CONCEPT LEARNING EXPERIMENT IN ELECTRONICS

Gale Allen, Ph.D.
Electrical and Computer Engineering and Technology Department (ECET)
Minnesota State University, Mankato

Introduction

Students in the Electronics Engineering Technology and Computer Engineering Technology programs are required to take a two semester course in electronics. The courses cover diodes, BJT/FET transistors, and common circuit configurations including clippers, clamps, amplifiers, active filters, regulators, power amplifiers, differential amplifiers and operational amplifiers. Algebraic tools are used to predict the amplitudes and phase angles of voltages and currents at various points in the circuits for a range of amplitude and frequency values of an input signal source. The classes meet each week for three hours of lecture and two hours of lab (minus time to transfer between classes) for sixteen weeks in both semesters.

In Fall07 the author introduced the use of circuit simulation as an active-learning tool. This involved students working with the simulator at computer stations during lecture classes. Students observed the overall operation of each circuit prior to performing an analysis of the circuit. Short lectures involving the simulator were followed by active-learning sessions during which students worked together, helped each other, and compared results. Lectures on circuit analysis were given that were followed by students working example problems in class. Student comments were positive about the classroom process and about use of the simulator in homework assignments.

Background

During the prior three years several learning issues were observed. Some students found it difficult to analyze circuits, particularly when components were added or the structure altered from those circuits covered in lecture and homework. Some failed to get the big picture; i.e., the function and operation of circuits. Some students had not mastered critical topics in earlier courses.

Several efforts were made to address these issues. More circuit analysis examples were covered in lecture. Students were given time in lecture to work on example problems with each other in small groups, followed by the instructor working through the problems with the class. A circuit simulator was used in lecture and in homework assignments. More short quizzes were given at the start of lectures. These efforts produced some improvement in learning the tools and techniques, but not much progress was made in improving the student’s ability to use them effectively in new situations. That issue was the motivation for using the circuit simulator as an active-learning tool.

The idea for this effort was the result of learning about new teaching methods in a course given by Professor Stewart Ross, Director, Center for Excellence in Teaching and Learning[1,2]. Dr. Ross in the CETL November 2007 newsletter summarized the program, “We are now in our fourth year of offering the Faculty Teaching Certificate Program. In the past three years we have “graduated” 180 faculty and teaching assistants and this year we have 56 more participants learning about teaching theories, pedagogy and ideas.” The training was very helpful to the author in this course and others.

Approach

Students used the simulator to experimented with basic concepts such current division, voltage division, equivalent circuits, graphical analysis, Q-point, and load-lines. They use it to experience the behavior of simple and more complex circuits. They use it to better understand topics covered in earlier courses. Simulators are related to electronic games which students enjoy playing. There is opportunity for similar social interaction, teamwork, and competition. Students get instant feedback from the simulator, analogous to feedback in games.

Using a simulator in some ways is similar to learning in laboratory. In the laboratory, students build, test and fix circuits. They learn from mistakes. They focus considerable time and energy learning. Students predict results and compare predictions with experiment results. For many students the laboratory work is interesting and relatively fun. Learning seems high in the laboratory.

Fortunately a computer room (Figure 1) was available at the times the course was scheduled. Each student was able to use the simulator tool which was installed on the computers. The computers were arranged at right-angles to the front of the room. This arrangement tended to minimize students being distracted by email and games since the instructor could move a little and easily see the screens. The room had an active white-board that may be useful that provided additional capabilities for the instructor to use when presenting simulations and lecture material.

Figure 1. Computer Classroom

During lecture period each student simulated the component or circuit. The students made changes and observed the effects of changes. The students helped each other to work the simulations and to understand the results. The students are taught how to analyze the circuit and how to predict the response of the circuit to various input signals. The students worked in small groups and helped each other analyze example circuits.

During the simulation-based lecture the students explored circuit variations such as shown below. They simulated and analyzed these circuits and others in class and in homework assignments. For example, in this capacitor-coupling circuit (Figures 2, 3) a 3V battery added on the input side of the circuit was shown to have no effect on the output voltage waveform.

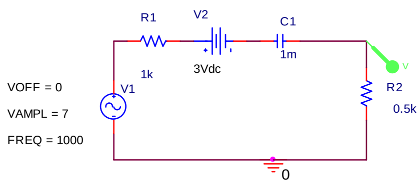

Figure 2. Capacitor-Circuit

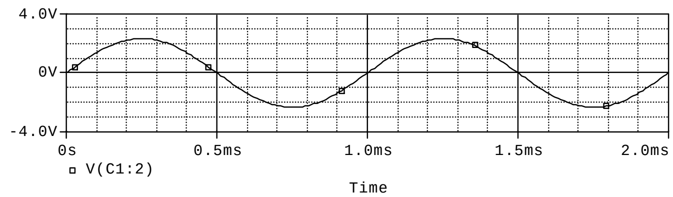

Figure 3. Output Voltage

A 2V battery added to the output side of the circuit (Figure 4) resulted in the output waveform being shifted up by 2V (Figure 5). The average output level was 2V due to the battery. The DC level was not affected by the input waveform.

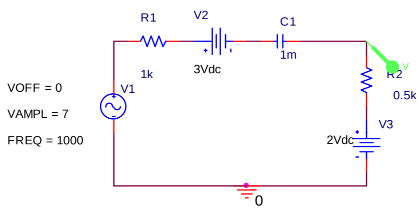

Figure 4. Battery in Output Ckt

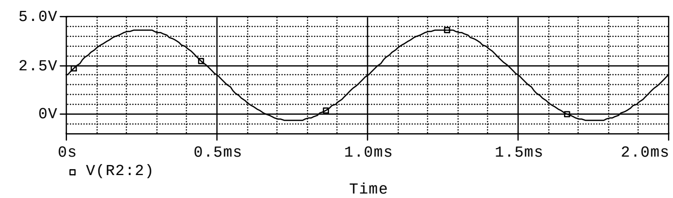

Figure 5. 2V Shift in DC Level

The addition of another battery had no effect on the output voltage in the circuit (Figures 6, 7). The DC level remained at 0V.

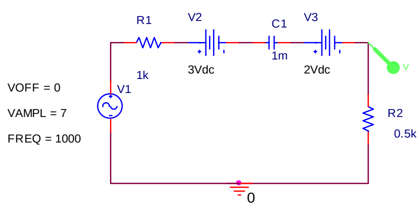

Figure 6. Battery in Input Ckt

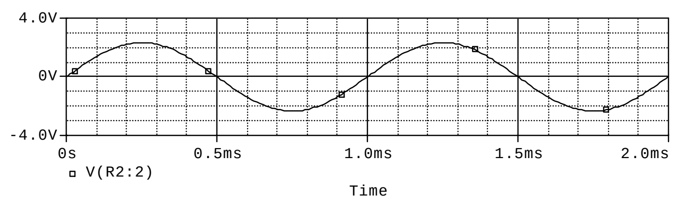

Figure 6. No Change in DC Level

Students quickly performed the simulations and understood the variations presented in lectures.

The process of training students to use the simulator involved working with students slowly through simple simulations. It was possible to make sure that every student was keeping up. Many simple example circuits were worked.

Students worked homework assignments using the simulator. Each student was given a disk copy of the program to use with their personal computers. Written instructions were provided on loading the software and getting started. It was important to closely monitor the students during the startup process in order to resolve the issues. Several students had problems printing the homework simulation results. This was resolved by having the students use the school printing system.

Simulator Capabilities

The simulator used for this course was Cadence Orcad Capture CIS Demo[3]. The tool is available as a free download or Cadence will send a free copy. The tool has a graphical user interface that is easy to use. The tool has many simulation capabilities including the following: DC analysis, transient analysis, two parameter DC sweep, frequency sweep, Monte Carlo, parametric Sweep, temperature sweep. The tool has the capability to mix component and mathematical simulation. Cadence will authorize the free use of the tool on all computers. The author has used the tool in industry and consulting work. Multisim from National Instruments provides similar capabilities.

Examples of Simulations Developed for Electronics I

The diode was introduced early in the course. The diode's current vs. voltage characteristics was plotted using the DC Sweep settings in the simulator (Figures 7, 8, 9).

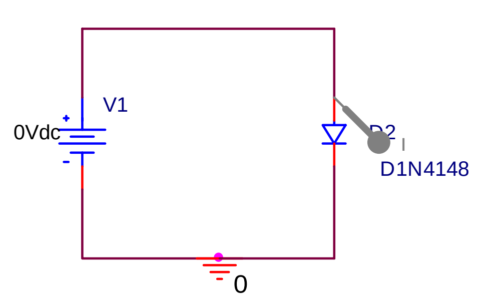

Figure 7. Diode Circuit

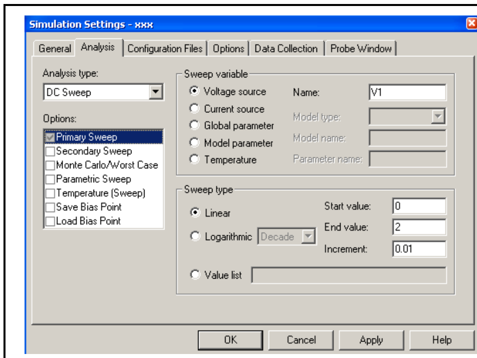

Figure 8. Simulation Profile

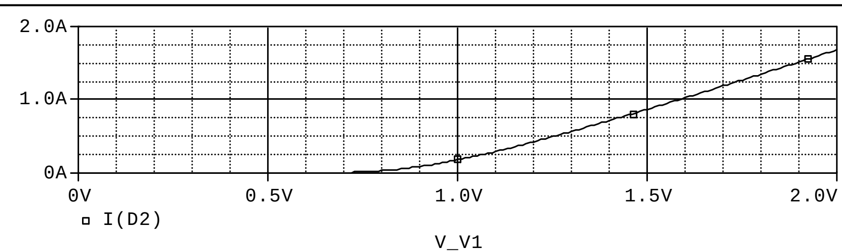

Figure 9. Diode Characteristics

Several diode circuits were studied including half-wave and full-wave rectifiers (Figures 10-13).

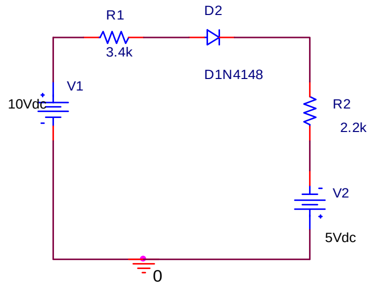

Figure 10. DC Diode Ckt

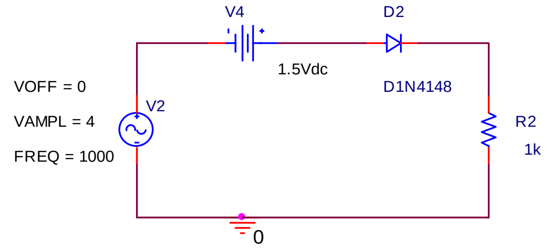

Figure 11. Half-Wave Rectifier

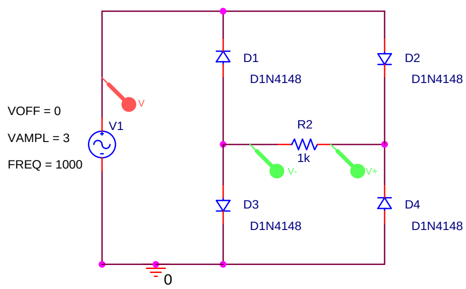

Figure 12. Full-Wave Rectifier

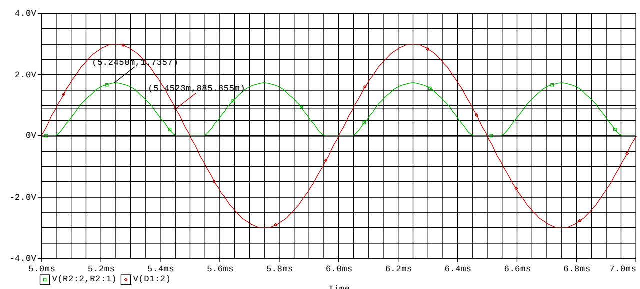

Figure 13. Full-Wave Rectifier Input and Output Voltage Waveforms

This simulation was used to study the load-line in a common-emitter transistor amplifier circuit (Figures 14,15,16.

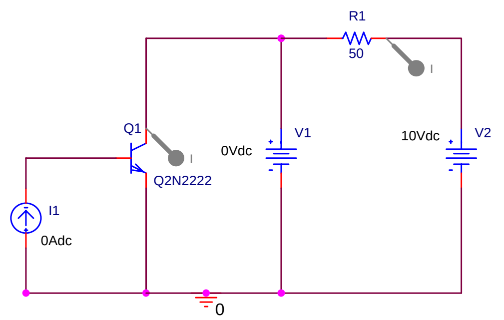

Figure 14. Load-Line Study Ckt

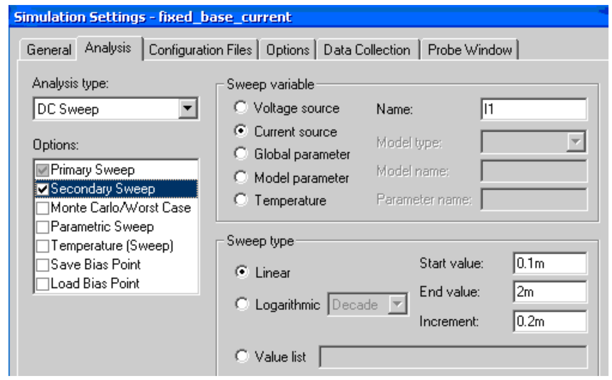

Figure 15. Load-Line Study Simulation Profile

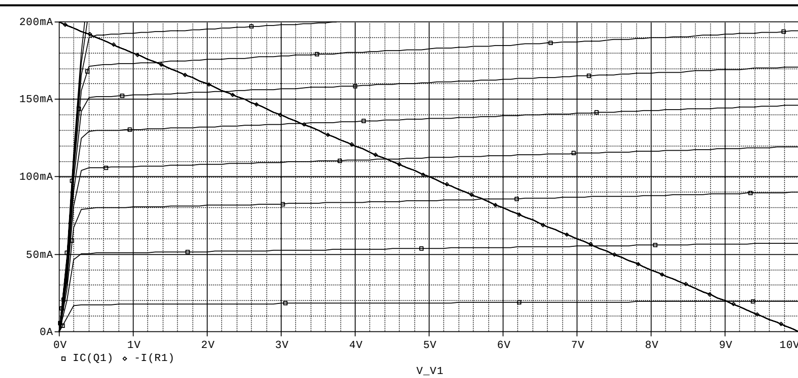

Figure 16. Transistor Characteristics and Load-Line

Students learned how to bias the common-emitter amplified and they learned the midband characteristics of the amplifier (Figure 17).

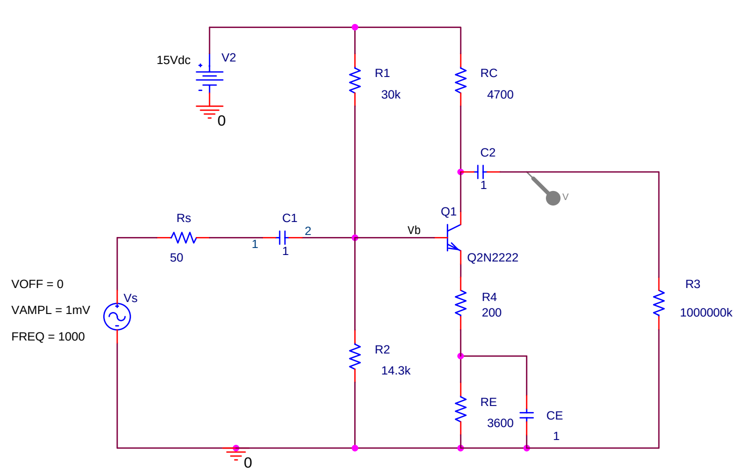

Figure 17. Common-Emitter Amplifier

Students made many changes in component values while studying the DC bias conditions and midband gain of this common-emitter amplifier (Figures 18, 19).

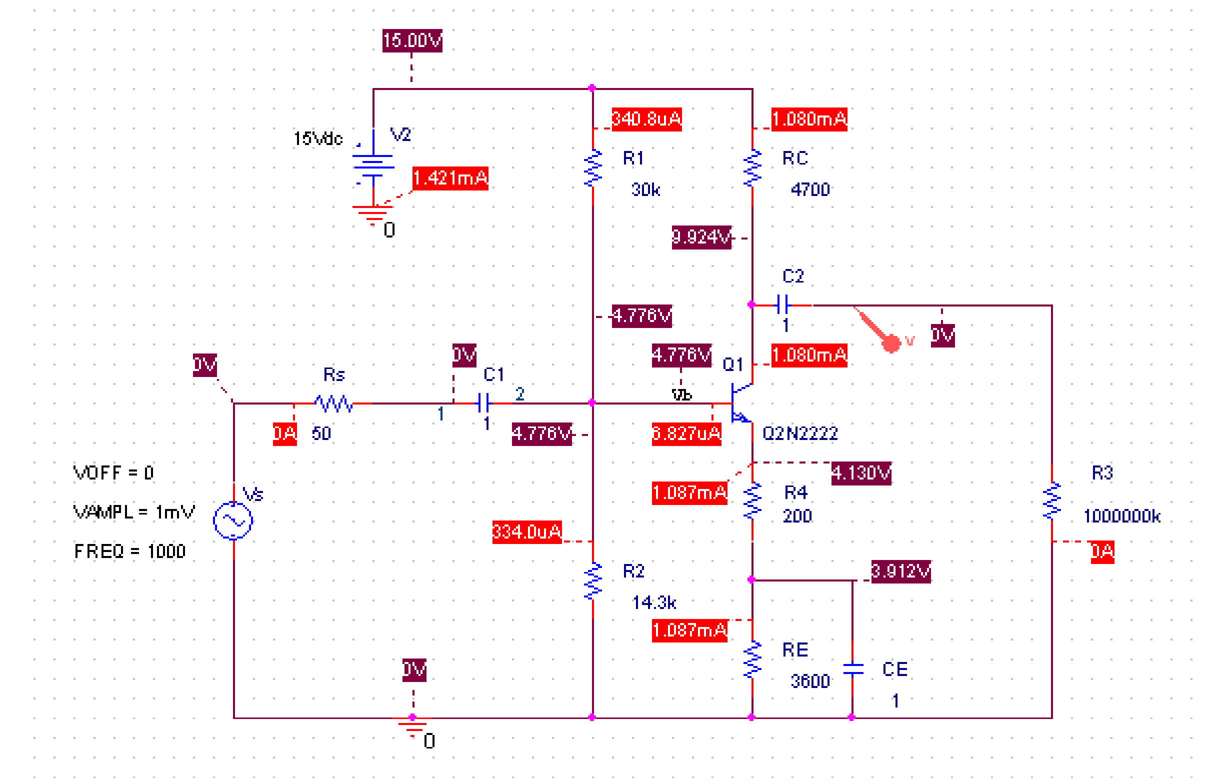

Figure 18. DC Voltage and Currents in Common-Emitter Amplifier Circuit

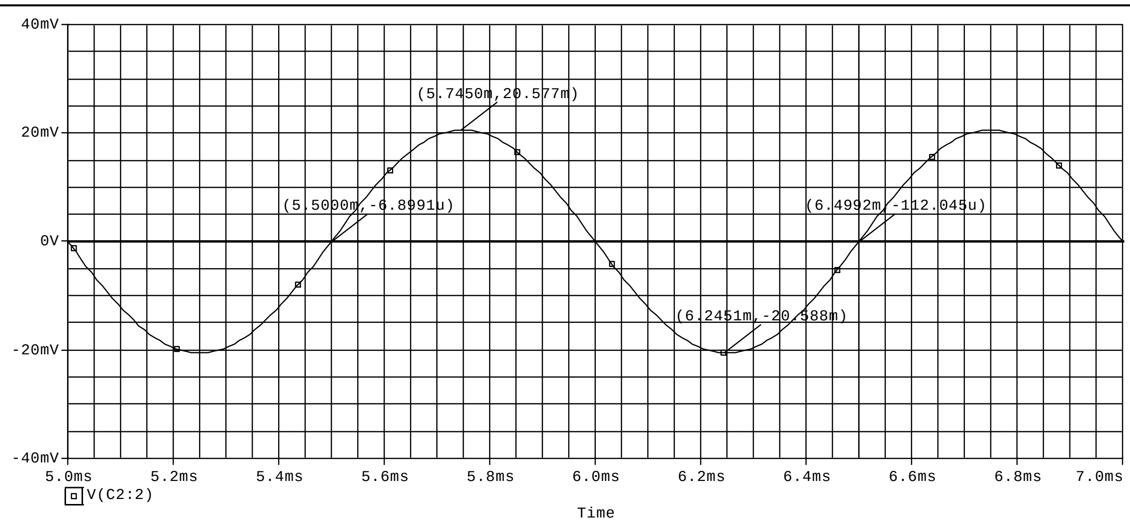

Figure 19. Common-Emitter Output Voltage Waveform

Conclusions

Students made many positive comments about use of the simulator during lecture as an active-learning tool. Students said they gained a better understanding of the operation of the circuits during lecture and when working homework assignments. Students said they got more out of the lecture period as compared with other courses.

Test results were encouraging and there were indications that students were doing better learning the concepts. Some exam problems from prior years were used and the results indicated improvement. This year development of course material was the first priority and consumed most of the course development time. Future task include work on assessment including developing methods of comparing results with and without the simulator.

Bibliography

1. Center for Excellence in Teaching and Learning. Retrieved from http://www.mnsu.edu/cetl/

2. CETL Newsletter. Retrieved from http://www.mnsu.edu/cetl/newsletter/CETL%20Newsletter%20November%205.pdf

3. Orcad Capture CIS – Demo. ORCAD, Retrived from http://www.cadence.com/products/orcad/downloads/orcad_demo/index.aspx. Two links at the bottom of the webpage are available to select download or a disk copy.

Gale R. Allen, Ph.D. is an Associate Professor and tenure-track member of the faculty of the Electrical and Computer Engineering & Technology Department at Minnesota State University, Mankato. For several years Allen worked for companies in the Minneapolis-St. Paul area. He has taught courses in circuit analysis, electronics, semiconductor devices, microprocessors, analog communications, digital communications, field-programmable-gate-arrays, and industrial automation. Allen is a senior member of the IEEE. His hobby is amateur radio.
gale.allen@mnsu.edu