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**A comparison and evaluation of the effectiveness of computer  
simulated laboratory instruction versus traditional laboratory  
instruction in solid state electronics circuitry**

**Nejad, Mahmoud Arshadi, Ph.D.**

**Iowa State University, 1992**

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Ann Arbor, MI 48106**



**A comparison and evaluation of the effectiveness of computer simulated  
laboratory instruction versus traditional laboratory instruction  
in solid state electronics circuitry**

by

**Mahmoud Arshadi Nejad**

**A Dissertation Submitted to the  
Graduate Faculty in Partial Fulfillment of the  
Requirements for the Degree of  
DOCTOR OF PHILOSOPHY**

**Major: Industrial Education and Technology**

**Approved:**

Signature was redacted for privacy.

**In Charge of Major Work**

Signature was redacted for privacy.

**For the Major Department**

Signature was redacted for privacy.

**For the Graduate College**

**Iowa State University  
Ames, Iowa**

**1992**

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## **CHAPTER I. INTRODUCTION**

Simulations are essential for meeting many instructional needs (Milner and Wildberger, 1974). They focus on the learning environment without usurping control from the learner, offering unique learning opportunities in nearly every subject area. As a result, simulations permit the attainment of learning goals which are beyond traditional and other computer-based instructional methods (Thomas & Hooper, 1991).

Simulations existed long before computers were invented, but the two media have been associated ever since computers came onto the scene (Crookall, 1988). First, computers were appended to simulation, mainly as number crunchers. Then, in the late 1970s, simulations were designed explicitly for the computer; their shape was determined by the capabilities of the computer. More recently, especially with the advent of the flexible microcomputer (e.g., PCs), there has been a movement back to using the computer more as a peripheral aid, as one among a number of components, in simulation.

Simulations and computers have had a mutually beneficial effect. There is little doubt that the advent of the microcomputer has conferred a greater legitimacy upon, and promoted a more widespread use of simulation. This is not to say that computers determine, or should determine, simulation characteristics; rather, it is an indirect commentary on the fact that just as other educational media (e.g., paper, video) have their limitations, so do the computers. One might say that simulation has

come to the rescue of computer use in the classroom (Crookall, 1988).

Classroom uses of the computer generally fall into one of three categories. Computers have been used as a direct means of instruction. This use of the computer is often referred to as Computer Assisted Instruction (CAI). A broad range of courses have been programmed for CAI. Schwarz, Kromhout, and Edwards (1969), Hansen, Dick, and Lippert (1968), and Bork and Luehrmann (1968) describe physics programs. Chemistry programs are described by Boblick (1972), Castleberry and Lagowski (1970), and Dannhauser (1970). Other areas include mathematics and Russian described by Suppes and Morningstar (1968), reading by Atkinson and Hansen (1966), and statistics by Grubb and Selfridge (1964). The most widespread use of the computer in secondary schools has been as a calculation tool and an aid for solving classroom questions and problems. Articles related to this use of the computer have been reported by Blum and Bork (1969), Ahl and Bailey (1971), Schwarz (1969), and Hughes (1970). A third use of the computer is when it is used as a device for Computer Simulated Experimentation (CSE).

Computers can be used to simulate laboratory situations. An experimental situation can be represented by a set of questions programmed into the computer. The student enters a set of initial values. The computer generates data like that the student would have collected in a laboratory experiment. The simulation program can be written so that the data generated by the computer reflects uncertainties corresponding to the experimental errors. The magnitude of these uncertainties can be varied from trial to trial through the use of the computer's random number

generator.

The student activities in conducting a Computer Simulated Experiment are similar to those involved when conducting an actual experiment. Both investigations are started by asking pertinent questions about the situation. An experiment is then designed that permits the student to answer his/her original question.

In a laboratory experiment, the student would manipulate the laboratory experiment or apparatus to obtain the data required. In a Computer Simulated Experiment, the student would manipulate the input and output data through the use of a computer terminal. Once the data are obtained, whether by laboratory equipment or by computer, the objective is to determine relationships from the data by curve plotting and data analysis (Hughes, 1974).

Bushnell and Allen (1967) suggested that computer simulation offers many advantages over natural events in that simulation brings a sense of immediacy to the learning task and challenges the student to participate more actively. Boblick (1970) stated that computer simulations of laboratory environments will enable the physics student to experiment with environments which are unattainable in any other form. Showalter (1970) suggested that computer simulations offer a medium for educational research into the problems associated with how individuals learn to inquire and how their strategies of inquiry develop and change. Craig, Sheretz, Carlton and Ackerman (1971) state that computer simulation provides a student with a richer experience in data interpretation and hypothesis making.

There is evidence to suggest that the instructional potential of laboratory

simulations is substantial (Hughes, 1974).

This study is directed towards providing data to permit an evaluation of the effectiveness of computer simulated laboratory instruction versus traditional laboratory instruction in solid state electronics circuitry.

### **Statement of the Problem**

This study was designed to compare and evaluate the effectiveness of computer simulated laboratory instruction versus traditional laboratory instruction (utilizing actual electronics components) for educating college students about solid state electronics circuitry.

### **Objectives of the Study**

The objectives of this study were to:

1. Compare the achievement levels of college students who are receiving the computer simulated laboratory instruction with students who are receiving the traditional form of laboratory instruction.
2. Evaluate the effectiveness of computer simulated laboratory instruction in educating college students in solid state electronics circuitry.
3. Compare which instructional method helps students to better understand the underlying applied concepts of solid state electronics circuitry.
4. Evaluate the effectiveness of comparative results between computer simulated laboratory instruction and the traditional method by means of a pretest and a posttest differential.

5. Assess the students' attitude toward computer simulation as a mode of instruction as opposed to the traditional laboratory approach.

### **Questions of the Study**

This study seeks answers to the following questions:

Question I: Will there be a significant difference between the pretest mean scores of the experimental and control groups?

Question II: Will there be a significant difference between the pretest and posttest II mean scores of the experimental and control groups?

Question III: Will there be a significant difference between the posttest I and posttest II mean scores of the experimental and control groups?

Question IV: Will there be a significant difference between the posttest II and posttest III mean scores of the experimental and control groups?

Question V: Will there be a significant difference between the pretest and posttest III mean scores of the experimental and control groups?

Question VI: Will there be a significant difference between the combined pretests and the combined posttest III mean scores of the experimental and control groups?

Question VII: Will there be a significant difference between the pretest, student attitude mean scores of the experimental and control groups?

Question VIII: Will computer simulated laboratory instruction affect the students' attitude toward: a) computer simulated instruction? b) traditional method of instruction?

### **Assumptions of the Study**

This study was based upon the following assumptions:

1. Students were normally and independently distributed in both the experimental and control groups with respect to ability in computer simulated laboratory work and traditional laboratory work.
2. The effect of the teacher was approximately the same on the experimental and the control groups.
3. The presence of experimental and control groups in the same class had no differential effect on either group.
4. The experimental set up during the entire study did not differ in any manner, thus not affecting the experiment.
5. No interaction (social, academic, or otherwise) occurred among students outside of the experimental setting which affected the results of the study.

### **Delimitations of the Study**

The participating classes of this study were limited to those students who enrolled in IEDT 240 Fundamentals of Electronics class during the spring semester of the 1992 school year at Iowa State University, Department of Industrial Education and Technology.

The study was limited also to the selected existing software.

The experimental units for this study were limited to four circuits.

These included:

1. RC circuit (low-pass filter)

2. RC circuit (high-pass filter)
3. Operational amplifier integrator (low-pass filter)
4. Operational amplifier differentiator (high-pass filter)

### **Procedures of the Study**

The procedure of the study consisted of the following:

1. Formulating the problem.
2. Reviewing related literature concerning computer simulated instruction.
3. Identifying the population and samples for the study.
4. Developing and refining pretest and posttest instruments.
5. Administering the pretest.
6. Implementing instruction.
7. Administering the posttest.
8. Gathering research data.
9. Analyzing the data through the SAS or SPSS package.
10. Interpreting the findings.
11. Writing the summaries, conclusions, and recommendations.

### **Definition of Terms**

**Advance organizer:** The introductory material that activated existing cognitive structures in order to facilitate the assimilation of new information. Advance organizers lay the foundation for concept learning by providing a framework for the student to use when integrating new information with old.

**Breadboarding:** The term breadboarding refers to the process of installing components on a circuit board and interconnecting them to form a specified circuit (Floyd, 1991).

**Computer-assisted instruction (CAI):** Use of the computer as an aid in a classroom setting to enhance student learning.

**Concept:** A specific set of objects, symbols, or events which share common characteristics and can be referred to by a particular word or symbol.

**Discovery learning:** Instructional process that places responsibility for finding information or problem solutions on the learner. The learner must use investigative procedures to obtain information.

**Experiencing program:** Computer program used prior to traditional instruction to set the cognitive or affective stage for learning.

**Experimental treatment:** The computer simulated laboratory instruction used in this study as an independent variable.

**Meaningful learning:** Process in which the learner relates new information to previously acquired knowledge.

**Probe:** The graphical waveform analyzer used to view and manipulate PSpice simulation results.

**PSpice:** The analog and mixed analog/digital circuit simulator.

**Schema:** The components of long term memory activated during learning.

**Simulation:** Simulation is a representation of a system by a device that imitates the behavior of that system.

**SPICE**: Stands for Simulation Program with Integrated Circuit Emphasis.

**Traditional treatment**: Actual laboratory equipment and electronics components (breadboarding) used in this study as an independent variable.

## **CHAPTER II. REVIEW OF LITERATURE**

This chapter focuses upon the following sections: (1) History of Computers in Education; (2) Current Uses of Computers in Education; (3) A Taxonomy of Educational Software; (4) Computer Simulations; and (5) Summary.

### **History of Computers in Education**

Computer assisted instruction basic methods and vocabulary appeared early in the 1960s during a period of time in which educators were using mainframe computers to conduct research and do their projects. It was during this period of time that the computer's potential as an educational tool was noticed, however, inaccessibility and cost prevented adoption on a wide scale (Berg & Bramble, 1983).

In approximately 1977, microcomputers were introduced in schools. Public schools began to purchase microcomputers for educational purposes as they were inexpensive as well as powerful. Three phases of educational computing are proposed by Berg and Bramble (1983). The experimental phase of the 1960s was the first of these phases. The second phase proposed was the popularization phase which began with microcomputers in 1977. This phase is characterized by the low level educational use of computers. Schools purchased computers and teachers received inservice education about the computers. The third phase proposed by Berg and Bramble was the transition phase which began in the mid-1980s. It is during this phase that educators have had the opportunity to improve and transform public education through technology. The transformation was predicted to take place

through less costly, but more powerful microcomputers, digitalized voice, high quality classroom management software, and more sophisticated instructional software.

### **Current Uses of Computers in Education**

Currently instructional software is most commonly classified in one of four categories. The first of these categories is drill and practice. When using drill and practice software, the computer provides the students a series of questions to respond to, immediate feedback is given, and a summary of performance is given.

The second classification of software used in instruction is tutorial. Tutorial software presents instructional material and asks the user appropriate questions over the material. Tutorial software branches to new material or remediation depending on the student's responses to the questions.

The third category of instructional software is problem solving. Problem solving software allows the user to solve specific problems. It provides answers to problems and/or performs calculations. Problem solving software can perform statistical calculations such as t-scores on data.

Simulation software is the fourth classification of educational software being used currently. This type of software places the student in a simulated realistic setting. Simulation software may teach a student to fly a plane or drive a car as well as other psychomotor and academic skills. When utilizing simulation software, a student is confronted by situations that require active participation in initiating and carrying through a sequence of inquiries, decisions, and actions (McGuire, 1976). In assessing the educational importance of simulations in computer-based instruction

Crookall (1988) stated, "One might say simulation has come to the rescue of computer use in the classroom" (p. 3).

Taylor (1980), proposes another classification scheme which allows an instructional computing view based on the learner's association with the computer rather than the software characteristics. In Taylor's classification scheme, the computer is used as a tutor, tool, or tutee. The computer presents information and reacts to feedback from the learner as a tutor. As a tool, the computer performs a function for the user such as database management or word processing. The computer is programmed by the learner in its role as a tutee.

### **A Taxonomy of Education Software**

Several taxonomies of educational computing have been suggested, similar to the above classification systems. Thomas and Boysen (1984) believe the traditional classification schemes, such as the ones listed above, have major deficiencies. They do not provide guidance on how a particular application should be used in the educational setting, nor do they focus the teacher's attention on a student's weakness. They have developed a classification scheme to focus on the needs of the learner. It provides guidance for the development of lessons and their instructional use and facilitates the design and communication of research studies. The classification places the focus on the students. Their taxonomy for the instructional use of computers consists of the following five categories:

1. **Experiencing**—sets the cognitive and affective stages for future meaningful learning.

2. Informing—provides new information to the learner.
3. Reinforcing—develops mastery of new information.
4. Integrating—new material is associated with existing long term memory via meaningful learning.
5. Utilizing—using the computer as a tool to perform a task.

Each category of the taxonomy represents a step in the learning process with experiencing being the first step and utilizing being the last (Thomas & Boysen, 1984). If the learner uses the program prior to learning to set the stage for learning, the program is said to be an experiencing program. If the program is used to acquire information, it is said to be an informing program. Informing and reinforcing applications are usually computer-directed. Experiencing applications are learner-directed as are integrating and utilizing applications. It is through these type of applications that the highest levels of learning and computer literacy are achieved, and the greatest degree of teacher competence and deepest philosophy are required (Thomas & Boysen, 1984).

### Experiencing

Experiencing programs are used to set the cognitive or affective stage for future learning. Use of these programs precedes the formal presentation of the material to be learned. Simulations are ideally suited for this purpose. They encompass a model of a concept, subject area, or situation which the student can manipulate in order to gain an intuitive understanding of the learning goal.

Experiencing programs can be used to: (a) provide motivation, (b) provide an

organizing structure, (c) serve as a concrete example, or (d) expose misconceptions and areas of knowledge deficiency (Thomas & Hooper, 1991).

Hooper (1986) investigated a simulation of computer memory operations. In this simulation, students performed specified tasks on the model as an initial experience in a beginning programming course. The simulation was designed to operate just as a generalized version of computer memory does, but with a much slower speed (of course) and a graphic display giving the user a "window" into each memory cell's contents. The use of the simulation helped students concentrate only on computer memory operations, without other programming variables being involved. Hooper (1986) reported that students using the simulation employed more sophisticated algorithms during their programming than did students who were not exposed to the model.

In a study to determine the appropriate sequential placement of a simulation on genetics, Brant, Hooper, and Sugrue (1991) compared three groups of students. One group used the simulation prior to the lecture on genetics, one after the lecture and one group did not use the simulation until after the test. The group using the simulation prior to the lecture scored significantly higher than the control group. Those using the simulation after the lecture scored only slightly better than the control group. In a follow-up experiment involving only two groups, the before group scored significantly better than the after group. The test questions involved moderate transfer of the material covered in the lecture. A post hoc analysis of questions on a unit test over the material showed no group differences. These questions required

recall and direct application of the material taught.

In a study in which simulation was used at different times during the semester was reported by Taylor (1987). In Taylor's study, one group of students enrolled in a university sociology course in which one group used the simulation early in the semester and the other used it later. Three tests were given which revealed no differences. However, students who used the simulation early in the course had a more favorable attitude toward the simulation and its value as an instructional method.

Thomas and Hooper (1991) concluded that the above studies provided evidence that experiencing simulations can be an effective learning aid. However, care must be taken in their evaluation and use. The Hooper, Hooper and Thomas, and Brant, Hooper, and Sugrue studies indicated that the effects of experiencing simulations do not appear on the tests of knowledge but do appear on the tests of application and transfer.

### Informing

Informing programs are used to transmit information to the student. These programs supplement or replace the textbook and lecture as a means of initial formal exposure to a topic. Although simulations are sometimes used for this function, more common formats are tutorial, demonstration, inquiry, and dialog (Thomas & Hooper, 1991).

Emery and Enger (1972), in a study in economics, compared a lecture-recitation group with a group which used a simulation and question sheet. In this

study the simulation was found to improve performance on analysis questions but did not affect performance on questions measuring recognition and understanding. The author suggested that students who received the simulation but missed the lecture may have spent extra time reading the textbook. Thomas and Hooper (1991) concluded that if this were the case, the simulation would have served an experiencing rather than an informing function.

Choi and Gennaro (1987) reported a comparison between computer simulations and physical laboratories in science courses. They compared three groups of eighth grade students. One group used computer simulations while another used laboratory apparatus to study Archimedes' Principle. Following the treatments, the groups jointly participated in a ten minute discussion of the principle. A third group, the control group, received no treatment. Both treatment groups performed better than the control group, but no differences were found between the treatment groups. In both treatment groups, males scored higher than females; however, the authors report that males may have been better served by the laboratory while females may have been better served by the computer.

In another study, Baird and Koballa (1988) combined simulation with cooperative learning using four groups of preservice teachers trained in hypothesis formation and testing. Two groups practiced cooperative learning and two worked on an individual basis. One cooperative learning group and one group of individual learners worked with two commercial simulations in which the participants formed and tested hypotheses to solve the problems. The other two groups worked with

computer delivered text containing multiple choice questions. The experiment preceded for all students by a discussion of hypotheses and followed by a test. No differences were found between the treatments; however, students with high formal reasoning ability scored higher in non-computer, non-cooperative situations.

Baird (1986) summarized research in which the teacher supplemented a simulation used with eighth grade students. The simulation was used as the primary means of instruction while the teacher assumed one of two supporting roles. In one role, the teacher provided Socratic questioning, whereas in the other role, the teacher provided only minimal technical assistance. No differences in measures of performance on a posttest were found as both groups scored "low."

In another study by Mills, Amend and Sebert (1985) simulation was used to transmit information. In this study, the simulation was a classroom display unit which showed the results of cooperatively developed water management strategies. Students using the simulation were compared to a non-treatment control group on knowledge and attitude related to water management. Users of the simulation showed more overall knowledge, while no differences in attitude were observed. However, more users of the simulation erroneously believed that nature would solve water supply problems before they became serious. From this study, Thomas and Hooper (1991) concluded that since simulations do not direct the student to explore all facets of a topic and do not provide specific feedback on student responses, misconceptions and learning voids of this type should be expected.

Alperson and O'Neil (1990) compared computer based tutorials with

simulations for transmitting knowledge in beginning anthropology and psychology courses. The comparisons were based on multiple choice tests and student perceptions of the value of the lessons. In both cases, the tutorials produced higher achievement scores and more favorable student comments than did the simulations.

Based on the above studies Thomas and Hooper (1991) reported that when a simulation compares favorably with other more direct methods of instruction in transmitting information, the results make a stronger statement about the weakness of the other methods rather than the strength of the simulation.

### Reinforcing

A program is classified as reinforcing if the knowledge is applied in the same context in which it was learned. Students use reinforcing programs to strengthen specific learning objectives. The most common format for a reinforcing program is drill and practice in which a sequence of stored or generated exercises is presented for the student to be completed. These programs can be designed to adjust to the knowledge level of the student and to track the student's progress (Thomas & Hooper 1991).

Munro, Fehling and Towne (1985) investigated the disruptive effect of feedback on student learning. They compared two methods of feedback on simulated problems of tactical air control. One method provided students a message every time they made an error. The other method announced a waiting message which the student could receive on request. The second method was designed to be less disruptive to the thinking process. The students were given the same initial training.

The group which was interrupted (intrusive instruction) made more total errors and more non-crucial errors but not more crucial errors. This indicated that the students receiving the intrusive treatment were able to distinguish between important and less important situations but may have been overloaded by the feedback and, as a consequence, lost some of the details. On the basis of this study, the authors advocate non-disruptive feedback for complex simulations and for simulations in which the performance defect cannot be easily detected by the students.

Rivers and Vockell (1987) investigated the use of support materials with simulations to stimulate scientific problem solving. A series of science simulations was used in three different studies. Each study consisted of three groups: (a) traditional instruction, (b) simulation with study guide and support materials, and (c) simulation that contained in their introduction a set of strategies to use in solving the simulations. No significant differences were found on unit posttests covering the content of the course. Differences were found on improvement of general problem solving skills, in which guided discovery was superior and discovery was better than the traditional instruction. In this case, the assistance was provided before the simulation was used rather than during the process of the simulation. According to Thomas and Hooper (1991), this simulation falls into two categories: a reinforcing lesson for course content and an integrating lesson for problem solving skills.

In another study, Woodward, Carnine, and Gersten (1988) supported a simulation within teacher supervision and guidance. Their study involved the use of a simulation by learning about disabled students in a unit of health. Over a twelve day

period, students received classroom instruction for twenty minutes and then were separated into two treatment groups. One group received traditional enrichment and application activities while the other group was instructed by a simulation game. Although the simulation work was individual, the work was observed and critiqued by a teacher. The students experiencing simulation performed somewhat better on recall and understanding of facts and concepts and considerably better on application of problem solving steps.

Based on the above studies Thomas and Hooper (1991) reported that simulation may be useful for reinforcing complex sequences. In using these simulations the learner is forced to assume responsibility for executing the process whereas in the alternative methods the learner responds to external questions or instructions. This distinction may explain the improved performance on higher level objectives. Although reinforcing simulations were perceived to be useful, they were not perceived as being adequate. In most cases the investigators supplemented the simulations by embedding tutorial segments or providing support materials. Advanced instruction involving the steps required to solve the simulation, nondisruptive feedback, and teacher guidance were found to enhance the simulation as a learning aid.

### Integrating

Isolated facts, concepts and principles are usually of little practical value to the student. These pieces of knowledge must be integrated into functional units and assimilated with other units in order to be useful. Integrating programs are designed

to aid the student in making the necessary assimilations. They are appropriately used in any situation where several knowledge elements have been learned independently and need to be applied collectively. Integrating simulations are used to promote organization and reorganization of learned material. From this process the learner is expected to develop new and more meaningful associations among elements that have been learned (Thomas & Hooper 1991).

In an investigation by Boysen, Thomas, and Mortenson (1979), a simulation of reading skill weaknesses was used with preservice teachers. Two classes of elementary education majors received traditional classroom instruction on administering an informal reading inventory to diagnose children's reading weaknesses. The students were randomly divided into two groups. One used a simulation in which they diagnosed simulated children's reading weaknesses. A second group received no formal integrating instruction. Significant differences were found on a sixteen item test of analysis and procedure questions favoring the simulation group. The second group then used the simulation and a second posttest revealed no significant differences. Although the simulation required several selections and decisions to be made, explicit feedback was not provided until a case had been completely diagnosed.

To improve knowledge application by medical students in computer-based clinical simulation, Krahn and Blanchaer (1986) provided students with a review, stated in general terms, of the information needed to diagnose a problem. This study compared two versions of the same simulation. The only difference between the

versions was an introduction in which the simulation was briefly described and information was provided that the student needed to use in solving the simulated case. Even though all students should have known this information, students receiving the introduction were more successful at diagnosing the problem and were more successful on analysis questions contained in the posttest.

In a study of simulated experiments in physics, Hughes (1974) combined simulation with actual lab experience to maximize the results. Three groups of students were compared. The first group used physics laboratory equipment. The second group used equipment to collect one set of data and used a computer simulation to control variables and collect the rest of the data. The final group used only the computer to generate the data for analysis. The laboratory-computer group was more successful on most measures. Using the lab to understand the problem and using the computer to produce the data was the most effective treatment.

In order to determine the practical value of a simulation, Diedrick and Thomas (1977) evaluated a computer simulation for teaching diagnosis of secondary ignition problems using job performance as the criteria. Students were given classroom instruction on the fundamentals of ignition systems and oscilloscope usage. One group used a computer simulation to diagnose problems while the other group received classroom lecture and demonstration and was given a reading assignment covering the material. Both groups were then assigned to diagnose problems in actual automobiles in which defective parts had been installed. The computer simulation class performed significantly better.

The use of integrating simulations seems to be most prevalent for the acquisition of diagnostic skills. In these studies, the students first learned the required factual information and principles and then used the simulations to relate and apply that knowledge. The effects of the simulations were revealed by questions requiring the student to apply the process or in the actual physical application of it. Questions about the process or specific facts needed to correctly apply the process did not reveal differences. Unlike the research on simulations used for reinforcing, the research on integrating simulations contains few instances in which the simulation was modified to enhance its effectiveness (Thomas & Hooper 1991).

### **Computer Simulations**

The purpose of a simulation is to recreate various events, devices, or phenomena via computers. A computer simulation can provide to students a scientific experience that might otherwise be considered too expensive, too dangerous, too time-consuming to undertake, or simply impractical. Simulations take advantage of one of the powerful features of the computer--its ability to be interactive. When the student makes a choice or decision within a simulation, the computer generates a response based upon that choice. In a well-designed simulation, the response closely approximates what might happen in real life. Simulations require the student to build a mental model of a process or event. He or she can then see how that process or event is altered by making different choices (Alessi & Trollip 1985). A well-designed computer simulation can allow the science teacher to conserve expensive equipment and materials while still teaching the concept or procedure. Another

advantage in simulations is that students' mistakes or errors are more easily rectified: if a mistake is made, the simulation is generally salvageable, unlike in real experiments where one error can ruin the entire project. Also, it is usually somewhat easier to control variables in a computer simulation than in an actual laboratory experiment, where the risk of contamination from outside factors constantly looms. Finally, a computer simulation can provide a sound basis for further experiments (Weaver, 1986).

An excellent way for students to use computer simulations is by assigning them to work in cooperative learning groups. Based upon the work of Roger Johnson and David Johnson (1985) of the University of Minnesota, cooperative learning has received increasing attention recently for its potential to allow students to learn from each other and to learn group process skills. The key to cooperative learning is "positive interdependence," students working together toward mutual goals in such a way that the labor is shared and members of the group must depend upon each other. Such skills as leadership, conflict resolution, and decision making are taught and practiced in a cooperative learning situation (Langhorne, Donham, Gross, & Rehmke, 1989).

### **Summary**

Over the past few years computer simulations have become more popular in the classroom. They have been proven to be safe, economical, and perhaps most importantly, have shown the ability to stretch or compress time according to student's needs (Carlson, 1989). Several researchers, including Hartley (1988), stressed the

importance of being able to use the simulations to simplify the design of a physical system by "stripping off extraneous or elaborate features while still retaining validity. Hence, students are able to focus on the main attributes of the model" (p 60).

In order for simulations to be the most effective, the student must be able to use them at the proper time in her/his training. According to Thomas and Boysen (1984), computer based instruction can be used effectively to help lay a foundation for proper student schemas prior to formal classroom instruction on a concept. In the above authors' view, a model of the concept should be introduced, usually by means of a computer simulation, and the student should be guided through sets of problems with the specific goals of the formal instruction in mind. All this is done with the simulation before the student receives the formal classroom instruction. This "pre-instruction" helps the student gain an intuitive feel for the concept, thus building a cognitive framework for the formal instruction. Thomas and Boysen (1984) emphasize that this kind of simulation is rarely "stand alone" and should be used as a foundation of the instruction to follow.

The review of the literature enabled the researcher to become familiar with the research results of previous studies, the varied applications of simulation instruction, the research design employed by previous researchers, and some insights into the limitations of the use of simulation.

### **CHAPTER III. METHODS AND PROCEDURES**

The main objective of this chapter is to provide a description of the methods and procedures used to conduct this study.

The following sections are included in this chapter: 1) Subjects; 2) Instruments; 3) Simulation Program; 4) Research Procedures; 5) Variables of the Study; 6) Classroom Procedures; 7) Laboratory Procedures; 8) Data Collection Procedures; 9) Hypotheses and Statistical Methods; and 10) Statistical Analysis of Data.

#### **Subjects**

Human subjects were involved in this study. As a result, the Human Subjects Committee at Iowa State University was consulted prior to conducting the study. A copy of the human subjects form approved by the committee can be found in Appendix A.

Each subject in the study signed a consent form. This document explained the purpose of the study, the procedures involved, and explanation to the subject that the subject was free to withdraw at any time without prejudice to him or her. A copy of the consent form can be found in Appendix B.

The population of this study consisted of undergraduate students who enrolled in IEDT 240A and 240B Fundamentals of Electronics class during the Spring semester of the 1992 school year at Iowa State University, Department of Industrial Education and Technology. All of the students had taken at least one class in Basic

Electronics. A total of twenty nine subjects participated in this study. One subject was eliminated from this study by the researcher because he failed to participate in the required laboratory experiments.

### **Instruments**

A total of six measuring instruments were used to collect data in this study:

1) pretest; 2) posttest I; 3) posttest II; 4) posttest III; 5) pretest student attitude questionnaire; and 6) posttest student attitude questionnaire.

#### **Pretest**

This pretest instrument was developed by the author. The pretest was administered during the first meeting before the teaching began. The pretest was a paper-and pencil test which consisted of forty multiple choice items, ten items for each experimental circuit. This test was designed to be used as a covariate to control for initial differences in the students' background and knowledge of electronics, and their ability to evaluate, compute, and analyze the responses to the test questions. The pretest items were selected from the tests and quizzes given to IEDT 140 and IEDT 240 students in previous semesters. The KR-20 reliability estimate of those tests and quizzes ranged from 0.73 to 0.79.

The test was administered to twenty-nine undergraduate students who enrolled in IEDT 240A and 240B Fundamentals of Electronics class during the Spring semester of the 1992 school year at Iowa State University, Department of Industrial Education and Technology. Scores on the pretest ranged from 7 to 27 out of a total

Table 1. Item analysis for pretest

Pretest	No. Items	Mean	S.D.	KR#20
1	40	16.76	4.93	0.67

of 40 possible, with the mean score of 16.76 (Table 1). The KR-20 reliability estimate of this test was 0.67. A copy of the pretest can be found in Appendix D.

#### Posttest I

After two weeks of the experiments, a twenty item posttest I was administered to all subjects. The test items were identical to the first twenty items of the pretest. Scores on the posttest I ranged from 8 to 20 out of a total of 20 possible, with the mean score of 13.21 (Table 2). The KR-20 reliability estimate of this test was 0.56.

Table 2. Item analysis for posttest I

Posttest I	No. Items	Mean	S.D.	KR#20
1	40	13.21	2.82	0.56

#### Posttest II

After two more weeks of the experiments, a twenty item posttest II was administered to all subjects. The test items were identical to the last twenty items of

the pretest. Scores on the posttest II ranged from 4 to 19 out of a total of 20 possible, with the mean score of 13.48 (Table 3). The KR-20 reliability estimate of this test was 0.79.

### Posttest III

This posttest III instrument was also developed by the author. The posttest III was conducted at the end of the study. The posttest III was a paper-and pencil test which consisted of forty multiple choice items, ten items for each experimental circuit. This test was similar in content to the pretest. The test was administered to twenty nine undergraduate students who enrolled in IEDT 240A and 240B Fundamentals of Electronics class during the spring semester of the 1992 school year at Iowa State University, Department of Industrial Education and Technology. Scores on the posttest III ranged from 15 to 37 out of a total of 40 possible, with the mean score of 28.59 (Table 4). The KR-20 reliability estimate of this test was 0.77. A copy of the posttest III can be found in Appendix D.

Table 3. Item analysis for posttest II

Posttest II	No. Items	Mean	S.D.	KR#20
1	20	13.48	3.94	0.79

Table 4. Item analysis for posttest III

Posttest III	No. Items	Mean	S.D.	KR#20
1	40	28.59	5.08	0.77

#### Pretest student attitude questionnaire

The pretest student attitude questionnaire was administered to both the experimental and control groups during the first meeting before the instruction began. This test was designed to be used as a covariate to control for initial differences in the students' attitude toward the computer simulated laboratory instruction and the traditional method of laboratory instruction. This questionnaire originally was developed by Bobby R. Brown at Pennsylvania State University (Mitzel & Brandon, 1966). Brown constructed his forty item questionnaire mainly on the basis of written comments of students and observations of students who had used Computer-Assisted Instruction as a part of their coursework, and he reports the KR-20 reliability of the instrument as 0.885 (Mitzel & Brandon, 1966, p. 101).

Kockler (1972) modified the questionnaire and omitted 15 questions which were inappropriate for her investigation. The form of the questionnaire used in this study contains twenty four item from Brown's questionnaire and three items, numbers 5, 6, and 8, from Kockler. The researcher modified this questionnaire by changing the term computer-assisted instruction to computer simulated laboratory instruction.

This test consists of twenty-seven items, ten of which are positively worded and seventeen negatively worded (Table 5). The items used a Likert scale with five responses from "strongly disagree" to "strongly agree". The reliability coefficient (Alpha) of this test was 0.822. A copy of the pretest student attitude questionnaire can be found in Appendix E.

Table 5. Lists of positive and negative items

Type Statement	Item Number	Total
Negative	1, 3, 4, 5, 9, 11, 12, 14, 15, 16, 18, 19, 20, 24, 25, 26, 27	17
Positive	2, 6, 7, 8, 10, 13, 17, 21, 22, 23	10
Total		27

#### Posttest student attitude questionnaire

This posttest was administered to both the experimental and control group at the end of the study. This test was similar in content to the pretest student attitude questionnaire with some appropriate changes in the wording, such as the tense. The reliability coefficient (Alpha) of this test was 0.77. A copy of the posttest student attitude questionnaire can be found in Appendix F.

#### **Simulation Program**

The computer simulation program that was used in this study is a schematics capture program called Schematics (the Evaluation version of the 5.1 release of The

Design Center) distributed by the MicroSim Corporation.

Schematics was designed and written as a native Windows 3.0 application for the PC (see Figure 1). It runs in either Standard or 386 Enhanced Mode. The program requires 3 megabytes of extended memory; however, 4 megabytes of extended memory is recommended by MicroSim Corporation.

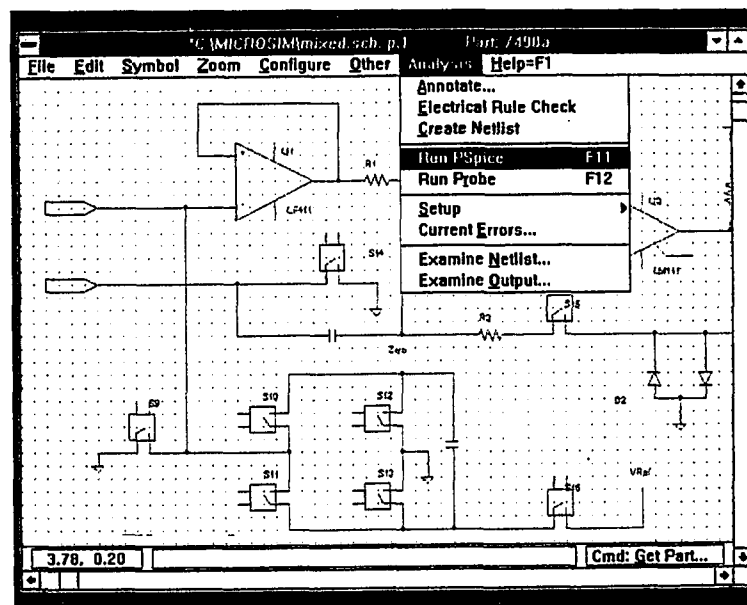


Figure 1. Schematic capture on Windows 3.0  
(MicroSim Corporation flyer, 1992)

Schematics is a schematic capture program with a direct interface to the PSpice circuit simulator and the Probe waveform analyzer. Schematics' editing capability provides a simple way to create and edit circuit diagram, as well as create new parts. This integrated system provides a complete environment for designing and

using Probe, all can be run without leaving the Schematics environment.

An integrated symbol editor encompasses full editing capability, allowing the user to create new symbols and define new part attributes while working on a circuit diagram.

Schematics provides pull-down menus and dialog boxes for specifying analysis parameters and running simulations directly from the schematic. There is no need to exit the system and invoke another software package to perform a circuit analysis. If device simulation parameters need adjustment after a simulation is run, they can be easily modified and the simulation rerun. Netlists for PSpice are generated automatically and can be examined on the screen. The electrical rule checker inspects the electrical connections on the schematic before the simulation is run. Probe may also be activated through the Schematics environment. Schematic pins and net name are used instead of arbitrary node numbers.

PSpice and its options form an integrated package for analyzing electronic and electrical circuits. That is, PSpice will calculate a circuit's voltages and currents and, in some cases, derived quantities such as group delay. Think of PSpice as a "software breadboard." You can perform the same measurements that you would do with an actual circuit and many others that would not be feasible with a breadboard.

Probe is the waveform analyzer for PSpice. Using high-resolution graphics, Probe allows you to view the results of a simulation both on the screen and on hard copy. In effect, Probe is a "software oscilloscope." Running PSpice corresponds to building or changing a breadboard, and running Probe corresponds to looking at the

breadboard with an oscilloscope (MicroSim Corporation, 1992).

Pspice is one of the many commercial derivatives of University of California Berkeley SPICE. Pspice was the first SPICE-derived circuit simulator available on the IBM personal computer, and was introduced when the IBM-PC was only 29 months old. Pspice is seven years old, with over 14,000 professional versions in use (Tuinenga, 1992).

### **Research Procedures**

This study used an experimental design in order to determine the effects of the independent variables on the dependent variables. This type of design involves comparisons between and among groups to which subjects have been randomly assigned (Mason & Bramble, 1978). Random assignments were used to establish equivalency between the two groups in the study.

The pretest-posttest control group design was used in the experiment. This design is schematically presented as the following:

Group I	R	O <sub>1</sub>	T	O <sub>2</sub>	S	O <sub>3</sub>	O <sub>4</sub>
Group II	R	O <sub>1</sub>	S	O <sub>2</sub>	T	O <sub>3</sub>	O <sub>4</sub>

R stands for random assignment of subjects.

O stands for observation, O<sub>1</sub> is the pretest, O<sub>2</sub>, O<sub>3</sub>, and O<sub>4</sub> are posttests.

S stands for experimental treatment.

T stands for traditional treatment.

In this study, the researcher randomly assigned subjects to particular groups. The experimental group received the pretest, experimental treatment, posttest I, traditional treatment, posttest II, and the posttests, while the control group received the pretest, traditional treatment, posttest I, experimental treatment, posttest II, and the posttests. The experimental design used in this study is shown in Figure 2.

### **Variables of the Study**

#### **Independent variables:**

The following independent variables were studied:

1. Computer simulated laboratory instruction.
2. Traditional laboratory instruction.

#### **Dependent variables:**

The following dependent variables were studied:

1. Posttest I, Posttest II, and Posttest III scores.
2. Posttest Attitude score.

#### **Covariates:**

The following covariates were studied:

1. Pretest score.
2. Pretest attitude score.

### **Classroom Procedures**

Both the experimental and control groups received theoretical instruction together from the same instructor. Both the experimental and control groups also received the same in-class quizzes and homework problems.

Group #1 (N1 = 14)		Group #2 (N2 = 14)	
Pretest			
Control Group #1		Experimental Group #1	
Traditional Method Instructor #1 Week #1 Meeting #1 (n1=7) Meeting #2 (n3=7)		Computer Simulation Method Instructor #2 Week #1 Meeting #1 (n2=7) Meeting #2 (n4=7)	
Traditional Method Instructor #2 Week #2 Meeting #1 (n1=7) Meeting #2 (n3=7)		Computer Simulation Method Instructor #1 Week #2 Meeting #1 (n2=7) Meeting #2 (n4=7)	
Posttest I			
Experimental Group #2		Control Group #2	
Computer Simulation Method Instructor #1 Week #3 Meeting #1 (n1=7) Meeting #2 (n3=7)		Traditional Method Instructor #2 Week #3 Meeting #1 (n2=7) Meeting #2 (n4=7)	
Computer Simulation Method Instructor #2 Week #4 Meeting #1 (n1=7) Meeting #2 (n3=7)		Traditional Method Instructor #1 Week #4 Meeting #1 (n2=7) Meeting #2 (n4=7)	
Posttest II			
Posttest III			

Figure 2. Experimental design

### **Laboratory Procedures**

In order to become familiar with the use of computer and software simulation, all the subjects had three weeks of computer simulated laboratory activity before this study began. A copy of the documentation for the computer simulation program as well as use of the computer can be found in Appendix G.

Both the experimental and control groups were supervised by different laboratory instructors at different times and locations.

The treatment (experimental) group used the computer simulation as means of conducting laboratory experiments. Students were provided instructions on the use of the computer, both through demonstration and in a written format. Students were monitored by the researcher during the computer simulation activities. The assistance given to students during laboratory activity consisted of instruction on the use of the computer, software simulation program, and step by step written laboratory procedures. The experimental group obtained its data from computer simulation. A copy of the computer simulated laboratory experiment can be found in Appendix H.

The control group used the traditional breadboarding (use of actual components) as laboratory experiments. The assistance given to students during laboratory activity consisted of instruction on the use of various equipment, components, and step by step written laboratory procedures. A copy of the traditional laboratory experiment can be found in Appendix I.

In a typical laboratory session, the instructor would first briefly review the objectives or the experiment plan and comment on special problems or safety precautions.

### **Data Collection Procedures**

At the beginning of the study, the general information sheet was administered in order to gather demographic information on each subject. At this time they were told that they would be participating in an experimental study involving the computer simulation and were requested to respond to the pretest student attitude questionnaire. Prior to instruction a paper and pencil pretest which consisted of forty multiple choice items was administered to all subjects to assess students background and knowledge of electronics, and their ability to analyze, compute, and evaluate the responses to the test questions.

After completion of the pretest and the student attitude pretest questionnaire, the subjects were randomly assigned to one of two groups, the experimental treatment group or the control treatment group (traditional treatment group).

After two weeks of experiments, a twenty item posttest I was administered to all subjects to measure treatment effects. The test items were identical to the first twenty items of the pretest. Then the experimental group switched with the control group (see experimental design on page 42).

After two more weeks of experiments, a twenty item posttest II was administered to all subjects to measure treatment effects. The test items were identical to the last twenty items of the pretest.

At the conclusion of the study, two posttests were administered to all subjects. The first was posttest III which was used to measure treatment effects. This test was similar in content to the pretest. The second was the posttest student attitude

questionnaire which was used to determine student attitudes toward the computer simulated laboratory instruction and the traditional method of laboratory instruction. This test was similar in content to the pretest student attitude questionnaire with some appropriate changes in the wording, such as the tense.

### **Hypotheses and Statistical Methods**

Eight hypotheses were tested in this study.

#### **Hypothesis I**

There is no significant difference between the pretest mean scores of the experimental and control groups.

$$H_0: \mu_{E.pre} = \mu_{C.pre}$$

$$H_a: \mu_{E.pre} \neq \mu_{C.pre}$$

The Student t-test was used to test this hypothesis. The 0.05 alpha level was selected to test the statistical significance.

#### **Hypothesis II**

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest I with a pretest covariate.

$$H_0: \mu_{E.postI} = \mu_{C.postI}$$

$$H_a: \mu_{E.postI} \neq \mu_{C.postI}$$

Analysis of covariance was used to test this hypothesis. The 0.05 alpha level was selected to test the statistical significance.

**Hypothesis III**

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest II with a posttest I covariate.

$$H_o: \mu_{EpostII} = \mu_{CpostII}$$

$$H_a: \mu_{EpostII} \neq \mu_{CpostII}$$

Analysis of covariance was used to test this hypothesis. The 0.05 alpha level was selected to test the statistical significance.

**Hypothesis IV**

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest III with a posttest II covariate.

$$H_o: \mu_{EpostIII} = \mu_{CpostIII}$$

$$H_a: \mu_{EpostIII} \neq \mu_{CpostIII}$$

Analysis of covariance was used to test this hypothesis. The 0.05 alpha level was selected to test the statistical significance.

**Hypothesis V**

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest III with a pretest covariate.

$$H_o: \mu_{EpostIII} = \mu_{CpostIII}$$

$$H_a: \mu_{EpostIII} \neq \mu_{CpostIII}$$

Analysis of covariance was used to test this hypothesis. The 0.05 alpha level was selected to test the statistical significance.

#### Hypothesis VI

There is no significant difference between the combined pretests and the combined posttests mean scores of the experimental and control groups.

$$H_0: \mu_{\text{preE+C}} = \mu_{\text{postE+C}}$$

$$H_a: \mu_{\text{preE+C}} \neq \mu_{\text{postE+C}}$$

The Student t-test was used to test this hypothesis. The 0.05 alpha level was selected to test the statistical significance.

#### Hypothesis VII

There is no significant difference between the pretest student attitude questionnaire mean scores of the experimental and control groups.

$$H_0: \mu_{\text{E.pre}} = \mu_{\text{C.pre}}$$

$$H_a: \mu_{\text{E.pre}} \neq \mu_{\text{C.pre}}$$

The Student t-test was used to test this hypothesis. The 0.05 alpha level was selected to test the statistical significance.

#### Hypothesis VIII

There is no significant difference between the adjusted group mean scores of the experimental and control groups attitude as measured by a posttest student attitude questionnaire with a pretest covariate.

$$H_0: \mu_{\text{Epost}} = \mu_{\text{Cpost}}$$

$$H_a: \mu_{\text{Epost}} \neq \mu_{\text{Cpost}}$$

Analysis of covariance was used to test this hypothesis. The 0.05 alpha level was selected to test the statistical significance.

### **Statistical Analysis of Data**

This section presents statistical techniques that were employed to analyze data for the research hypotheses of this experiment. All scores were coded by the researcher and provided as a data file for running statistical analysis by applying the Statistical Analysis System (SAS) computer statistical package. In addition, Statistical Package of the Social Science (SPSS) computer package was used to compute reliability of the instruments. Both packages were run on the mainframe system at Iowa State University.

The mean, standard deviation and frequency distribution were used to describe general characteristics of the demographic data and subjects' responses to the questionnaire items.

The statistical methods chosen for analyzing the data in this study were: the t-test for independent samples, the t-test for dependent samples, the correlation coefficient, and analysis of covariance.

## **CHAPTER IV. RESEARCH RESULTS AND FINDINGS**

In this chapter, the results of this study will be presented and discussed as they relate to the hypotheses of the study as presented in Chapter I. Each of the seven hypotheses is presented and the relevant results are discussed. The final section of this chapter provides a summary of the results of this study.

### **Characteristics of the Subjects**

The population of this study consisted of undergraduate students who enrolled in IEDT 240A and 240B Fundamentals of Electronics class during the Spring semester of the 1992 school year at Iowa State University, Department of Industrial Education and Technology. The prerequisite for IEDT 240 is successful completion of at least one course in Basic Electronics. A total of twenty-nine subjects participated in this study. One subject was eliminated from this study because the subject failed to participate in laboratory experiments.

A ten-item questionnaire was developed to collect demographic data including each participant's educational background, and extent of previous electronics and computer experience.

The questionnaire revealed that the average age of the subjects was twenty-two years with a range of twenty to thirty-two years. Twenty-eight of the subjects were males and one was female. Twenty-eight subjects were Industrial Education and Technology majors and one subject was an Agricultural Education major. The mean grade point average was 2.60 on a four-point scale, ranging from 1.90 to 3.90.

The subjects were classified as one sophomore, thirteen juniors, thirteen seniors, and one graduate student. The number of computer courses that were taken by the subjects at high school and/or college ranged from one to nine. The number of electronics courses that were taken by the subjects during high school and/or college ranged from one to ten.

The Pearson correlation coefficients for the variables are given in Table 6.

Table 6. Pearson correlation coefficients

	Pre	PostI	PostII	PostIII	Age	Major	GPA	Year	Comp	Elect
Pre	1.00	.50**	.10	.39*	.16	.13	.13	-.04	-.08	.19
PostI		1.00	.25	.48**	.03	.25	.28	-.09	-.30	.15
PostII			1.00	.45*	.24	.28	.12	.15	-.36	.03
PostIII				1.00	.07	.22	.19	.09	-.37	-.04
Age					1.00	.54**	.38*	.64**	-.08	.56**
Major						1.00	.57**	.56**	-.15	-.004
GPA							1.00	.04	.01	.28
Year								1.00	.01	-.02
Comp									1.00	.20
Elect										1.00

\* $p < 0.05$ , \*\* $p < 0.01$ .

The pretest scores correlated significantly with both the posttest I scores ( $r = 0.50$ ,  $p < 0.01$ ) and the posttest III scores ( $r = 0.39$ ,  $p < 0.05$ ). The posttest I scores correlated significantly with both the pretest scores ( $r = 0.50$ ,  $p < 0.01$ ) and the posttest III scores ( $r = 0.48$ ,  $p < 0.01$ ). There was a significant correlation

between the posttest II and posttest III scores ( $r = 0.45, p < .05$ ). The posttest III scores correlated significantly with both the posttest I scores ( $r = 0.48, p < 0.01$ ) and the posttest II scores ( $r = 0.45, p < 0.05$ ). Age correlated significantly with major ( $r = 0.54, p < 0.01$ ), with grade point average ( $r = 0.38, p < 0.05$ ), with the year in the college ( $r = 0.64, p < 0.01$ ), and with the number of electronic courses that were taken by the students ( $r = 0.56, p < 0.01$ ). In addition, major correlated significantly with age ( $r = 0.54, p < 0.01$ ), with grade point average ( $r = 0.57, p < 0.01$ ), and with the year in the college ( $r = 0.56, p < 0.01$ ). The student grade point average correlated significantly with both age ( $r = 0.38, p < 0.05$ ), and with major ( $r = 0.57, p < 0.01$ ). The year in the college highly correlated with both age ( $r = 0.64, p < 0.01$ ), and with major ( $r = 0.56, p < 0.01$ ).

### Hypothesis I

There is no significant difference between the pretest mean scores of the experimental and control groups.

$$H_0: \mu_{E.pre} = \mu_{C.pre}$$

$$H_a: \mu_{E.pre} \neq \mu_{C.pre}$$

As shown in Table 7, the pretest mean for the control group was 16.78 and the pretest mean for the experimental group was 16.64. Therefore, the control group scored 0.14 points higher than the experimental group. The t-value is 0.07. With  $p > 0.05$  and 26 degrees of freedom, a critical value of  $\pm 2.056$  was identified. The T-value of 0.07 is within the range of  $\pm 2.056$ . This verified that there was no significant difference between the pretest means of the experimental and control

groups at the 0.05 significance level, which would lend support to the assumption that random assignment had resulted in equivalent groups. Therefore, there was no significant difference between the two groups initially in terms of background and knowledge of electronics and their ability to evaluate, compute, and analyze the test questions. Based upon the above evidence, null hypothesis I was retained.

Table 7. The t-test for the difference between the pretest means of the experimental and control groups

PRETEST	N	MEAN	STD DEV	STD ERR	T	DF	R >   T
GROUP 1	14	16.78	5.25	1.403	0.07	26	0.9426
GROUP 2	14	16.64	5.15	1.377			

Group 1 - Traditional Treatment

Group 2 - Simulation Treatment

### Hypothesis II

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest I with a pretest covariate.

$$H_0: \mu_{EpostI} = \mu_{CpostI}$$

$$H_a: \mu_{EpostI} \neq \mu_{CpostI}$$

As shown in Table 8, the adjusted posttest I mean for the control group was 12.77 and the adjusted posttest I mean for the experimental group was 13.88. Therefore, the control group scored 1.11 points less than the experimental group. The F-value was 1.386, with  $p > 0.05$  for 1 and 25 degrees of freedom. This verified that there was no significant difference between the posttest I means of the

Table 8. The analysis of covariance for the posttest I with a pretest covariate

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-VALUE	PR>F	SIG.
Covariate	1	55.47	55.47	8.890	0.006	YES
Groups	1	8.65	8.65	1.386	0.249	NO
Error	25	155.99	6.24			
Total	27	220.11				

Regression Coefficient for adjusting Y = 0.282

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	12.79	2.80	1.67	12.77
2	13.86	13.52	3.68	13.88

experimental and control groups at the 0.05 significance level. Therefore, since there was insufficient evidence to reject the null hypothesis II, it was retained.

### Hypothesis III

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest II with a posttest I covariate.

$$H_0: \mu_{EpostII} = \mu_{CpostII}$$

$$H_a: \mu_{EpostII} \neq \mu_{CpostII}$$

As shown in Table 9, the adjusted posttest II mean for the control group was 11.02 and the adjusted posttest II mean for the experimental group was 16.06.

Therefore, the control group scored 5.04 points less than the experimental group.

The F-value was 20.864, with  $p < 0.05$  for 1 and 25 degrees of freedom. This verified

Table 9. The analysis of covariance for the posttest II with a posttest I covariate

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-VALUE	PR>F	SIG.
Covariate	1	24.33	24.33	2.963	0.094	NO
Groups	1	171.33	171.33	20.864	0.0001	YES
Error	25	205.30	8.21			
Total	27	400.96				

Regression Coefficient for adjusting Y = 0.504

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	11.29	17.14	4.14	11.02
2	15.79	2.80	1.67	16.06

that there was a significant difference between the posttest II means of the experimental and control groups at the 0.05 significance level. Therefore, null hypothesis III was rejected.

#### Hypothesis IV

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest III with a posttest II covariate.

$$H_0: \mu_{EpostIII} = \mu_{CpostIII}$$

$$H_a: \mu_{EpostIII} \neq \mu_{CpostIII}$$

As shown in Table 10, the adjusted posttest III mean for the control group was 28.40 and the adjusted posttest III mean for the experimental group is 29.60.

Table 10. The analysis of covariance for the posttest III with a posttest II covariate

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-VALUE	PR>F	SIG.
Covariate	1	108.94	108.94	6.385	0.017	YES
Groups	1	6.49	6.49	0.380	0.550	NO
Error	25	426.57	17.06			
Total	27	542.00				

Regression Coefficient for adjusting Y = 0.615

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	29.79	10.95	3.31	28.40
2	28.21	29.41	5.42	29.60

Therefore, the control group scored 1.20 points less than the experimental group.

The F-value was 0.380, with  $p > 0.05$  for 1 and 25 degrees of freedom. This verified that there was no significant difference between the posttest III means of the experimental and control groups at the 0.05 significance level. Based upon the above evidence, null hypothesis IV was retained.

#### Hypothesis V

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest III with a pretest covariate.

$$H_0: \mu_{EpostIII} = \mu_{CpostIII}$$

$$H_a: \mu_{EpostIII} \neq \mu_{CpostIII}$$

As shown in Table 11, the adjusted posttest III mean for the control group was 29.76 and the adjusted posttest III mean for the experimental group was 28.24. Therefore, the control group scored 1.52 points higher than the experimental group. The F-value was 0.919, with  $p > 0.05$  for 1 and 25 degrees of freedom. This verified that there was no significant difference between the posttest III means of the experimental and control groups at the 0.05 significance level. Based on the above evidence, null hypothesis V was retained.

Table 11. The analysis of covariance for the posttest III with a pretest covariate

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-VALUE	PR > F	SIG.
Covariate	1	84.60	84.60	4.794	0.036	YES
Groups	1	16.22	16.22	0.919	0.651	NO
Error	25	441.18	17.65			
Total	27	542.00				

Regression coefficient for adjusting Y = 0.345

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	29.79	10.95	3.31	29.76
2	28.21	29.41	5.42	28.24

### Hypothesis VI

There is no significant difference between the combined pretests and the combined posttests mean scores of the experimental and control groups.

$$H_0: \mu_{\text{preE+C}} = \mu_{\text{postE+C}}$$

$$H_a: \mu_{\text{preE+C}} \neq \mu_{\text{postE+C}}$$

As shown in Table 12, the combined pretests mean of the experimental and control groups was 16.71 and the combined posttests mean of the experimental and control groups was 29.00. Therefore, both groups scored 12.29 points higher on the combined posttests. The t-value was 12.272. With  $p < 0.05$  and 27 degrees of freedom, a critical value of  $\pm 2.056$  was identified. The T-value of 12.272 was not within the range of  $\pm 2.056$ . This verified that there was significant difference between the combined pretests and the combined posttests means of the subjects at the 0.05 significance level. Therefore, there was a significant gain in the subjects' knowledge of electronics and their ability to evaluate, compute, and analyze the test questions. Based on the above evidence, null hypothesis VI was rejected.

Table 12. The matched t-test analysis for the combined pretests and the combined posttests means of the experimental and control groups

Test	N	MEAN	STD DEV	STD ERR	T	DF	PR >   T
Pretest	28	16.71	5.10	0.96	12.272	27.0	0.0001*
PostIII	28	29.00	4.48	0.84			

\*Significant at 0.05 level.

### Hypothesis VII

There is no significant difference between the pretest student attitude questionnaire mean scores of the experimental and control groups.

$$H_0: \mu_{E,pre} = \mu_{C,pre}$$

$$H_a: \mu_{E,pre} \neq \mu_{C,pre}$$

As shown in Table 13, the pretest mean for the control group was 94.71 and the pretest mean for the experimental group was 94.79. Therefore, the control group scored 0.08 points less than the experimental group. The t-value was -0.02. With  $p > 0.05$  and 26 degrees of freedom, a critical value of  $\pm 2.056$  was identified. The t-value of -0.02 was within the range of  $\pm 2.056$ . This verified that there was no significant difference between the pretest means of the experimental and control groups at the 0.05 significance level, which would lend support to the assumption that random assignment had resulted in equivalent groups. Therefore, there was no significant difference initially between the two groups in terms of attitude toward computer simulated laboratory instruction and traditional method of instruction. Based on the results of analysis reported in Table 13, null hypothesis VII was retained.

Table 13. The t-test for the difference between the pretest student attitude questionnaire means of the experimental and control groups

PRETEST	N	MEAN	STD DEV	STD ERR	T	DF	PR >   T
GROUP 1	14	94.71	10.32	2.758	-0.02	26	0.4925
GROUP 2	14	94.79	9.02	2.411			

### Hypothesis VIII

There is no significant difference between the adjusted group mean scores of the experimental and control groups attitude as measured by a posttest with the pretest as a covariate.

$$H_0: \mu_{Epost} = \mu_{Cpost}$$

$$H_a: \mu_{Epost} \neq \mu_{Cpost}$$

As shown in Table 14, the adjusted posttest mean for the control group was 99.52 and the adjusted posttest mean for the experimental group was 94.91. Therefore, the control group scored 4.61 points higher than the experimental group. The F-value was 3.301, with  $p > 0.05$  for 1 and 25 degrees of freedom. This verified that there was no significant difference between the posttest means of the experimental and control groups at the 0.05 significance level. Therefore, there was no significant difference between the two groups in terms of attitude toward computer simulated laboratory instruction and traditional method of instruction. Based on the results of analysis reported in Table 14, null hypothesis VIII was retained.

Table 14. The analysis of covariance for the posttest, student attitude with the pretest as a covariate

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-VALUE	PR > F	Sig
Covariate	1	823.55	823.55	18.249	0.000	YES
Groups	1	148.95	148.95	3.301	0.078	NO
Error	25	1128.21	45.13			
Total	27	2100.71				

Regression Coefficient for adjusting Y = 0.582

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	99.50	73.35	8.56	99.52
2	94.93	76.99	8.77	94.91

### Summary

This chapter reviewed each hypothesis in the study. It addressed the results of the statistical analysis measures according to the relevant hypothesis.

In null hypothesis I, there were no initial differences between the two groups in terms of background and knowledge of electronics and their ability to evaluate, compute, and analyze the test questions.

In null hypothesis II, there were no significant differences between the posttest I mean scores of the experimental and control groups at the 0.05 significance level.

In null hypothesis III, there was a significant difference between the posttest II mean scores of the experimental and control groups at the 0.05 significance level.

In null hypothesis IV, there was no significant difference between the posttest III mean scores of the experimental and control groups at the 0.05 significance level.

In null hypothesis V, there was no significant difference between the posttest III mean scores of the experimental and control groups at the 0.05 significance level.

In null hypothesis VI, there was a significant gain in the subjects' knowledge of electronics and their ability to evaluate, compute, and analyze the test questions.

In null hypothesis VII, there was no significant difference initially between the two groups in terms of attitude toward computer simulated instruction and traditional method of instruction based on the pretest means.

In null hypothesis VIII, there was no significant difference between the two groups in terms of attitude toward computer simulated instruction and traditional method of instruction.

Findings did indicate significant differences beyond the 0.05 level in null hypotheses three and six. However, no significant differences resulted in the remaining five hypotheses.

## **CHAPTER V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS**

The first four chapters of this study dealt with the introduction of the study, a review of the literature, methodology and procedures, analysis of the data, and finding and discussion. The purpose of this chapter is to summarize the preceding chapters, draw conclusions based on the findings, and present recommendations.

### **Summary**

This study was designed to compare and evaluate the effectiveness of computer simulated laboratory instruction versus traditional laboratory instruction for educating college students about solid state electronics circuitry. The study also examined the students' attitude toward computer simulated laboratory instruction versus traditional laboratory instruction as a means of conducting laboratory activities.

Specifically, this study was concerned with answering the following questions:

1. Compare the achievement levels of college students who are receiving computer simulated laboratory instruction with students who are receiving the traditional form of laboratory instruction.
2. Evaluate the effectiveness of computer simulated laboratory instruction in educating college students in solid state electronics circuitry.
3. Compare which instructional method helps students to better understand the underlying applied concepts of solid state electronics circuitry.
4. Evaluate the effectiveness of comparative results between computer simulated

laboratory instruction and the traditional method by means of a pretest and a posttest differential.

5. Assess the students' attitude toward computer simulation as a mode of instruction as opposed to the traditional laboratory approach.

The population of this study consisted of twenty nine undergraduate students who enrolled in IEDT 240A and 240B Fundamentals of Electronics class during the Spring semester of the 1992 school year at Iowa State University, Department of Industrial Education and Technology.

A total of six measuring instruments were used to collect data in this study. The first pretest was a paper-and pencil test which consisted of forty multiple choice items, ten items for each experimental circuit. This test was designed to be used as a covariate to control for initial differences in the students' ability to evaluate, compute, and analyze the responses to the test questions. The second pretest was designed to be used as a covariate to control for initial differences in the students' attitude toward the computer simulated laboratory instruction and the traditional method of laboratory instruction. This test consisted of twenty-seven items, ten of which were positively worded and seventeen negatively worded. The items used a Likert scale with five responses from "strongly disagree" to "strongly agree". After two weeks of experiments, a twenty item posttest I was administered to all subjects. After two more weeks of experiments, a twenty item posttest II was administered to all subjects. At the conclusion of the study, two posttests were administered to all subjects. The first in the series was posttest III which was used to measure treatment effects. This

test was similar in content to the pretest. The second was the posttest student attitude questionnaire which was used to determine attitudes toward the computer simulated laboratory instruction and the traditional method of laboratory instruction. This test was similar in content to the pretest student attitudes questionnaire with some appropriate changes in the wording, such as the tense.

The computer simulation program that was used in this study was a schematic capture program called Schematics (the Evaluation version of the 5.1 release of The Design Center) distributed by the MicroSim Corporation.

A pretest-posttest control group design was used in this experiment. In this study, the researcher randomly assigned subjects to particular groups. The experimental group received the pretests, experimental treatment, posttest I, traditional treatment, Posttest II, and the posttests, while the control group received the pretests, traditional treatment, posttest I, experimental treatment, posttest II, and the posttests. It should be noted that the sequence of the two methods were not the same for both groups

### **Conclusions**

The major hypotheses of the study and the results of testing these hypotheses are summarized as follows:

#### **Null hypothesis 1**

There is no significant difference between the pretest mean scores of the experimental and control groups.

Since the calculated t-value was 0.07, which is not significant at 0.05 level, null hypothesis 1 was retained. This conclusion implies that the random assignment of the subjects produced equivalent groups.

#### Null hypothesis 2

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest I with a pretest covariate.

There was no significant difference between the adjusted group mean scores of the two groups on posttest I as indicated by an F-value of 1.386. Therefore, the null hypothesis 2 was retained. This conclusion suggests that both methods of instruction produced similar results.

#### Null hypothesis 3

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest II with a posttest I covariate.

There was a significant difference between the adjusted group mean scores of the experimental and control groups as indicated by an F-value of 20.864, which is significant at 0.05 level. The simulation group scored significantly higher than the control group on posttest II as indicated by the data reported in Table 9. Therefore, null hypothesis 3 was rejected.

#### Null hypothesis 4

There is no significant difference between the adjusted group mean scores of

the experimental and control groups as measured by a posttest III with a posttest II covariate.

There was no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest III with posttest II serving as a covariate. The F-value was 0.380, which is not significant at 0.05 level. Therefore, null hypothesis 4 was retained. It should be noted that posttest III contained 40 items whereas posttest II contained only 20 items.

#### Null hypothesis 5

There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest III with a pretest covariate.

There was no significant difference between the adjusted group mean scores of the experimental and control groups as indicated by an F-value of 0.919, which is not significant at 0.05 level. Therefore, null hypothesis 5 was retained. Both methods of instruction tended to produce similar effects.

#### Null hypothesis 6

There is no significant difference between the combined pretests and the combined posttests mean scores of the experimental and control groups.

There was a significant difference between the combined pretests and the combined posttests mean scores of the experimental and control groups. The calculated t-value was 12.272, which is significant at 0.05 level. Therefore, null hypothesis 6 was rejected. Both laboratory instructional methods contributed to

higher posttest III scores.

#### Null hypothesis 7

There is no significant difference between the pretest student attitude questionnaire mean scores of the experimental and control groups.

There was no significant difference between the pretest student attitude mean scores of the experimental and control groups. Therefore, based upon the finding reported in Table 13, null hypothesis 7 was retained. Prior to instruction, students' attitudes toward traditional and simulation instruction were relatively equivalent.

#### Null hypothesis 8

There is no significant difference between the adjusted group mean scores of the experimental and control groups attitude as measured by a posttest student attitude questionnaire with the pretest as a covariate.

There was no significant difference between the adjusted group mean scores of the experimental and control groups attitude as indicated by an F-value of 0.301, which is not significant at 0.05 level. Therefore, null hypothesis 8 was retained. This hypothesis indicates that, after treatment, both groups displayed similar attitudes toward computer simulation laboratory instruction as well as the traditional method of instruction after treatment.

### **Limitations**

One of the limitations of this study was the use of two instructors even though they did rotate in sequence, presenting simulation versus traditional laboratory instruction.

The other limitation was that the sample contained common subjects in the control and experimental groups, however, the sequence of simulation and traditional instruction differed for the two groups.

### **Discussion**

The results of this study revealed that integration of the computer simulated laboratory instruction with the traditional method of instruction significantly affected the students' understanding of the solid state electronics circuitry concepts.

The findings indicated that the sequence of laboratory instruction was a significant factor. Students learned more electronics circuitry concepts when they utilized the traditional method of instruction and then used computer simulations.

The findings also indicated that the study should be repeated with higher reliability coefficient instruments constructed to better reflect the course objectives and to better measure higher order thinking skills.

More complex problem solving and a higher order of integrated thinking skills if required, would perhaps have yielded additional significant differences. Also, the computer-based learning program could be used in an integrating mode rather than in the experiencing mode as it was in this study. In an integrating mode, the computer program is used to provide an opportunity to apply previously learned material to new situations as well as to associate previously unconnected ideas (Thomas & Boysen, 1984).

Chuang (1990) found a significant difference between simulation and traditional instruction in the time it took students to troubleshoot and repair color

T.V. sets.

Hwang (1989) found that students who worked on computer simulation with a partner scored as well as those who were provided traditional instruction, however, they asked the teacher fewer questions in carrying out their laboratory assignments.

Diedrick and Thomas (1977) found that high school students in automotive mechanics who used the computer simulation method of instruction performed significantly better than the traditional instructional group in diagnosing ignition problems.

Thomas and Hooper (1991) reported that simulation may be useful for reinforcing complex sequences. In using these simulations, the authors maintained, that the learner is forced to assume responsibility for executing the process whereas in alternative methods, the learner responds to external questions or instructions.

Future research should focus on diagnosis, synthesis of complex concepts and evaluation of consequences of practical problems in assessing the effectiveness of computer simulation instruction.

### **Recommendations**

The following recommendations are based upon the findings of this study and the experiences gained from conducting this experiment.

1. There is a need to expand the number of items and improve the reliability of the test items to perhaps 0.84 or higher.
2. There is a need to conduct research with a larger group of students, the use of simulation on more complex concepts of circuitry and applications requiring

actual analysis, troubleshooting, evaluation, and repair.

3. There is a need to extend the period of instruction from four weeks duration, as was the case in this study, to perhaps eight weeks.
4. One instructor should provide all phases of instruction to both groups, the treatment as well as the control group, to eliminate instructor bias.
5. Student learning style should be used as an independent variable to determine what effects simulation instruction does produce.

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## ACKNOWLEDGEMENTS

I wish to express my genuine appreciation to Dr. William Wolansky, my major professor, for providing guidance, continual encouragement, patience, and friendship during my doctoral program at Iowa State University.

I sincerely appreciate the contribution made by each of my program of study committee members: Dr. William Miller, Dr. John Dugger, Dr. Terry Smay, and Dr. Edwin Jones. I have learned a great deal from all of them.

I wish to express my gratitude to Dr. Rex Thomas who helped me perform a thorough review of the literature and Dr. Robert Strahan for helping me to solve SAS computer programming and statistical problems.

Also, I sincerely thank Mr. Saeid Moslehpour who served as instructor #2. I am grateful to Mr. Rashid Bax and Ms. Pat Hahn who helped proofread and edit the final draft for the Thesis Office.

Finally, I am eternally grateful and extend my love to my wife, daughter, mother, brothers and sisters who always prayed for me and encouraged me to complete my doctoral program.

**APPENDIX A: HUMAN SUBJECTS COMMITTEE APPROVAL**

## Checklist for Attachments and Time Schedule

The following are attached (please check):

12. ☒ Letter or written statement to subjects indicating clearly:
- a) purpose of the research
  - b) the use of any identifier codes (names, #'s), how they will be used, and when they will be removed (see Item 17)
  - c) an estimate of time needed for participation in the research and the place
  - d) if applicable, location of the research activity
  - e) how you will ensure confidentiality
  - f) in a longitudinal study, note when and how you will contact subjects later
  - g) participation is voluntary; nonparticipation will not affect evaluations of the subject
13. ☐ Consent form (if applicable)
14. ☐ Letter of approval for research from cooperating organizations or institutions (if applicable)
15. ☒ Data-gathering instruments

16. Anticipated dates for contact with subjects:

First Contact

3-30-1992

Month / Day / Year

Last Contact

5-15-1992

Month / Day / Year

17. If applicable: anticipated date that identifiers will be removed from completed survey instruments and/or audio or visual tapes will be erased:

5-15-1992

Month / Day / Year

18. Signature of Departmental Executive Officer      Date      Department or Administrative Unit

Dr. John C. Dugger2-28-1992IED & T

19. Decision of the University Human Subjects Review Committee:

☒ Project Approved      ☐ Project Not Approved      ☐ No Action Required
Patricia M. Keith

Name of Committee Chairperson

4-6-92 PM Keith

Date

Signature of Committee Chairperson

**APPENDIX B: CONSENT FORM**

**CONSENT FORM**

Your participation in my thesis is solicited. This participation is voluntary; you may withdraw at any time. Your participation will not affect your grade in IEDT 240A or IEDT 240B.

If you have any questions regarding this study, please feel free to contact:

Dr. William D. Wolansky  
E115 Lagomarcino Hall  
294-7350

Factors to consider;

1. The purpose of this study is to determine the effectiveness of the computer simulated laboratory instruction versus traditional breadboarding in IEDT 240.
2. No risks and/or discomforts to you are anticipated.
3. Your assignments will be identical to all other students enrolled in the course.
4. Your participation in the study will be confined to regular class time and includes you responses to the general information sheet, pre-post test on laboratory assignments and pre-post test student attitude questionnaire.
5. Based on the results of this study, laboratory instruction methods will be identified that are most effective. The revised methods will be incorporated into future courses.
6. All individual data will be confidential. The results of the study will be reported for group means only.

May we have your agreement to participate in the study.

Signature \_\_\_\_\_

Data \_\_\_\_\_

**APPENDIX C: GENERAL INFORMATION SHEET**

- 1. Last four digits of your SSN:** \_\_\_\_\_
- 2. Gender:** \_\_\_\_\_
- 3. Age:** \_\_\_\_\_
- 4. Major:** \_\_\_\_\_
- 5. College GPA:** \_\_\_\_\_
- 6. Year in college:** \_\_\_\_\_
- 7. How many courses have you taken (at high school and/or college) in which you used computer?** \_\_\_\_\_
- 8. How many electronic courses have you taken (at high school and/or college)?**  
\_\_\_\_\_
- 9. What job-related experience have you had with electronics (list below)?**
- 10. What job-related experience have you had with computers (list below)?**

**APPENDIX D: PRETEST/POSTTEST**

**Directions:** Please answer each question provided on this instrument. Mark your answers by filling in the corresponding circle on the answer sheet with a pencil. Your responses will remain confidential and will have no bearing in determining your course grade.

Identification Number: \_\_\_\_\_  
(Last four digits of your SSN)

1. The RC circuit in Figure 1 is a(n):

- a. differentiator
- b. integrator
- c. series clipper
- d. shunt clipper

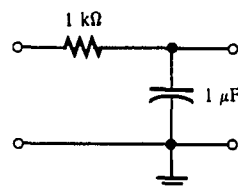


Figure 1.

2. An RC integrator circuit can be used for

- a. obtaining good dc output.
- b. wave-shaping input waveforms.
- c. timing circuits with pulse inputs.
- d. all of the above.

3. A circuit that can be used to change a square wave into a triangle wave is

- a. a tuned circuit
- b. a ladder circuit
- c. an integrator
- d. a differentiator

4. See figure 2. This circuit is known as

- a. a high-pass filter.
- b. a band-pass filter.
- c. a low-pass filter.
- d. parallel RC circuit.

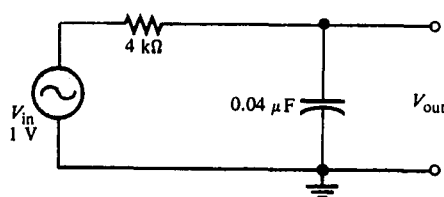


Figure 2.

5. See Figure 2. If the output were taken across the resistor, the circuit would be known as a \_\_\_\_\_ filter.

- a. high-pass
- b. band-pass
- c. low-pass
- d. band-notch

6. The cutoff frequency ( $F_{co}$ ) is defined as the frequency at which the output amplitude is equal to what percentage of the input?
- 7.07%
  - 70.7%
  - 80.7%
  - 0.707%
7. See Figure 2. The cutoff frequency is
- 6250 Hz
  - 99 Hz
  - 480 Hz
  - 995 Hz
8. See Figure 2. If the resistor is changed to 47 k $\Omega$ , what is the new cutoff frequency?
- 85 Hz
  - 118 Hz
  - 995 Hz
  - 1012 Hz
9. See Figure 2. If the input voltage were 17 V, what would the voltage be across the capacitor at the cutoff frequency?
- 0 V
  - 8 V
  - 12 V
  - 17 V
10. If the bandwidth of a certain low-pass is 1 kHz, the cutoff frequency is
- 0 Hz
  - 500 Hz
  - 2 kHz
  - 1000 Hz
11. See Figure 3. This circuit is known as
- differentiator
  - integrator
  - series clipper
  - shunt clipper

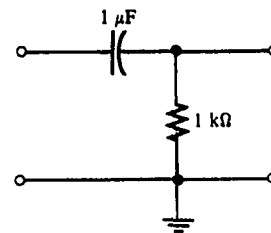


Figure 3.

12. In a series RC circuit, the voltage across the resistance is
  - a. in phase with the source voltage
  - b. lagging the source voltage by  $90^\circ$
  - c. in phase with current
  - d. lagging the current by  $90^\circ$
13. When the frequency of the voltage applied to a series RC circuit is increased, the impedance
  - a. increase
  - b. decrease
  - c. remain the same
  - d. double
14. When the frequency of the voltage applied to a series RC circuit is decreased, the phase angle
  - a. increase
  - b. decrease
  - c. remain the same
  - d. become erratic
15. The output of an RC differentiator is taken across the
  - a. resistor
  - b. capacitor
  - c. source
  - d. coil
16. When a square wave input is applied to the Figure 3, the output is a
  - a. triangle waveform
  - b. sinusoidal waveform
  - c. step waveform
  - d. series of positive and negative pulses
17. See Figure 4. This circuit is known as
  - a. low-pass filter
  - b. high-pass filter
  - c. band-pass filter
  - d. band-notch filter

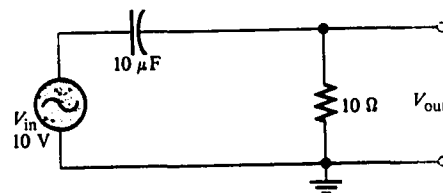


Figure 4.

18. See Figure 4. The cutoff frequency is
- 6250 Hz
  - 1.59 kHz
  - 48.0 kHz
  - 2.5 kHz
19. See Figure 4. If the resistor is changed to 10 k $\Omega$ , what is the new cutoff frequency?
- 1.59 Hz
  - 118 Hz
  - 995 Hz
  - 1012 Hz
20. The critical frequency of Figure 4 is the frequency at which the output signal, when compared to the midband level, is attenuated by:
- 0 dB
  - 3 dB
  - 6 dB
  - depend on the number of poles
21. In an integrator, the feedback element is a
- resistor
  - capacitor
  - zener diode
  - voltage divider
22. For a step input, the output of an integrator is
- a pulse
  - a triangle waveform
  - a spike
  - a ramp
23. The rate of change of an integrator's output voltage in response to a step input is set by
- the RC time constant
  - the amplitude of the step input
  - the current through the capacitor
  - all of these
24. When a square wave is the input signal of an integrating circuit, the output is a
- triangle waveform
  - sinusoidal waveform
  - step waveform
  - series of positive and negative pulses

25. See Figure 5. If  $R = 47 \text{ k}\Omega$  and  $C = 0.02 \text{ }\mu\text{F}$ , find  $F_{co}$ .

a. 169 Hz  
 b. 1.69 kHz  
 c. 1.063 kHz  
 d. 11.2 kHz

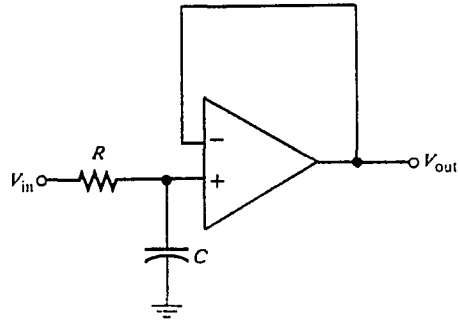


Figure 5.

26. See Figure 5. If the ac input  $V_{in} = 22 \text{ V}$ , find the out voltage at  $F_{co}$ .

a. 31.1 V  
 b. 15.55 V  
 c. 7.79 V  
 d. 0 V

27. See Figure 5. What would be necessary to change this circuit to a high-pass filter?

a. increase the value of the resistor.  
 b. decrease the value of the capacitor.  
 c. place the capacitor in the feedback loop.  
 d. switch the positions of the R and C.

28. The input frequency of a single-pole, low-pass active filter increases from 1.5 kHz to 150 kHz. If the critical frequency is 1.5 kHz, the gain decreases by

a. 3 dB  
 b. 20 dB  
 c. 40 dB  
 d. 60 dB

29. If an inverting amplifier has a capacitor in the feedback loop, the circuit is known as a(n) \_\_\_\_\_ and the output with a square wave input would be a \_\_\_\_\_.

a. differentiator, triangle wave  
 b. integrator, square  
 c. integrator, triangle  
 d. open loop, triangle

30. What is the critical frequency for Figure 6?

- a. 1.45 Hz
- b. 23 Hz
- c. 1.59 kHz
- d. 2.3 kHz

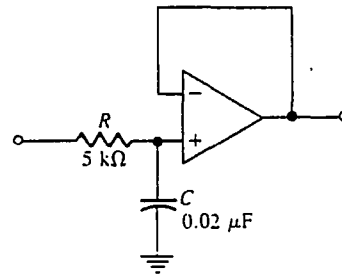


Figure 6.

31. In an differentiator, the feedback element is a

- a. resistor
- b. capacitor
- c. zener diode
- d. voltage divider

32. The output of a differentiator is proportional to

- a. the RC time constant
- b. the rate at which the input is changing
- c. the amplitude of the input
- d. a and b

33. When you apply a triangular waveform to the input of a differentiator, the output is

- a. a dc level
- b. an inverted triangular waveform
- c. a square waveform
- d. the first harmonic of the triangular waveform

34. When a square wave is the input signal of a differentiating circuit, the output is a

- a. triangle waveform
- b. sinusoidal waveform
- c. step waveform
- d. series of positive and negative pulses

35. Which of the following circuits has a gain of one?

- a. active filter
- b. comparator
- c. summing amplifier
- d. voltage follower

36. What is the critical frequencies for Figure 7?

- a. 6772.6 Hz
- b. 1012 Hz
- c. 995 Hz
- d. 2.34 kHz

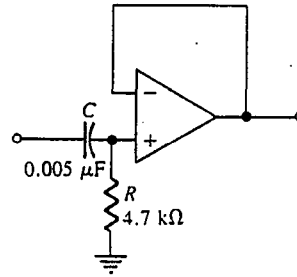


Figure 7.

37. A \_\_\_\_\_ blocks the low frequencies and passes the high frequencies.

- a. low-pass filter
- b. high-pass filter
- c. active filter
- d. passive filter

38. See Figure 7. This circuit is known as a \_\_\_\_\_ and it has a rolloff of -----.

- a. high-pass filter, 20 dB/decade
- b. low-pass filter, 20 dB/decade
- c. band-pass filter, 20 dB/decade
- d. low-pass filter, 40 dB/decade

39. See Figure 7. This circuit could also be called a

- a. single-pole, active high-pass filter.
- b. two-pole, active high-pass filter.
- c. two-pole, active low-pass filter.
- d. single-pole, active low-pass filter.

40. See Figure 8. This frequency response curve represents the output from a

- a. low-pass filter.
- b. passive filter.
- c. high-pass filter.
- d. band-pass filter.

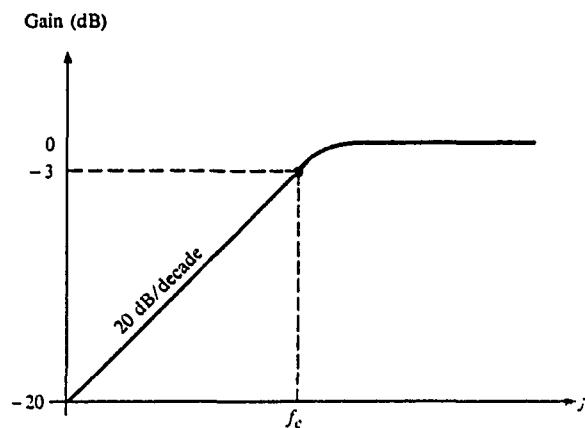


Figure 8.

**APPENDIX E:      PRETEST STUDENT ATTITUDE QUESTIONNAIRE  
MEASURING ATTITUDE TOWARD COMPUTER  
SIMULATED LABORATORY INSTRUCTION**

**Directions:** Please read each statement and decide which response most correctly describes your attitude toward the statement. Then mark the number corresponding to this response on the answer sheet only. (Please do not mark this questionnaire.)

1. While taking computer simulated laboratory instruction I would feel challenged to do my best work.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
2. While taking computer simulated laboratory instruction I would be concerned that I might not be understanding the material.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
3. While taking computer simulated laboratory instruction I would feel isolated and alone.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
4. While taking computer simulated laboratory instruction I would find myself just trying to get through the material rather than trying to learn.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
5. Computer simulated laboratory instruction should not be used in any form in the college classes.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree

6. Computer simulated laboratory instruction could be used effectively in many college classes.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
7. In a situation where I am trying to learn something, it is important to me to know where I stand relative to others.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
8. Computer simulated laboratory instruction would make this course more interesting.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
9. While taking computer simulated laboratory instruction I would be more involved in running the machine than in understanding the material.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
10. I feel I could work at my own pace with computer simulated laboratory instruction.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
11. Computer simulated laboratory instruction makes the learning too mechanical.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree

12. I would feel as if I had a private tutor while on computer simulated laboratory instruction.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
13. While taking computer simulated laboratory instruction I would be aware of efforts to suit the material specifically to me.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
14. While taking computer simulated laboratory instruction I would find it difficult to concentrate on the course material because of the hardware.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
15. Computer simulated laboratory instruction is an inefficient use of student's time.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
16. While on computer simulated laboratory instruction I would encounter mechanical malfunctions.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
17. Computer simulated laboratory instruction would make it possible for me to learn more quickly than traditional laboratory instruction.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree

18. I would feel frustrated by the computer simulated laboratory instruction situation.
- a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
19. The computer simulated laboratory instruction approach is inflexible.
- a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
20. Even otherwise, interesting material would be boring when presented by computer simulated laboratory instruction.
- a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
21. In view of the effort I put into it, I would be satisfied with what I had learned while using computer simulated laboratory instruction.
- a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
22. In view of the amount I would learn, I would say computer simulated laboratory instruction is superior to traditional laboratory instruction.
- a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
23. With a course such as the one I am taking, I would prefer computer simulated laboratory instruction to traditional laboratory instruction.
- a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree

24. I am not in favor of computer simulated laboratory instruction because it is just another step toward depersonalized instruction.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
25. Computer simulated laboratory instruction is too fast.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
26. Typing experience is necessary in order to perform satisfactorily on computer simulated laboratory instruction
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree
27. Computer simulated laboratory instruction is boring.
  - a. strongly disagree
  - b. disagree
  - c. uncertain
  - d. agree
  - e. strongly agree

**APPENDIX F: POSTTEST STUDENT ATTITUDE QUESTIONNAIRE  
MEASURING ATTITUDE TOWARD COMPUTER  
SIMULATED LABORATORY INSTRUCTION**

**Directions:** Please read each statement and decide which response most correctly describes your attitude toward the statement. Then mark the number corresponding to this response on the answer sheet only. (Please do not mark this questionnaire.)

1. While taking computer simulated laboratory instruction I felt challenged to do my best work.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
2. While taking computer simulated laboratory instruction I was concerned that I might not be understanding the material.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
3. While taking computer simulated laboratory instruction I felt isolated and alone.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
4. While taking computer simulated laboratory instruction I found myself just trying to get through the material rather than trying to learn.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
5. Computer simulated laboratory instruction should not be used in any form in the college classes.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree

6. Computer simulated laboratory instruction could be used effectively in many college classes.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
7. In a situation where I am trying to learn something, it is important to me to know where I stand relative to others.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
8. Computer simulated laboratory instruction made this course more interesting.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
9. While taking computer simulated laboratory instruction I was more involved in running the machine than in understanding the material.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
10. I felt I could work at my own pace with computer simulated laboratory instruction.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
11. Computer simulated laboratory instruction makes the learning too mechanical.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree

12. I felt as if I had a private tutor while on computer simulated laboratory instruction.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
13. While taking computer simulated laboratory instruction I was aware of efforts to suit the material specifically to me.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
14. While taking computer simulated laboratory instruction I found it difficult to concentrate on the course material because of the hardware.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
15. Computer simulated laboratory instruction is an inefficient use of student's time.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
16. While on computer simulated laboratory instruction I encountered mechanical malfunctions.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
17. Computer simulated laboratory instruction made it possible for me to learn more quickly than traditional laboratory instruction.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree

18. I felt frustrated by the computer simulated laboratory instruction situation.
1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
19. The computer simulated laboratory instruction approach is inflexible.
1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
20. Even otherwise, interesting material would be boring when presented by computer simulated laboratory instruction.
1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
21. In view of the effort I put into it, I was satisfied with what I learned while using computer simulated laboratory instruction.
1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
22. In view of the amount I learned, I would say computer simulated laboratory instruction is superior to traditional laboratory instruction.
1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
23. With a course such as the one I am taking, I would prefer computer simulated laboratory instruction to traditional laboratory instruction.
1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree

24. I am not in favor of computer simulated laboratory instruction because it is just another step toward depersonalized instruction.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
25. Computer simulated laboratory instruction is too fast.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
26. Typing experience is necessary in order to perform satisfactorily on computer simulated laboratory instruction.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree
27. Computer simulated laboratory instruction was boring.
  1. strongly disagree
  2. disagree
  3. uncertain
  4. agree
  5. strongly agree

## **APPENDIX G: COMPUTER SIMULATION PROGRAM**

This document is extracted from the Genesis - User's Guide with permission of MicroSim Corporation.

This document includes two tutorials to help get you started using *Schematics*. These tutorials are provided to give you step-by-step, "hands-on" instruction on how to use the Schematic Editor and the Symbol Editor.

The Schematic Editor tutorial demonstrates how to use *Schematics* to modify a schematic, generate a netlist, run *PSpice* and *Probe*, and print the schematic.

The Symbol Editor tutorial demonstrates how to create new parts and libraries and edit existing parts and libraries for use in the Schematic Editor.

### **Tutorial 1: Schematic Editor Tutorial**

#### **Using the Schematic Editor:**

This tutorial will show you how to accomplish the following:

1. **Invoke the Schematic Editor and Open a Schematic.**
2. **Draw a Wire.**
3. **Choose a part from the component libraries and place it on the schematic.**
4. **Save your work.**
5. **Perform a *PSpice* Analysis:**
  - a. **Set up parameters.**
  - b. **Generate a *PSpice* Netlist.**
  - c. **Run *PSpice*.**
6. **Run *Probe*.**
7. **Print a schematic.**
8. **Exit from the Schematic Editor.**

## Invoking the Schematic Editor and Opening a Schematic

### To invoke the Schematic Editor:

1. In Windows, double-click on the *Schematics* icon to bring up the Schematic Editor. In Open Windows, double-click on a schematic file in the File Manager window, or enter "psched" on a shell command line.

### To open a Schematic:

1. Choose **Open** from the **File Menu**.
2. Select "tutorial.sch" from the list of file names appearing in the **Open** dialog box, and then choose **OK**. Or, (in Windows) double-click on the file name to bring up the file.

By comparing "tutorial.sch" in your window to "example.sch" in Figure 2, you will notice that the voltage sources labeled V2 and V3, located in the lower right portion of your schematic, are not connected to ground.

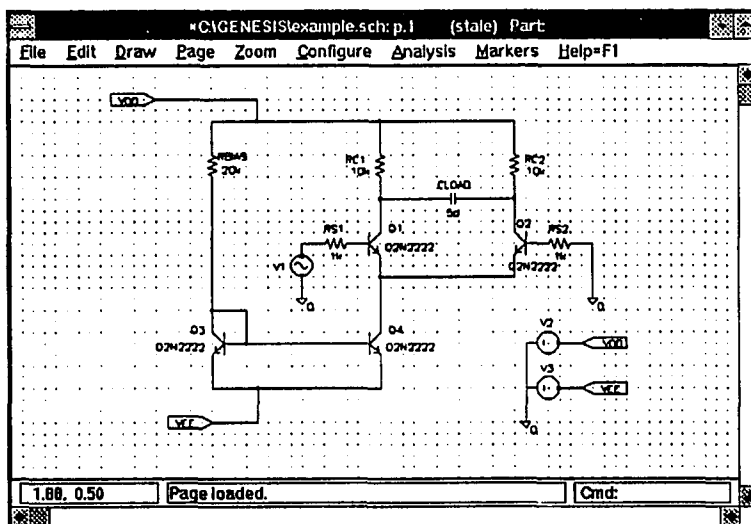


Figure 1. Example.sch

### **Drawing a Wire**

The following procedure explains how to place a wire segment on your schematic to connect V2 and V3, which can then be connected to a single ground symbol.

1. Choose **Wire** from the **Draw Menu**. Notice that the cursor changes to the shape of a pencil.
2. Place the pencil cursor at the starting point for the wire (at V2) and click the mouse to connect the wire and begin drawing (you can see the wire being drawn as you move the mouse).
3. Extend the wire to V3 and double-click the mouse to connect and end the wire.  
  
Another way to end the wire is to click the mouse once at the ending point, check to see that the wire placement is correct, and then click on the right mouse button to end the wire.

### **Choosing a Part From the Component Libraries:**

Now, let's complete our sample schematic by choosing a ground symbol from the library and connecting it to V2 and V3.

1. Choose **Get New Part** from the **Draw Menu**.
2. In the dialog box, choose **Browse** to browse the list of parts in the libraries.
3. When you choose **Browse**, another dialog box appears listing the available parts within the selected library.
4. Select the library called "global.slb," and then select the part titled AGND. Choose **OK** to bring up the part. You will notice that the cursor changes to the shape of the ground symbol.
5. Move the part toward V2 and V3 to connect it to the wire you just drew. Attach the AGND symbol to V2 and V3, as shown in Figure 2. Click the mouse to place the part,

and then click the right mouse button to end the "place part" mode. Notice that the junction is automatically inserted for you.

### **Saving Your Work:**

To save your schematic, choose **Save As** from the **File Menu**. Specify a file name in the dialog box. Your file is automatically saved into the "current working directory," unless you specify a different pathname.

### **Selecting a PSpice Analysis:**

Before you can generate a netlist, you need to select which analyses to run on your circuit.

1. Choose **Setup** from the **Analysis Menu**. A submenu appears.
2. Choose **Transient** from the **Setup Menu**.
3. A dialog box appears allowing you to modify the analysis parameters or use the defaults given. For this example, we will use the default values.
4. To select **Transient** analysis, click the mouse on **Enabled** at the bottom of the dialog box. When enabled, an "X" will appear in the selection box. Then choose **OK**.

### **Generating a PSpice Netlist:**

1. Choose **Create Netlist** from the **Analysis Menu**.
2. Choose **Examine Netlist** from the **Analysis Menu** to browse the netlist before running the simulation, if you wish.
3. Choose **Exit** from the **File Menu** to exit the netlist file.

### **Running PSpice:**

Now that you have generated a *PSpice* netlist, you are ready to run the simulation on your circuit.

1. Choose **Run PSpice** from the **Analysis Menu**. The *PSpice* circuit simulation screen appears in its own window, displaying the status of the analysis.
2. When the analysis is complete, the *Schematics* screen will reappear. Select **Examine Output** to examine the analysis results. These results are contained in the "tutorial.out" file produced by *PSpice*. Now you are ready to run *Probe*.

**Running Probe:**

The *Probe* waveform analyzer is used to review the results of the *PSpice* analysis. You can display voltages, currents, and digital waveforms using *Probe*. Schematic names (rather than node numbers) are used to specify what will be displayed.

**To specify a voltage:** use the pin name inside, such that "V (<pin name>)." For example, the voltage at pin "c" of part "Q3" would be specified by "V(Q3:c)."

**To specify a current:** use the device name inside, such that "I(<device name>)." For example, the current through part "R4" would be specified by "I(R4)."

**To specify a digital waveform,** use the <pin name>:<part name>. For example, the digital signal at pin "clk" of part "U4" would be "U4:clk."

Voltages and digital signals on labeled nets can be displayed by using the net name, inside "V (<netname>)", or on its own, respectively. For example, the voltage on a net labeled "Power" would be specified by "V(Power)"; the digital signal "Preset" by "Preset."

**To run *Probe*:**

1. Choose **Run Probe** from the **Analysis Menu**. The *Probe* screen appears in its own window, showing a list of available voltages, currents, and digital values.
2. Select **Add Trace** from the menu at the bottom of the *Probe* screen. You can examine any of the variables listed by following the screen prompts.
3. Press <F4> or click the right mouse button to see a list of values to examine. Use the arrows or the mouse to move to the desired value, as directed on the screen.
4. Press <Enter> to select the value, or click the right mouse button. You will see the value(s) you selected listed at the bottom of your screen. Press <Enter> again to view the *Probe* display of the selected traces.
5. Select **Exit** to exit from *Probe* and return to your schematic.

**Printing a Schematic:**

This section describes how to set up your printer and how to print a schematic drawing within *Schematics*. Before printing a schematic, you must first configure your printer through Windows.

**Note:** Setting the printer from within *Schematics* will give your *Schematics* program it's own private printer setup that cannot be changed by other windows applications.

**To set your printer for landscape mode:**

1. Select **Printer Setup** from the **File Menu**.
2. In the dialog box, select **Landscape** under **Orientation**.

**To print a hard copy of your schematic:**

1. Choose **Print** from the **File Menu**.
2. In the **Print** dialog box, verify that the **Auto-Fit** option is selected. This option will automatically fit your schematic onto one sheet of printer paper if the printer is configured in the landscape mode.
3. Choose **OK**.

**Exiting From the Schematic Editor:**

To exit, choose **Exit** from the **File Menu**. A message prompts you to save/not save your changes.

## **Tutorial 2: Symbol Editor Tutorial**

### **Using the Symbol Editor:**

The Symbol Editor allows you to create new parts and libraries and edit existing parts and libraries for use in the Schematic Editor.

**Note:** Changes made to parts in the Symbol Editor have a global implication; any changes will affect all instances of the part modified.

This tutorial will show you how to accomplish the following:

1. Invoke the Symbol Editor from the Schematic Editor.
2. Edit the definition for a selected part. You can edit the symbol definition in the following ways:
  - a. Edit the name and description.
  - b. Edit the graphics and pins, or create new graphics.
  - c. Adjust the pin names and numbers.
  - d. Edit the attributes.
3. Save the symbol and Exit the Symbol Editor.

### **Invoking the Symbol Editor to Edit a Symbol:**

1. From the Schematic Editor, choose **Open** from the **File Menu**.
2. Select "example.sch" from the list in the dialog box and choose **OK**.
3. On the schematic, click the left mouse button on the zigzag portion of resistor RS2 to select it. (This resistor is located on the right side of the schematic.) The selected portion changes color to indicate that it is selected. (If you have not changed the default colors, the zigzag portion changes from green to red.) You can change the default colors in the "msim.ini" file.

**Note:** If you have difficulty which resistor is RS2 due to the size of the schematic on your screen, select a resistor by clicking on it with the mouse. Then choose **In** from the **Zoom Menu** to see the part at closer range. A crosshair appears. Position the crosshair in the center of the area you wish to view, and click the mouse. You can repeat this process until the viewing area is large enough to suit your needs.

4. With resistor RS2 selected, choose **Symbol** from the **Edit Menu**. The **Symbol** command invokes the Symbol Editor.
5. The menu bar changes to that of the Symbol Editor. The resistor symbol you selected appears on the screen, enlarged and ready for editing.

#### **Editing the Symbol Definition:**

The symbol definition consists of a symbol's graphics, pins, and attributes.

#### **To edit the description:**

1. Choose **Definition** from the **Part Menu**.
2. The **Definition** dialog box appears, displaying the following items:
 

<b>Description</b>	The textual description of the symbol.
<b>Part Name</b>	The most commonly used full name of the part.
<b>Alias List</b>	The exact electrical equivalents of the part that can be used to reference the symbol.
<b>AKO Name</b>	Specifies that the symbol will use the graphics, pins, and attributes of another part. Attributes on the symbol being edited will override those from the named part, and new attributes may be added.
<b>Type</b>	The symbol types include: primitive, port, annotation, border, and title block.

For this tutorial, we will edit only the **Description**. (Changing the **Part Name** field in the tutorial would invalidate the tutorial schematic, since the original part name for the resistor symbol would not be found.)

3. In the **Description** field of the dialog box, replace the description with the words "special resistor."

4. Then choose **OK** to produce the change. You will see no change in the symbol on your screen. However, the description of the symbol changes in the **Get New Part** menu item in the Schematic Editor's **Draw Menu**.

**To edit the graphics:**

So that you can see how symbol graphics are created and modified, we will replace the graphical representation of resistor RS2 with a simple rectangle shape.

1. Select the "zigzag portion" of the resistor symbol by positioning the mouse cursor slightly above and to the left of the zigzags.
  - a. Hold down the left mouse button and drag the mouse to the right and down, so that the expanding rectangle encloses the zigzag portion of the resistor only.
  - b. Release the button when the selection box surrounds the entire zigzag portion of the resistor.
2. Choose **Cut** from the **Edit Menu** to delete the zigzag portion.
3. To replace the zigzags with a rectangle, choose **Box** from the **Graphics Menu**. The cursor changes to a pencil shape.
4. Move the pencil to a position on the dotted line at the top of symbol's bounding box, directly over the space where the zigzags began. Click the left mouse button.
5. Move the cursor to the right dragging the mouse down toward the bottom dotted line of the bounding box. You will see the outline of a rectangle appear. When the rectangle outline fills the space between the top and bottom dotted lines, in the area in which the zigzags were removed, click the left mouse button to fix the rectangle and click the right mouse button to end the mode.

You have now edited the graphics for this "special resistor."

**To adjust the pin names and numbers:**

With the **Pin List** command you can change the pin names, display types, and orientation of the pins. You can edit all of the pins by using on dialog box, or you can edit an individual pin by double-clicking on the desired pin. For this example, we will change the display of the pin names for the two pins on resistor RS2, so that they will appear on the schematic.

1. Choose **Pin List** from the **Part Menu** to bring up the **Pin List** dialog box.
2. Click the left mouse button on the number "1" in the box in the upper right corner of the **Pin List** dialog box to select pin 1 for modification.
3. Click on the circle to the left of **Display Name** in the dialog box to enable the feature. A black dot appears within the circle to show that it is enabled. With **Display Name** enabled, the pin name will appear on your screen.
4. Click on the **Save Pin** button at the bottom of the dialog box to save the change to the pin.
5. Now click on the number "2" in the box in the upper right corner of the **Pin List** dialog box. Repeat steps 3 and 4 to cause the name for Pin 2 to be displayed on your schematic. Then choose **OK** to produce the changes. You will see the name for Pin 1 and Pin 2 displayed on the screen.

**To edit a symbol attribute:**

We will add a new attribute for resistor RS2, by giving it a "part identification number."

1. Choose **Attributes** from the **Part Menu**.
2. In the **Attributes** dialog box, enter "partid" in the **Name** field.
3. Press the <Tab> key or click the left mouse button to position the cursor in the **Value** field. Then enter "345" in the **Value** field.
4. Click on the circle to the left of **Display Value** to enable the value to be visible on the screen.
5. Click on the **Save Attr** button at the bottom of the dialog box to temporarily save the

attribute to the list of attributes appearing on the right side of the dialog box.

6. Choose **OK** to produce the change. This incorporates the new attribute into the attribute list. You should see the value of the new partid attribute on your symbol.

You can move the attributes displayed on the symbol. Let's move the partid attribute and center it within the symbol rectangle. To move the partid number:

1. Click on the partid attribute "345" to select it.
2. With the mouse cursor pointed at the partid attribute, hold down the left mouse button and drag the attribute to the new location. Release the mouse button to place the attribute at its new location.

**To save the symbol and exit from the Symbol Editor:**

1. Choose **Save** from the **Part Menu** to save the symbol.
2. Choose **Save As** from the **File Menu** to save the part to another library (in this case, "tutorial.slb").

**Note:** You would choose **Save** from the **File Menu** if you wanted to save the changed part to the current library. However, choosing this menu item while working in the tutorial would result in a global change to the resistor symbol.

3. Choose **Exit** from the **File Menu** to return to the Schematic Editor.

**APPENDIX H: COMPUTER SIMULATED LABORATORY INSTRUCTION**

**Experiment 1: Frequency Response of RC Circuits****OBJECTIVE:**

1. To use the series RC circuit as a low-pass filter.
2. To calculate and plot the critical frequency of a low-pass filter.
3. To calculate and graph the numerical gain of a low-pass filter.

**THEORY:**

To use an RC circuit as a low-pass filter, we define the voltage across the capacitor as the output voltage. At high frequencies, the reactive capacitance approaches  $0 \Omega$ ; hence our output voltage must be approach 0 V. At very low frequencies, the large capacitive reactance prevents any current from flowing, causing the voltage across the resistor to be close to zero and the capacitor voltage to be approximately equal to  $V_{in}$  (Monssen, In Press, p-468).

**PROCEDURE:**

1. Use the Schematic Editor to design a low-pass RC circuit. Choose  $R1 = 100 \text{ k}\Omega$ ,  $C1 = 1 \text{ nF}$ , and  $V_{in} = 1.0 \text{ VAC}$ .
2. Select Setup from the Analysis Menu. A submenu appears. Choose AC Sweep from the Setup menu. Set up Sweep Parameters for frequencies from 1 Hz to 1 MHz by a factor of ten.
3. Run Electrical Rule Check, and then generate a Netlist.
4. Run Circuit Simulations using PSpice.
5. Use Probe waveform analyzer to obtain a graph of the output voltage. The output level varies from 1 V at  $f = 1\text{Hz}$  to almost 0 V at  $f = 1\text{MHz}$ .
6. From the graphs, obtain the cutoff frequencies.
7. On the probe screen, use the cursor to find the frequency that gives  $V_{out} = 0.707 V_{in}$ . Verify that this is at 1.591 kHz.
8. Print the graph obtained from step 5.
9. Print the output data file created in step 4.
10. Write a short conclusion.

## Experiment 2: Frequency Response of RC Circuits

### OBJECTIVE:

1. To use the series RC circuit as a high-pass filter.
2. To calculate and plot the critical frequency of a high-pass filter.
3. To calculate and graph the numerical gain of a high-pass filter.

### THEORY:

A high-pass filter is a device that passes only signal containing frequencies above a certain magnitude and diminishes and ultimately rejects those signals with frequencies below that magnitude. That frequency at the division between frequencies that pass and those that are rejected is called the **critical frequency** of the filter; it is determined by the values of R and C. The region above the critical frequency is called the **passband region**, whereas region below the critical frequency is called the **reject region** (Monssen, In Press, p-458).

### PROCEDURE:

1. Use the Schematic Editor to design a high-pass RC circuit. Choose  $R1 = 1\text{ k}\Omega$ ,  $C1 = 0.1\text{ }\mu\text{F}$ , and  $V_{in} = 10\text{ VAC}$ .
2. Select Setup from the Analysis Menu. A submenu appears. Choose AC Sweep from the Setup menu. Set up Sweep Parameters for frequencies from 100 Hz to 100 kHz by a factor of ten.
3. Run Electrical Rule Check, and then generate a Netlist.
4. Run Circuit Simulations using PSpice.
5. Use Probe waveform analyzer to obtain a graph of the output voltage. The output level varies from 0.62 V at  $f = 100\text{ Hz}$  to about 9.87 V at  $f = 100\text{ kHz}$  which is almost identical in magnitude to the input voltage.
6. From the graphs, obtain the cutoff frequencies.
7. On the probe screen, use the cursor to find the frequency that gives  $V_{out} = 0.707 V_{in}$ . Verify that this is at 1.591 kHz.
8. Print the graph obtained from step 5.
9. Print the output data file created in step 4.
10. Write a short conclusion.

### Experiment 3: Frequency Response of Low-Pass Active Filter

#### OBJECTIVE:

1. To show how an op-amp low-pass filter will pass frequencies below the **cutoff frequency ( $F_c$ )** with little or no attenuation and attenuate the frequencies above this point.
2. To measure, calculate, and plot the critical frequency of a high-pass filter.

#### THEORY:

A low-pass filter has a constant output voltage from DC up to a specific cutoff frequency. This cutoff frequency,  $F_c$ , is also called the 0.707 frequency, or the -3 dB frequency. A simple active low-pass filter is shown in Figure 1. The circuit configuration is a voltage follower. R and C at the noninverting input form a voltage divider. For frequencies of  $V_{in}$  below  $F_c$ , the capacitor's  $X_c$  is large, and nearly all of  $V_{in}$  is dropped across C. With  $V_{in}$  being large,  $V_{out}$  is also large. The gain of the stage is maximum for these lower frequencies. When the frequencies of  $V_{in}$  increase above  $F_c$ , the capacitor's  $X_c$  decreases and most of  $V_{in}$  is dropped across the resistor. In effect, capacitor C shunts much of  $V_{in}$  to ground. With  $V_{in}$  small,  $V_{out}$  is also small; hence, the gain of the stage is less than maximum for higher frequencies (Hughes, 1986).

#### PROCEDURE:

1. Use Schematic Editor to design an active low-pass filter. Choose  $R1 = 5\text{ k}\Omega$ ,  $C1 = 0.02\text{ }\mu\text{F}$ , op-amp 741C, and  $V_{in} = 1\text{ VAC}$ .
2. Select Setup from the Analysis Menu. A submenu appears. Choose AC Sweep from the Setup menu. Set up Sweep Parameters for frequencies from 1 Hz to 1 MHz by a factor of ten.
3. Run Electrical Rule Check, and then generate a Netlist.
4. Run Circuit Simulations using PSpice.
5. Use Probe waveform analyzer to obtain a graph of the output voltage. The output level varies from 1 V at  $f = 1\text{ Hz}$  to almost 0 V at  $f = 1\text{ MHz}$ .
6. From the graphs, obtain the cutoff frequencies.
7. On the probe screen, use the cursor to find the frequency that gives  $V_{out} = 0.707 V_{in}$ . Verify that this is at 1.591 kHz.
8. Print the graph obtained from step 5.
9. Print the output data file created in step 4.
10. Write a short conclusion.

### Experiment 4: Frequency Response of High-Pass Active Filter

#### OBJECTIVE:

1. To demonstrate how an op-amp high-pass filter will block or attenuate frequencies below the cutoff frequency ( $F_c$ ) and pass frequencies above this point.
2. To measure, calculate, and plot the critical frequency of a high-pass filter.

#### THEORY:

A high-pass filter attenuates all frequencies below a specific cutoff frequency  $F_c$  and passes all the frequencies above the  $F_c$ . Similar to the low-pass filter, the  $F_c$  for high-pass filter also occurs when  $V_{out} = 0.707 V_{in}$ . A simple Active high-pass filter is shown in Figure 1. With  $V_{in}$  to the noninverting input, C and R form a voltage divider. When  $V_{in}$  is below  $F_c$ , the  $X_c$  of C is large and drops most of  $V_{in}$ . The voltage drop across R is low and since the circuit is a follower,  $V_{out}$  is also low. When  $V_{in}$  increases above  $F_c$ , the  $X_c$  of C is low, allowing more  $V_{in}$  to be dropped across R; hence  $V_{out}$  is larger. This circuit has a slope of about -20dB/decade (Hughes,1986).

#### PROCEDURE:

1. Use Schematic Editor to design an active high-pass filter. Choose  $R1 = 5 \text{ k}\Omega$ ,  $C1 = 0.02 \text{ }\mu\text{F}$ , op-amp 741C, and  $V_{in} = 10 \text{ VAC}$ .
2. Select Setup from the Analysis Menu. A submenu appears. Choose AC Sweep from the Setup menu. Setup Sweep Parameters for frequencies from 100 Hz to 100 kHz by a factor of ten.
3. Run Electrical Rule Check, and then generate a Netlist.
4. Run Circuit Simulations using PSpice.
5. Use Probe waveform analyzer to obtain a graph of the output voltage. The output level varies from 0.62 V at  $f = 100 \text{ Hz}$  to about 9.88 V at  $f = 100 \text{ kHz}$  which is almost identical in magnitude to the input voltage.
6. From the graphs, obtain the cutoff frequencies.
7. On the probe screen, use the cursor to find the frequency that gives  $V_{out} = 0.707 V_{in}$ . Verify that this is at 1.591 kHz.
8. Print the graph obtained from step 5.
9. Print the output data file created in step 4.
10. Write a short conclusion.

**APPENDIX I: TRADITIONAL (BREADBOARDING) LABORATORY INSTRUCTION**

**Experiment 1: Frequency Response of RC Circuits****OBJECTIVE:**

1. To use the series RC circuit as a low-pass filter.
2. To calculate and plot the critical frequency of a low-pass filter.
3. To calculate and graph the numerical gain of a low-pass filter.

**THEORY:**

To use an RC circuit as a low-pass filter, we define the voltage across the capacitor as the output voltage. At high frequencies, the reactive capacitance approaches  $0 \Omega$ ; hence our output voltage must be approach  $0 \text{ V}$ . At very low frequencies, the large capacitive reactance prevents any current from flowing, causing the voltage across the resistor to be close to zero and the capacitor voltage to be approximately equal to  $V_{in}$  (Monssen, In Press, p-468).

**PROCEDURE:**

1. Obtain the following components;  $R1 = 100 \Omega$ , and  $C1 = 1 \text{ uF}$ .
2. Measure all components and record the measured values.
3. Construct a low-pass RC circuit.
4. Set the signal generator for a  $1 \text{ Hz}$  sine wave at  $V_{in} = 1 \text{ VAC}$ .
5. Check both voltage and frequency with the oscilloscope.
6. Use oscilloscope, measure and record the output voltage over the range of frequencies from  $1 \text{ Hz}$  to  $1 \text{ MHz}$  by a factor of ten. The output level varies from  $1 \text{ V}$  at  $f = 1 \text{ Hz}$  to about  $0 \text{ V}$  at  $f = 1 \text{ MHz}$ .
7. Tabulate listing of the data for the graph will facilitate obtaining the cutoff frequencies.
8. Plot the output voltage as a function of frequency.
9. Obtain the cutoff frequency from the plot. Verify that this is at  $1.591 \text{ kHz}$ .
10. Use plot to find the frequency that gives  $V_{out} = 0.707 V_{in}$ .
11. Write a short conclusion.

**Experiment 2: Frequency Response of RC Circuits****OBJECTIVE:**

1. To use the series RC circuit as a high-pass filter.
2. To calculate and plot the critical frequency of a high-pass filter.
3. To calculate and graph the numerical gain of a high-pass filter.

**THEORY:**

A high-pass filter is a device that passes only signal containing frequencies above a certain magnitude and diminishes and ultimately rejects those signals with frequencies below that magnitude. That frequency at the division between frequencies that pass and those that are rejected is called the **critical frequency** of the filter; it is determined by the values of R and C. The region above the critical frequency is called the **passband region**, whereas region below the critical frequency is called the **reject region** (Monssen, In Press, p-458).

**PROCEDURE:**

1. Obtain the following components;  $R1 = 1\text{ k}\Omega$ , and  $C1 = 0.1\text{ }\mu\text{F}$ .
2. Measure all components and record the measured values.
3. Construct a high-pass RC circuit.
4. Set the signal generator for a 100 Hz sine wave at  $V_{in} = 10\text{ VAC}$ .
5. Check both voltage and frequency with the oscilloscope.
6. Use oscilloscope, measure and record the output voltage over the range of frequencies from 100 Hz to 100 kHz by a factor of ten. The output level varies from 0.62 V at  $f = 100\text{ Hz}$  to about 9.88 V at  $f = 100\text{ kHz}$  which is almost identical in magnitude to the input voltage.
7. Tabulate listing of the data for the graph will facilitate obtaining the cutoff frequencies.
8. Plot the output voltage as a function of frequency.
9. Obtain the cutoff frequency from the plot. Verify that this is at 1.591 kHz.
10. Use plot to find the frequency that gives  $V_{out} = 0.707 V_{in}$ .
11. Write a short conclusion.

### Experiment 3: Frequency Response of Low-Pass Active Filter

#### OBJECTIVE:

1. To show how an op-amp low-pass filter will pass frequencies below the **cutoff frequency** ( $F_c$ ) with little or no attenuation and attenuate the frequencies above this point.
2. To measure, calculate, and plot the critical frequency of a high-pass filter.

#### THEORY:

A low-pass filter has a constant output voltage from DC up to a specific cutoff frequency. This cutoff frequency,  $F_c$ , is also called the 0.707 frequency, or the -3 dB frequency. A active low-pass filter is shown in Figure 1. The circuit configuration is a voltage follower. R and C at the noninverting input form a voltage divider. For frequencies of  $V_{in}$  below  $F_c$ , the capacitor's  $X_c$  is large, and nearly all of  $V_{in}$  is dropped across C. With  $V_{in}$  being large,  $V_{out}$  is also large. The gain of the stage is maximum for these lower frequencies. When the frequencies of  $V_{in}$  increase above  $F_c$ , the capacitor's  $X_c$  decreases and most of  $V_{in}$  is dropped across the resistor. In effect, capacitor C shunts much of  $V_{in}$  to ground. With  $V_{in}$  small,  $V_{out}$  is also small; hence, the gain of the stage is less than maximum for higher frequencies (Hughes, 1986).

#### PROCEDURE:

1. Obtain the following components;  $R1 = 5\text{ k}\Omega$ ,  $C1 = 0.02\text{ }\mu\text{F}$ , and op-amp 741C.
2. Measure all components and record the measured values.
3. Construct an active low-pass filter.
4. Set the signal generator for a 1 Hz sine wave at  $V_{in} = 1\text{ VAC}$ .
5. Check both voltage and frequency with the oscilloscope.
6. Use oscilloscope, measure and record the output voltage over the range of frequencies from 1 Hz to 1 MHz by a factor of ten. The output level varies from 1 V at  $f = 1\text{ Hz}$  to about 0 V at  $f = 1\text{ MHz}$ .
7. Tabulate listing of the data for the graph will facilitate obtaining the cutoff frequencies.
8. Plot the output voltage as a function of frequency.
9. Obtain the cutoff frequency from the plot. Verify that this is at 1.591 kHz.
10. Use plot to find the frequency that gives  $V_{out} = 0.707 V_{in}$ .
11. Write a short conclusion.

### Experiment 4: Frequency Response of High-Pass Active Filter

#### OBJECTIVE:

1. To show how an op-amp low-pass filter will pass frequencies below the **cutoff frequency ( $F_c$ )** with little or no attenuation and attenuate the frequencies above this point.
2. To measure, calculate, and plot the critical frequency of a high-pass filter.

#### THEORY:

A high-pass filter attenuates all frequencies below a specific cutoff frequency  $F_c$  and passes all the frequencies above the  $F_c$ . Similar to the low-pass filter, the  $F_c$  for high-pass filter also occurs when  $V_{out} = 0.707 V_{in}$ . A simple Active high-pass filter is shown in Figure 1. With  $V_{in}$  to the noninverting input, C and R form a voltage divider. When  $V_{in}$  is below  $F_c$ , the  $X_c$  of C is large and drops most of  $V_{in}$ . The voltage drop across R is low and since the circuit is a follower,  $V_{out}$  is also low. When  $V_{in}$  increases above  $F_c$ , the  $X_c$  of C is low, allowing more  $V_{in}$  to be dropped across R; hence  $V_{out}$  is larger. This circuit has a slope of about -20dB/decade (Hughes, 1986).

#### PROCEDURE:

1. Obtain the following components;  $R1 = 5\text{ k}\Omega$ ,  $C1 = 0.02\text{ }\mu\text{F}$ , and op-amp 741C.
2. Measure all components and record the measured values.
3. Construct an active high-pass filter.
4. Set the signal generator for a 100 Hz sine wave at  $V_{in} = 10\text{ VAC}$ .
5. Check both voltage and frequency with the oscilloscope.
6. Use oscilloscope, measure and record the output voltage over the range of frequencies from 100 Hz to 100 kHz by a factor of ten. The output level varies from 0.62 V at  $f = 100\text{ Hz}$  to about 9.88 V at  $f = 100\text{ kHz}$  which is almost identical in magnitude to the input voltage.
7. Tabulate listing of the data for the graph will facilitate obtaining the cutoff frequencies.
8. Plot the output voltage as a function of frequency.
9. Obtain the cutoff frequency from the plot. Verify that this is at 1.591 kHz.
10. Use plot to find the frequency that gives  $V_{out} = 0.707 V_{in}$ .
11. Write a short conclusion.

**APPENDIX J: THE ROUGH SCORES OF THE SUBJECTS**

Treatment	Pre	PostI	Treatment	PostII	PostIII
1	18	12	2	15	29
1	18	14	2	14	32
1	27	15	2	14	32
1	11	11	2	15	31
1	19	11	2	15	23
1	16	12	2	15	30
1	08	13	2	19	26
1	19	13	2	19	37
1	11	10	2	17	31
1	21	14	2	14	28
1	24	12	2	16	32
1	15	12	2	15	27
1	12	14	2	16	30
1	16	16	2	17	29
<hr/>					
Group One Means:	16.79	12.79		15.79	29.79
2	16	13	1	16	31
2	15	09	1	13	24
2	07	08	1	04	21
2	21	18	1	14	33
2	21	17	1	12	29
2	16	11	1	08	30
2	10	13	1	08	34
2	18	09	1	09	24
2	21	14	1	06	25
2	27	20	1	12	37
2	14	16	1	15	30
2	14	13	1	09	19
2	13	16	1	13	24
2	20	17	1	19	34
<hr/>					
Group Two Means:	16.64	13.86		11.29	28.21

Treatment: 1 - Traditional      2 - Simulation