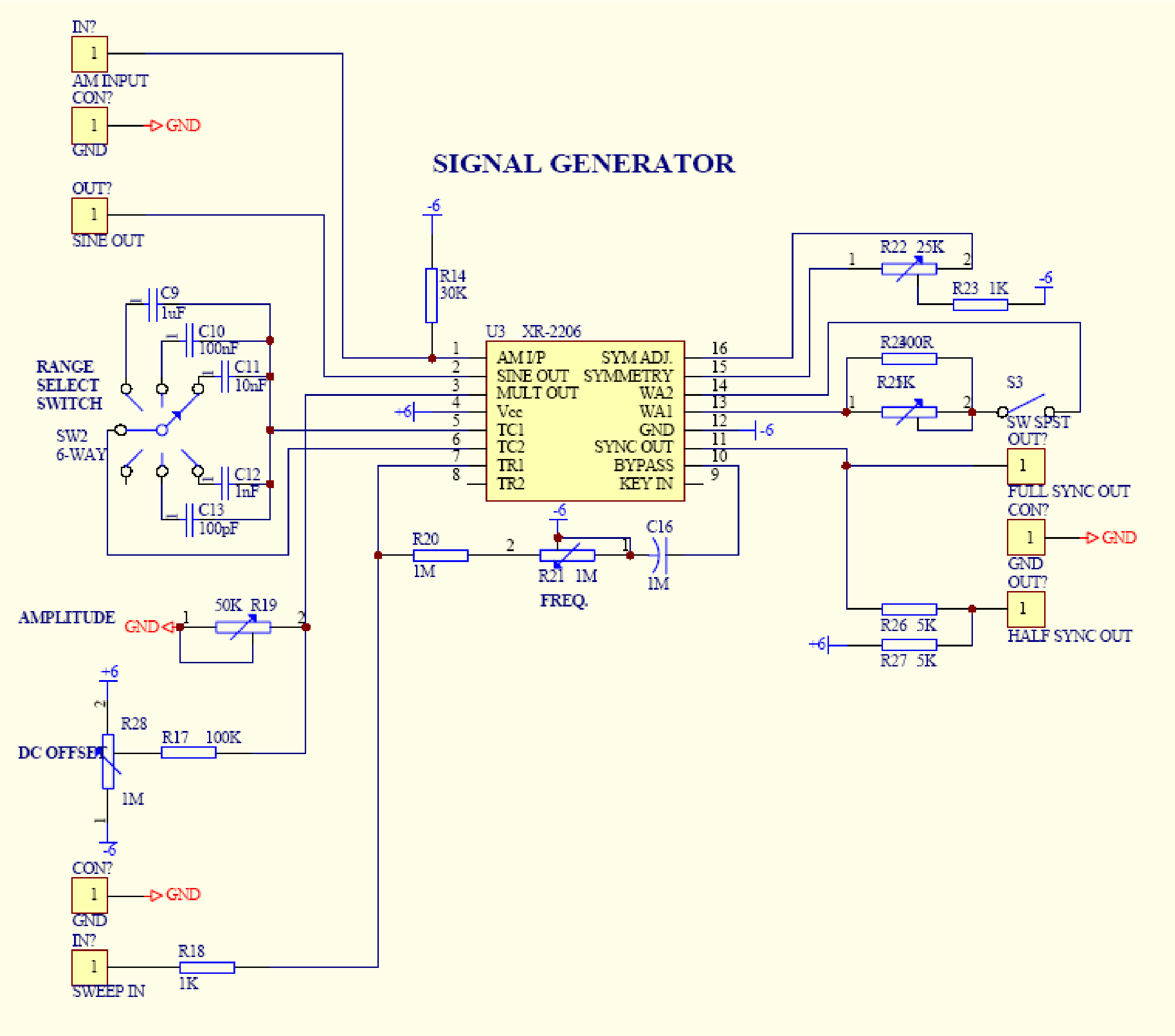
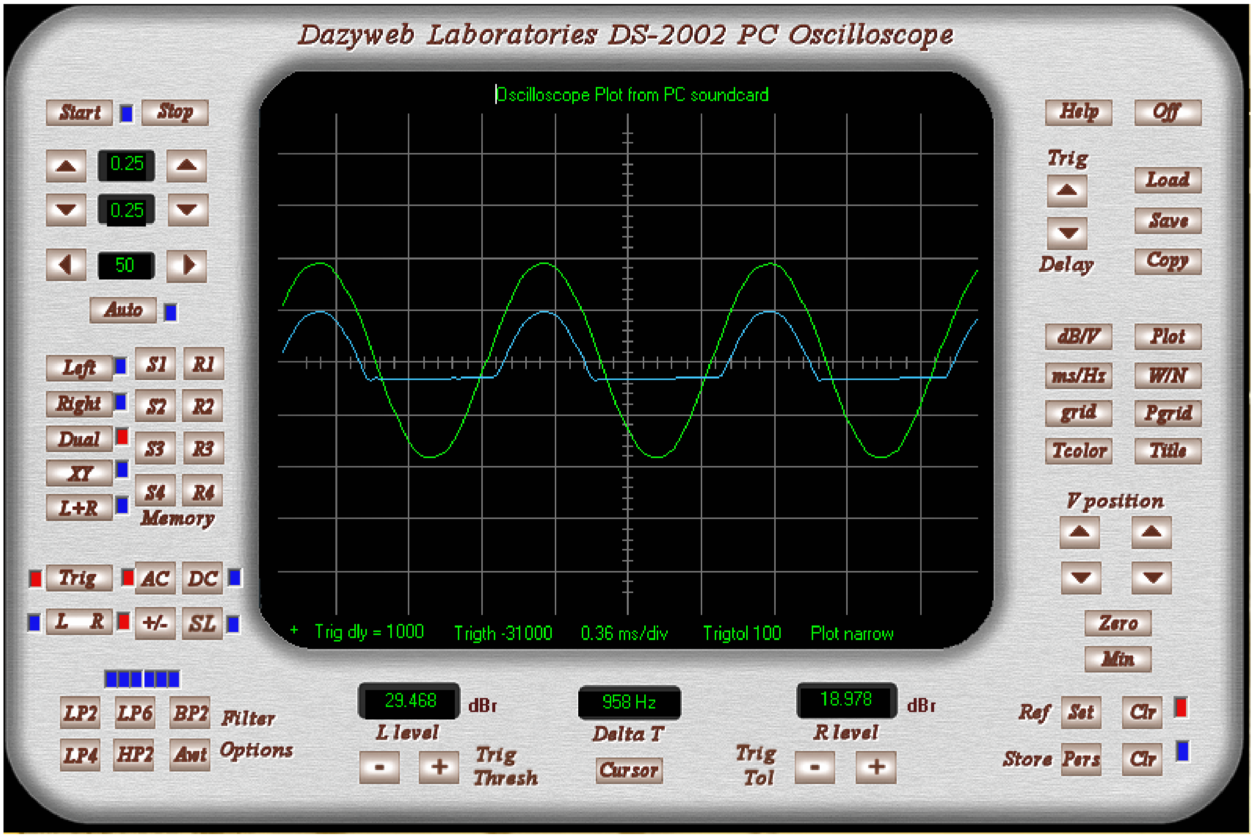


Figure 1: Signal generator schematic.

The isolator component is a simple FET unity-gain buffer circuit based on the TL084 op amp. We also added a 10:1 voltage divider circuit to the input to keep "large" input signals from saturating the soundcard. The package was tested on two different PC systems, one a Pentium 4 running under Windows XP, and the other a Pentium 3 with Windows 2000. Preliminary testing of a prototype, based on a standard –3dB bandwidth test, yielded good performance of the frequency range 20 Hz to 7 kHz. Although this is a lower bandwidth than that produced by the signal generator, we believe that it is adequate for practicals in basic electronics, which tend to focus on frequencies in the audio range.



0.25

0.25

50

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L level: 29.468 dBr

Delta T: 958 Hz

R level: 18.978 dBr

Figure 2: Screenshot of the DS-2002 PC oscilloscope,
showing data from a student half-wave rectifier exercise.

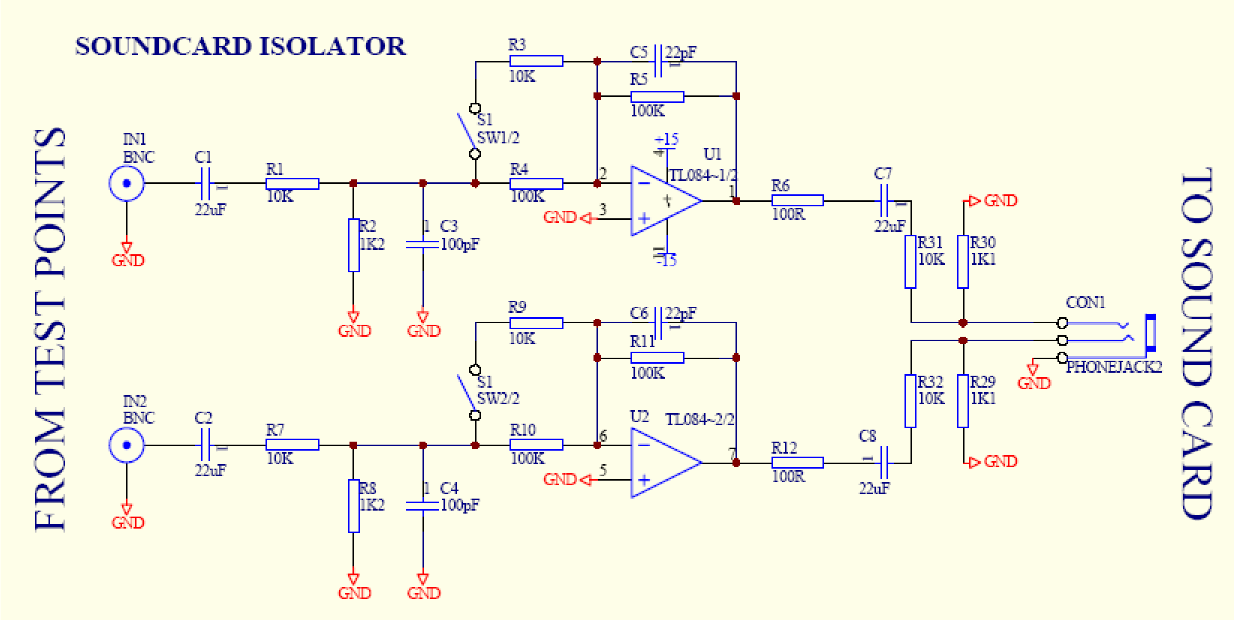

Figure 3: Isolator circuit for soundcard protection.

Discussion

Because the soundcard is the measuring device, only relative voltage measurements are possible. This is perhaps the chief limitation of using the soundcard for detecting AC signals. Perhaps a more elegant and complete design could have used a PC's USB port. However, USB ports may not yet be universally available on the average student's home PC, and the cost of such an approach would certainly have been greater than that for the soundcard design. Furthermore, many experimental activities in undergraduate electronics involve relative comparisons between an input signal and an output signal. In such cases absolute voltage measurements are not absolutely necessary. Alternatively, the student could calibrate the oscilloscope against some known voltage amplitude, or use a multimeter to provide the absolute voltage measurement. Our further testing found this package fully suitable for measuring the AC signals typical of the first-year electronics practicals offered at Deakin University.

This project is at the prototype stage. Final design work is in progress, to be followed by arranging for the package to be mass produced for delivery to off-campus students in first-year electronics. Our goal is to keep the total cost of one package to $A80 or less. The package will also be tested in a traditional on-campus setting and we will observe how both on-campus and off-campus students respond. We plan a full set of student and instructor evaluations to determine the package's usefulness and to make improvements. We expect this to be a useful package that students can use in all years of their study, complementing the electronics components kit that they currently receive.

Conclusion

Hands-on laboratory practicals are an essential component of any electronics education curriculum. Distance students at Deakin University use a components kit to perform at-home exercises in basic electronics, but the kit does not support performing real-time AC experiments. To satisfy this need, we propose to provide off-campus students with a low-cost, battery-powered, AC signal-generator and oscilloscope package. The signal-generator component produces sine, square, and triangular waves up to 860 kHz and 7 volts peak-to-peak. The oscilloscope package allows one to use a PC as an oscilloscope, by means of an input to the computer's sound card. The package will allow distance students to complete AC experiments in electronics without the need for on-campus attendance or relying completely on computer simulations.

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Biography

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