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STUDENT ACHIEVEMENT AND AFFECTIVE TRAITS IN ELECTRICAL  
ENGINEERING LABORATORIES USING TRADITIONAL  
AND COMPUTER-BASED INSTRUMENTATION

by

Matthew D. Lammi

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

MASTER OF SCIENCE

in

Engineering and Technology Education

Approved:

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UTAH STATE UNIVERSITY  
Logan, Utah

2009

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## ABSTRACT

Student Achievement and Affective Traits in Electrical Engineering Laboratories  
Using Traditional and Computer-based Instrumentation

by

Matthew D. Lammi, Master of Science

Utah State University, 2009

Major Professor: Dr. Paul Schreuders  
Department: Engineering and Technology Education

Distance education has the ability to transcend distance and time, reaching students anywhere at any time, particularly those underrepresented in engineering. Engineering is a practice-oriented profession requiring an interweaving of scientific theory and applied hands-on activities. Despite the need for distance education in engineering, few studies have systematically investigated the impact of student achievement and attitude in distance engineering laboratories. This quasi-experimental research addressed that need by studying the cognitive and affective domains of achievement in engineering laboratories while employing computer-based and traditional oscilloscopes. The students from two courses, electrical engineering for nonmajors and electronic fundamentals, were randomly assigned into treatment and comparison groups. The students' achievement and attitudes were gauged using assessment instruments and an attitudinal survey. These results were statistically analyzed and conclusions are

discussed. The results suggested that computer-based instruments were viable in engineering laboratories.

(149 pages)

## ACKNOWLEDGMENTS

I would like to thank my committee members, Drs. Paul Schreuders, Ward Belliston, and Anhong Zhou who assisted, encouraged, and supported me in this research.

I want to thank my wife for her great support at school and at home. I also want to thank my children for their prayers and enduring my regular absence.

Matthew D. Lammi

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## CHAPTER I

### INTRODUCTION

Distance education has the ability to transcend distance and time, reaching students anywhere at any time (Bourne, Harris, & Mayadas, 2005). With an open environment and widely accessible resources, distance courses and learning activities become available to a diverse population of asynchronous learners: single parents, those limited by travel or access to a campus, working professionals, secondary educators, and those with disabilities (Keeler & Horney, 2007). Distance education has potential benefits for engineering education by mitigating the barriers of geography and costs and reaching underrepresented demographics such as rural (Rabbi & Arefin, 2006) and minority (Colom, Cruz-Pol, Marrero, Bringi, & Droegemeier, 2005) students.

Although engineering education could benefit from distance delivery, there are obstacles that need to be overcome. Two of these obstacles include costs and manually intensive laboratory activities (Feisel & Rosa, 2005). Engineering is a practice-oriented discipline requiring students to couple the mastery of scientific theory with practical skills. Kolb (1984) described the complementing relationship of concrete experiences (e.g., laboratories) and abstract reflection (e.g., lectures) as part of the total learning experience. Laboratories cement theoretical understanding, augment analytical reasoning, enhance troubleshooting ability, and strengthen psychomotor skills by employing a variety of the students' senses and aptitudes (Feisel & Rosa, 2005). Laboratories also aid in student motivation, engaging students in stimulating, collaborative, and real-world activities (Ma & Nickerson, 2006).

Educational engineering laboratories have not been easily facilitated over a distance partially due to the steep financial costs of laboratory equipment and the hands-on applications often found in engineering laboratory activities. Educational laboratories are integral to engineering studies, but how well will the learning objectives be achieved when delivered in a distance format? Despite the need for distance education engineering laboratories, few studies have systematically investigated the impact of student achievement and attitude in distance engineering laboratories (Feisel & Rosa, 2005; Ma & Nickerson, 2006). This study attempted to begin addressing the lack of research in student learning and attitude in engineering laboratories. As the computer is the prevalent interface for distance laboratories (Ko, Chen, & Cheng, 2005; Massachusetts Institute of Technology, 2005; Nickerson, Corter, Esche, & Chassapis, 2007; Ringwood & Galvin, 2002), this research specifically researched distance laboratories through the human-computer interface. This was accomplished by evaluating student achievement and affective characteristics in electrical engineering laboratories utilizing software-based instrumentation.

### Research Questions

This study sought to find if there were differences in student achievement and student affective traits in engineering laboratories utilizing traditional (stand-alone instruments commonly used in engineering laboratories) versus software-based instrumentation? Within this study, student achievement is a measure of cognition reflected by the extent to which students attain a specific learning objective or goal.

While affective traits are non-cognitive traits including, values, attitudes, self-concept, interests, and opinions. If differences exist between achievement and affective traits using traditional and software-based instrumentation, how do they compare?

### Problems and Subproblems

To better address the aforementioned questions, the following problems and subproblems were delineated.

1. Student achievement: Investigate if there were differences in student achievement while using a traditional or a software (computer-based) oscilloscope. Measurement of the student achievement required that the following subproblems be addressed:

- a. Why was student achievement analyzed?
- b. What laboratory activities were appropriate for electrical engineering learning goals in this research study?
- c. How was laboratory achievement assessed?
- d. How was validity of the assessment instrument determined?
- e. How were the data to be analyzed?

2. Student affective traits: Investigate if there were differences in students' affective traits between a traditional and software-based oscilloscope. The affective traits under consideration in this study were student satisfaction with the laboratory activities, the software-based and traditional scopes, instructor support, and preferences for laboratory activities, working with engineering software, and software-based

instrumentation. The subproblems for measuring the affective traits included:

- a. Why were affective traits analyzed?
- b. Which affective traits were analyzed and why were they chosen?
- c. How were the affective traits measured?
- d. How was validity of the assessment instrument determined?
- e. How were the data to be analyzed?

3. Generalizability: To further understand the applicability of the investigation and analysis, the characteristics of the student population were determined using the following subproblems:

- a. What demographics were chosen and how were they determined?
- b. To whom were the demographics compared?
- c. What was the participant pool?
- d. How was the participant group compared to the target population of engineering students?

### Research Design

This quasi-experimental research studied student achievement and affective traits, the cognitive and affective domains of learning respectively, in engineering laboratories employing traditional and software-based instrumentation. The research involved two courses at Utah State University (USU): ETE 2210 Electrical Engineering for Nonmajors and ETE 2300 Electronic Fundamentals. ETE 2210 is a course offered to engineering students outside the electrical engineering discipline with an introduction to fundamental

electrical engineering concepts that may be encountered in their collegiate and professional careers. ETE 2300 is a general education course offered to all students, yet it is primarily taken by students in the engineering and technology education (ETE) department. The ETE department offers majors in engineering and technology education, professional pilot, and maintenance management in aviation technology. Relevant learning objectives for the electrical engineering laboratory activities were stated and defined. The achievement instrument was derived from these learning objectives. A software oscilloscope was identified and implemented in the laboratories (Spexarth, 2007). Three laboratory modules were developed that could incorporate either the traditional or software oscilloscope. The students were randomly assigned into software-based oscilloscope and traditional oscilloscope groups. However, keeping with the historic practice in the course, the students were allowed to choose their laboratory partners. The students' knowledge and attitudes were gauged using an achievement assessment instrument and an attitudinal self-report survey. The data were analyzed with descriptive and inferential statistics.

### Hypotheses

The following null hypotheses were used below for statistical analysis.

1. There is no statistical significance in student achievement between engineering laboratories utilizing traditional instrumentation and laboratories utilizing software-based instrumentation.
2. There is no statistical significance in student affective traits between

engineering laboratories utilizing traditional instrumentation and laboratories utilizing software-based instrumentation.

### Assumptions

Assumptions that were made for this study are listed below. These assumptions were made because they could not be ascertained empirically. Additionally, the study identified these assumptions to maximize validity.

1. Laboratory instructors provided consistent instruction and assessment across all laboratory sections and laboratory groups.
2. Students were honest on the self-report survey and exams.
3. The software-based oscilloscope was equivalent to a traditional oscilloscope in function, user interface, and feel within the scope of this study.

### Limitations

The limitations in this study are listed below. All research includes biases and limitations (Glesne, 2006). The limitations help define the scope of the research.

1. The statistical sample only consisted of students from one university. Research has shown that each college and even department develop their own discourse and heuristics (Atman, Kilgore, & McKenna, 2008).
2. The university is predominantly Caucasian with few underrepresented demographics. This topic is further discussed in Chapters IV and V.
3. The study participants only included students who attended the university on



campus. There were no participants in this study who were enrolled in primarily distance courses.

4. This study only uses one form of software-based instrumentation.
5. This study only included two courses.

### Definition of Key Terms

The definitions of the terms or phrases below are for clarification and understanding with reference to this study.

1. Distance education – Any form of structured education where the student does not interact with the instructor face-to-face. Related terms may include: cyber, online, web-based, remote, computer assisted, asynchronous, synchronous, and e-learning.

2. Software-based instrumentation – The incorporation of software and hardware (computer) to acquire, analyze, and manipulate data similar to traditional measurement instruments. An example is a data acquisition unit with instrumentation software.

3. Traditional engineering laboratory – Educational engineering laboratories offered on-campus at an institute of higher education with face-to-face interaction between the instructor and the student. The laboratory also includes equipment to aid in the objectives.

4. Fundamentals of Engineering (FE) Exam – An exam given to engineering students or graduates who aspire to embark upon the road to professional licensure (Lindeburg, 2002).

5. Affective traits – Traits that are represented in the affective domain including,

values, attitudes, self-concept, interests, and opinions.

6. Student achievement – The measure of cognition reflected by the extent to which students attain a specific objective or goal.

7. Simulation – A software tool used to replicate a system or process.

Educational simulations may be used as a learning activity to either convey a concept or teach a process.

## CHAPTER II

### REVIEW OF LITERATURE

Distance education has potential benefits for engineering education by overcoming the barriers of geography and costs and reaching underrepresented demographics (Bourne et al., 2005; Keeler & Horney, 2007). Despite the need for distance education in engineering, few studies have systematically investigated the student achievement and the affective domain in distance engineering laboratories (Feisel & Rosa, 2005; Ma & Nickerson, 2006; National Academy of Engineering, 2005). The state of the current knowledge in these areas hinders educational researchers' abilities to make informed inferences and decisions regarding the implementation and assessment of distance education in engineering laboratories. The results of the review were used to frame this research study.

#### Purpose of the Review

The purpose of this literature review is to synthesize and critique current and historical literature related to distance educational laboratories with an emphasis on software-based instruments. The objectives of this review were to:

1. Describe the current state of research concerning student achievement and affective traits in distance education, particularly in engineering laboratories utilizing traditional or software-based instruments.
2. Discuss the strengths, limitations, and issues in the literature.
3. Discuss methodologies for analyzing the data.

## Role of Educational Laboratories in Engineering

There is a general consensus for the need of laboratories in the engineering curriculum (Feisel & Rosa, 2005; Grinter, 1955; Ko et al., 2005; Ma & Nickerson, 2006). However, the roles and expectations of educational laboratories in engineering have not come to a general consensus (Ma & Nickerson) hindering the progress of research in this area (Feisel & Rosa). From a survey of over a five year period in the late 1990s of the *Journal of Engineering Education*, the keyword “laboratory” accounted for less than seven percent of all the keywords (Wankat, 2004).

To further clarify and establish the role of engineering laboratories, ABET, Inc. along with engineering education professionals convened to address the matter (Feisel et al., 2002). The result was a list of 13 objectives for successful engineering laboratories (Carnevale, 2002) shown in Table 1 and described in detail in Appendix A. Although these objectives have not been formally validated, they assist in developing sound laboratory objectives and activities. The objectives spread across all three domains, cognitive, psychomotor, and affective, in Bloom’s Taxonomy (Bloom, 1956) ranging from simple to complex outcomes. Modeling, design, analysis, and creativity employ higher order cognition. Instrumentation and sensory awareness objectives are found in the psychomotor domain. Affective skills are required for communication, teamwork, and ethics. Also included in the affective domain is the motivational aspect of engineering laboratories (Crosthwaite & Lee, 1994). The laboratories may also introduce the student to experiences drawn from engineering practice, lending further relevance to the learning activity. Students benefit from practical examples, real world applications, and hands-on

Table 1

*Objectives of Engineering Laboratories (Carnevale, 2002)*

Objective	Description
1	Instrumentation: Apply appropriate tools to make measurements
2	Models: Identify the strengths and limitations of models
3	Experiment: Devise an experimental approach
4	Data analysis: Demonstrate the ability to collect, analyze, and interpret data
5	Design
6	Learn from failure
7	Creativity
8	Psychomotor: Demonstrate competence engineering tools and resources
9	Safety: Identify health, safety, and environmental issues
10	Communication
11	Teamwork
12	Ethics in the laboratory
13	Sensory awareness: Use the human senses to gather information

activities often found in laboratories, increasing motivation and mitigating apathy (Schluz, 1991). ABET (2007) has also included learning objectives in their accreditation criteria similar to the outcomes listed in Table 1 (Appendix B).

To appropriately develop successful learning activities and assessments, the objectives must be clearly defined (Gronlund, 2006). Feisel and Rosa (2005) claimed that not many educational laboratories have explicit and relevant objectives. This is due, in part, to the faculty reward system focusing primarily on research accomplishment rather than on instructor pedagogy (Feisel & Rosa). Additionally, writing activities to objectives is not common practice in most curricula (Wiggins & McTighe, 2005). Laboratories are often seen as supplemental to lectures. Even in their current state, engineering

laboratories are useful and play an integral part of the curriculum. However, engineering laboratories can be enhanced by clearly defining their roles and objectives.

### Distance Engineering Laboratories

Engineering continues to struggle with the idea of how to best provide laboratory experiences (Bourne et al., 2005; Carnevale, 2002; Corter et al., 2007; Feisel & Rosa, 2005; Ma & Nickerson, 2006). This challenge is also manifest in providing distance laboratories. The response to this challenge has triggered the development of multiple methods used to deliver distance laboratories. The methods are influenced by learning effectiveness, design and implementation costs, feasibility, availability of student resources, and the impact on faculty (Bourne et al.). A variety of distance formats are presented below.

#### *Web-Based Materials*

The most common form of distance education comes from web-based courses (Ko et al., 2005). The course material is offered for viewing online or it can be downloaded. Software-based bulletin boards are used to post announcements, assignments, exams, and even grades. Discussion panes allow the students to discuss the course material and may be recorded for future viewing editing or analysis. There are also online content pages that allow for multiple editors and writers, coined Wikis. Online office hours are generally arranged and online e-tutoring is made available. Asynchronous communication may also exist through email. Blackboard Vista™ (Blackboard Inc., Washington, DC) and Adobe® Acrobat Connect™ (Adobe Systems,

San Jose, CA) are common commercial tools used to deliver courses over the web. Web-based courses are prominent due to the fact that the software already exists and is well known. Although web-based solutions may be prevalent, they have in the past fallen short in providing realistic hands-on laboratory experiences because the students generally only interacted with a computer screen and a mouse and not actual laboratory instruments and component diminishing authentic and transferable experiences (Feisel & Rosa, 2005). Web-based laboratories are further explained below.

#### *Video Delivery*

Video is another alternative that is either delivered through live video conferencing or asynchronously for later viewing. Live video may be streamed through the internet, sent across a terrestrial or satellite link, or broadcast on a television station. A recorded video may also be included with the course material sent to the student (Sala, 2005). Video is often augmented with web-based delivery (Feisel & Rosa, 2005). For example, the online masters of engineering through the Electrical Engineering Department at USU incorporates live video streaming as part of the Adobe Connect software suite (USU, 2008a). Although video aids in the student's perception of presence, video alone does not replace face-to-face interaction (Koen, 2002).

#### *Laboratory Kits*

Laboratory kits can also be sent to the student. In an electrical engineering laboratory, these kits may include small electronic components and prototype boards. However until recently, the analytical instrumentation has been limited in function and/or

cost-prohibitive (Alhalabi, Hamza, Hsu, & Romance, 1998). There have been recent improvements in analytical instruments using personal computers (State University of New York, 2008) and their components which have reduced the costs (National Instruments, 2007) as demonstrated by National Instruments USB data acquisition units, Lego Mindstorm, or the Infinity Project kits. Lego Mindstorm is controller unit using Lego products accompanied with educational activities and design challenges. Lego Mindstorm is primarily used in robotics it may also be used in other engineering and science curriculum (LEGO, 2008). The Infinity Project is a yearlong high school course intended to engage students in high-tech engineering projects using a curriculum and a technology kit (Infinity Project, 2008). These kits are used to teach electrical engineering concepts to young students with engaging and meaningful activities.

#### *Arranged Laboratories*

Another option is to have the distance student make arrangements with local educational or professional laboratories (Feisel & Rosa, 2005). This idea is well suited for students who have laboratory access through their current employment. Students may also seek sponsorship from an institution of higher education that is in close proximity to perform laboratory experiments.

#### *Simulations*

Of the literature surveyed, simulations are the most common single form of distance engineering laboratories (Campbell, Bourne, Mosterman, & Brodersen, 2002; Feisel & Rosa, 2005; Ko et al., 2005; Ma & Nickerson, 2006). Educational simulations



are software tools used to replicate systems or processes in order to facilitate learning. If not the primary component of the laboratory, simulations are used to augment other methods such as remote and traditional laboratories. Simulations differ from web-based laboratories in that simulations do not have to be performed remotely. Simulations are often run on computer terminals within the laboratory setting itself (Campbell et al.). Simulations allow the student to interact gaining experiential knowledge (Crosthwaite & Lee, 1994). Additionally, the simulations can provide graphics, animations, collaboration when data are recorded (Bennet, 2005), and give students instant feedback (Ringwood & Galvin, 2002). This delivery is improved through the addition of virtual failures and random variations (Feisel & Rosa). When experiments are too large to reproduce or where there might be a considerable amount of danger a simulation is valuable alternative (Carnevale, 2002). Furthermore, the simulations generally offer the advantages of reduced costs and time of development when compared to remote laboratories. Alhalabi and colleagues asserted (1998) that regardless of quality and relevance, simulations will never completely replace engineering laboratories.

### *Remote Controlled*

Remote controlled online laboratories are able to partially reproduce an educational laboratory at a distance (Alhalabi et al., 1998). Although the students do not physically interact with the equipment in the same room, they remotely control the equipment through software. To improve the sense of presence, an online video is often added to show the equipment in operation (Sala, 2005). This type of laboratory experience requires the most complex architecture and introduces additional points of

failure (Ko et al., 2005). iLabs is an example of a remote controlled laboratory site maintained by Massachusetts Institute of Technology (Massachusetts Institute of Technology, 2005).

### *Hybrid Solutions*

Although each method may be used individually, a common approach is to use a combination of deliveries. The education experiment Neptune Consortium uses simulations with a web-based approach augmented with video (Sala, 2005). Both Utah State University and State University of New York offer degrees in electrical engineering using a hybrid approach (State University of New York, 2008; Utah State University, 2008a). The remote laboratories also enhance their delivery methods with the World-Wide-Web and video (Alhalabi et al., 1998).

### Software-Based Instrumentation in Distance Laboratories

The operation of instruments and manipulation of components is important to the hands-on engineering laboratory (ABET, 2007; Bourne et al., 2005; Feisel et al., 2002). Yet, one of the primary impediments to distance engineering laboratories is the failure to meet the objective of “applying appropriate sensors, instrumentation, and/or software tools to make measurements of physical quantities” (Bourne et al.; Feisel et al.). The first objective of this study is to further understand software-based instrumentation as a component to distance laboratories.

Simulations address the limitations of costs and wide spread availability, however they commonly lack: noise or the inherent variation found in the physical world (Feisel &

Rosa, 2005), presence (Koen, 2002), and realistic problem solving skills (Alhalabi et al., 1998). Software-based instruments may help mitigate these issues. Software-based instruments are those instruments that incorporate computer hardware and software to acquire data. While software-based instruments are integral to simulations, they are not limited to the simulated domain. Software-based instrumentation is also used in conjunction with remote laboratories, nondistance educational laboratories, and distance laboratory kits. Software-based instruments have the advantage of reduced costs, a common and familiar platform (the computer), and near-ubiquitous availability through the internet. Furthermore, when software-based instruments are coupled with hands-on laboratory delivery methods, the laboratories can maintain the variability inherent in the natural world.

The software-based instruments must not take away or distract from the laboratory objectives. Both the students' and the instructor's time must be considered. As with traditional as well as software-based instrumentation, students' learning will be diminished if too much attention is given to instrument training. Yet, software-based instruments do offer the advantage of being mediated by a personal computer, as computer literacy is high amongst college students (Olsen, 2000). The software-based instrument must also relate to the traditional instrument by giving the end user a similar experience to a traditional laboratory. To ensure broad application, the time to deploy the software-based instruments must be kept to a minimum, reducing the demand on instructors' resources. Regardless of the tool's effectiveness, it will not obtain widespread adoption if the training is overly cumbersome.

## Student Achievement Assessment in Engineering Laboratories

Student achievement is an important measure of success for most educational studies (Becker & Maunsaiyat, 2004; Campbell et al., 2002; Crosthwaite & Lee, 1994; Sonnenwald, Whitton, & Maglaughlin, 2003) and is part of the ABET engineering accreditation process (ABET, 2007). However, few studies of engineering and scientific laboratories have produced empirical data of student cognition. In a September 2006 review of literature, Ma and Nickerson found that only 5% (n = 3 of 60) of articles were based on empirical data (Ma & Nickerson, 2006). The literature review search included three electronic databases: ACM, IEEE, and ScienceDirect. Additionally, the keywords included “remote laboratory or remote experiment,” “virtual laboratory or virtual experiment,” “real laboratory or real experiment,” and “hands-on laboratory or hands-on experiment.” This number has increased since 2006 as evidenced by further empirical studies (Castrillo et al., 2008; Takayama, 2007).

### *Formative and Summative Assessment*

In order to gauge student learning in laboratory activities, proper assessment must be administered. Formative evaluations form an important part of student assessment in the laboratory (Wiggins & McTighe, 2005). Formative assessments differ from summative assessments in that formative evaluations are administered in an ongoing basis while summative evaluations are performed at the conclusion of a unit or course. Formative evaluations allow for timely feedback of the learning in laboratory activity to both the instructor and the student. The instructor can adapt pedagogy and instruction

accordingly. Within the educational laboratory setting problems and anomalies will surface. These issues can be with the equipment, student misunderstanding, or the laboratory activity itself. If the instructor is keenly aware of these issues in the laboratory changes can be made or accommodated. When formative assessments are performed frequently, they also allow for broader or deeper evaluations of content (McKeachie, 2006). The students can also measure their progress on a more regular basis increasing their satisfaction with the laboratory curriculum (Bourne et al., 2005). Formative assessments give the student a better understanding of how their achievement will be evaluated and how they will evaluate themselves. This self-awareness of learning is commonly termed metacognition (Brown, 2001). Laboratories allow the student to practice metacognition while engaged in an activity as opposed to passively listening to a lecture.

Summative assessment is an assessment of learning and is used to determine learning up to a certain point. Summative assessments are often administered as a written test and are used to assign scores (Gronlund, 2006). However, summative assessments may also be used as an evaluation of how well the instructor is performing in helping the students learn the material (McKeachie, 2006). Laboratories are often grade summatively by evaluating the laboratory handbook or reports. Summative assessments should be derived from and evaluated against the primary learning objectives for the laboratory (Wiggins & McTighe, 2005). Summative assessment is characterized as assessment *of* learning, whereas formative assessment is assessment *for* learning (Gronlund). In the laboratory, summative assessments may be taken for a final “pass-off.”

*Research Design for Student Achievement*

Tests are the most commonly utilized form of assessment in the classroom (Gronlund, 2006). Therefore, testing has become a common research method to assess student achievement. Although there exist robust research methods such as the Solomon Four-Group and factorial designs, time and capital limitations have restricted most student achievement research to pretest-posttest designs (Campbell et al., 2002; Corter et al., 2007). The Solomon Four-group and factorial designs employ more than just one control and one treatment group. The Solomon Four-group uses two control and two treatment groups to isolate pretest sensitivity (Gall, Gall, & Borg, 2007). The results of the pretest form the baseline for student achievement. An intervention is administered to the treatment group only. Then the posttest is administered and compared to the baseline. Laboratories may be assessed outside the laboratory setting to further triangulate the data. Research studies assessed laboratory student achievement using quizzes and tests during lecture periods (Campbell et al.; Ringwood & Galvin, 2002). When time is less of a constraint, a delayed posttest may also be included which adds the learning retention component to the assessment (Becker & Maunsaiyat, 2004).

Pretest-posttest control-group designs are effective in controlling for many threats to internal validity, such as history, maturation, testing, instrumentation, regression towards the mean, differential selection, experimental mortality, and selection-maturation interaction (Gall et al., 2007). However, the design might be subject to pretest sensitivity, diffusion, and compensatory rivalry of the control group. The pretest-posttest design allows for the controlling of the independent variable and measuring of dependent

variables in a before and after design (Gall et al.).

### *Student Achievement Assessment Instruments*

Student achievement may be assessed by a variety of methods including informal observation, tests, performance assessment, product assessment, and portfolios (Gronlund, 2006; McKeachie, 2006; Wiggins & McTighe, 2005). Testing is a prevalent assessment tool for student achievement. Tests may consist of true-false, multiple choice, matching, comparison, open-ended questions, extended- and restricted-response essay questions (Gronlund). Educational laboratories for engineering often include two components: a performance assessment and an evaluation of the student's written work. If a rigorous evaluation of the performance is achieved, each student is able to demonstrate the minimum capabilities specified by the objectives (Gronlund). Engineering assessments often involve multiple choice questions coupled with open-ended problems that involve mathematical and scientific equation manipulation. Multiple-choice questions have the advantage of covering a broad swath of learning objectives in a relatively quick manner and are easily administered. Furthermore, multiple choice questions are found in many standardized tests such as the FE Exam (Lindeburg, 2002) and other professional licensing evaluations such as the Law School Admissions Test, Graduate Management Admissions Test, and the Graduate Record Examination. However, multiple choice questions are subject to guessing and do not generally allow the assessor to probe why the student did not understand or meet the objectives. Tests may be administered during class or offered outside of class online or in a testing facility with various advantages in both methods. Congruent with lecture-type or

classroom assessments, laboratory assessments may employ test questions generally coupled with a performance assessment.

The individual test items and their placement is the interface with the students. Particular attention must be given to how the items are written and how they correlate with the learning objectives. Multiple choice and true-false questions must include distracters (incorrect answers) that are viable in each item. Much of the engineering education research does not address test item validity (Campbell et al., 2002; Corter et al., 2007; Ma & Nickerson, 2006; Ringwood & Galvin, 2002). There are sources for individual test items and they may be selected from test items beds, professional licensing practice exams, textbooks, and previous research. Laboratory activities may also include problems and exercises in addition to procedural type tasks.

#### *Analysis of Student Achievement Data*

The alpha level set for this study  $\alpha = .05$ . Therefore, the  $p$ -value was set to  $p < .05$  for statistical significance. The  $p$ -value is used in statistical hypothesis testing and is based on the probability of arriving at a result that is statistically different than the hypothesis. Varying  $p$ -values are used depending on the nature of the study. The most common  $p$ -value in social science is set to 0.05 (Gall et al., 2007).

The American Psychological Association's (APA) has made recommendations for data analysis in the social sciences so as not to become over reliant to the Null Hypothesis Testing (NHT; American Psychological Association, 2001). Traditionally, NHT has included setting a statistical standard by which the results would be compared to ascertain if there was a statistical significance. However, if an experiment had a small



number of participants or impact, the results could be statistically significant and be reported. This could be misleading without knowing the proper additional facts. Although some of the recommendations are controversial (Fidler, 2002), the suggestions are a move to improve the credibility of the statistical research findings. Among some of the suggestions that APA puts forth include reporting effect size (Nickerson et al., 2007), confidence intervals, and statistical power. These suggestions have direct application in educational research. Although a study might have statistically significant results, small effects sizes and low power might otherwise render the research irrelevant.

Laboratory achievement has been analyzed using various statistical methods. Student achievement data is often seen as gain scores resulting from an assessment test. Gain scores are well suited for analyses of variance or covariance and have been used in multiple studies (Campbell et al., 2002; Corter et al., 2007; Gall et al., 2007; Sonnenwald et al., 2003) In addition to APA's aforementioned recommendations, linear model analyses are other powerful statistical tools which address many of the shortcomings of analysis of variances (ANOVA; Cohen, 2007). The limitations of ANOVA include the limitation of the independent variable to categorical data, testing of factors that may not be of interest, strict assumptions of using a balanced design, and limited tools for diagnosing and correcting data that do not fit the assumptions. Analysis of covariance (ANCOVA) is an analysis method that allows for testing of other variables, covariates, while comparing the variances of the main factors (Pandy, Petrosino, Austin, & Barr, 2004). ANCOVA is based on the linear regression model and also shares similar methods as the ANOVA in the reporting or output of data analysis.

## Affective Traits Assessment in Engineering Laboratories

Student achievement is not the sole measure of success in engineering laboratories. Student affective traits like attitude, satisfaction, and motivation are integral, if not foundational, to a successful education experience (ABET, 2007; Bloom, 1956). Student cognition is only one component necessary for proficient problem solving skills (Jonassen, 2000). These traits are not easily measured employing a cognitive assessment instrument like a written test, but are more effectively assessed by an instrument such as a self-report survey. In addition to providing insight into the affective domain, affective traits may also correlate with other variables in the cognitive and psychomotor domains. Certain affective traits like motivation and preferences may directly impact how well a student performs on an achievement test or performance evaluation (Felder & Silverman, 1988).

Affective traits have been measured in various studies throughout the distance education domain (Campbell et al., 2002; Corter et al., 2007; Ringwood & Galvin, 2002). These studies included self report questions regarding preferences, satisfaction, and effectiveness of the control and treatment methods. Nickerson and colleagues (2007) measured ease of use, overall satisfaction with the delivery methods, instructor support, teamwork, and reliability of the software-based instruments. Campbell and colleagues (2002) included questions regarding ease of use, overall satisfaction with the laboratory modules, instructor support. Rutherford (2007) included demographics in his study to further analyze the study participants' responses. Demographics may also be included the data analysis. Variables such as age, gender, socioeconomic status (SES), and city size

may play a significant role in either cognitive or affective outcomes (Philbin, Meier, Huffman, & Boverie, 1995). Engineering laboratory assessments of affective traits allows the researcher to not only see a change in knowledge, but also perhaps the reasoning behind the scores.

### *Research Validity*

There are studies that found student achievement to be nearly equivalent in distance education and traditional delivery (Bourne et al., 2005; Campbell et al., 2002; Corter et al., 2007; Ringwood & Galvin, 2002). These specific studies did not thoroughly address all facets of validity. When random selection is not implemented issues of internal validity are of concern. Differences between the types of students who volunteer for distance courses may vary greatly from those who are enrolled in traditional settings (Gall et al., 2007). Validity is further compromised when participants are not randomly assigned to the treatment or control groups.

Study participants are assumed to answer the self-report measures honestly and openly (Rutherford, 2007). Students might feel obligated to make a favorable response if it is not anonymous. Furthermore, a survey is also subject to instrument validity and reliability. Merely including a survey does not imply valid and reliable results. To begin validating the instrument the survey should accurately measure what it intended to measure. Furthermore, the instrument should be triangulated from other sources to ensure reliability. Although these research studies employed surveys to evaluate affective traits, the instrument sources were not described (Campbell et al., 2002; Corter et al., 2007; Ringwood & Galvin, 2002).

Corter and colleagues (2007) found student achievement to be equal or better with the distance treatment, yet students rated the control or previously used method higher in the self-report measures. Corter postulated that the laboratory experiment was unique in its complexity; therefore, a hands-on approach might have augmented the learning. Perhaps the students might have been reticent in taking on a new approach in learning.

### *Analysis of Survey Data*

Like parametric data, surveys are also evaluated by descriptive statistics. The descriptive statistics allow the evaluator to make summaries or describe the data. Additionally, survey data may be analyzed for inferences, where one tries to draw conclusions that extend beyond the immediate data alone (Gall et al., 2007). Some surveys do not fit the assumptions of parametric data: (a) normal distribution, (b) ratio or interval scales, and (c) homogeneity of variance (Cohen, 2007).

Surveys are sometimes analyzed with nonparametric test such as the Mann-Whitney U test and chi-squared test (Gall et al., 2007). The Mann-Whitney U test is used for ordinal data, such as the results of a Likert scale. The test is used to determine whether the distribution of the scores in two samples differ significantly from each other (Cohen, 2007). The chi-square test is performed on categorical data arranged in frequency counts (Greenwood & Nikulin, 1996). This test compares the set of expected frequencies against observed or actual data. However, surveys employing a Likert scale can be seen as data on a continuum if the number of study participants is high (Zywno, 2003). This data may be included into ANCOVA analyses if the data fits the assumptions of parametric data (Ali & Elfessi, 2004).

## CHAPTER III

### METHODS AND PROCEDURES

The purpose of this study was to: (a) determine if there was a difference in student achievement in an engineering laboratory when a traditional versus software-based oscilloscope was used; and (b) determine if there was a difference in student affective traits in an engineering laboratory when a traditional and software-based oscilloscope was used; and (c) if there were differences between the traditional and software-based oscilloscope, determine how they compare. These findings may then be applied to the role of software-based instruments in distance education laboratories.

#### Study Design

##### *Setting and Studied Population*

*Laboratory setting.* This study included students from two sophomore level courses in electrical engineering taught at USU in Logan, UT during the Spring semester of 2008, ETE 2210 Electrical Engineering for Nonelectrical Engineers and ETE 2300 Electronic Fundamentals. There were 27 participants in the electrical engineering course and 34 participants in the electronic fundamentals course for a total of 61 participants. The groups were randomly assigned with the treatment group including 31 participants and the control group including 30 participants. These courses shared widely overlapping curriculum and objectives but were intended for distinctly different audiences. The course descriptions and syllabi are included in Appendices H and I for electrical engineering course and electronic fundamentals respectively. There was one laboratory section for

electrical engineering course and three sections for electronic fundamentals.

The laboratory included 24 workstations of which 16 were equipped with traditional oscilloscopes (models # 2235, Tektronix, Beaverton, OR) and eight were equipped with software oscilloscopes. The workstations included the necessary accoutrements for basic alternating current (AC) electrical engineering course activities, including oscilloscopes and function generators (Appendices J-L). The laboratory activities were designed to be completed within a 3-hour session. The laboratory experiences in the course curriculum were to enhance conceptual understanding of AC electronics, gain familiarity with electrical measurement equipment, expand problem-solving capabilities, and strengthen design skills in the electrical engineering domain.

*Instructors.* The instructor for the study was an associate professor, Ward Belliston, with over 35 years of experience in electronics instruction. Two laboratory assistants, one of whom was the researcher, rotated through the four different sections of the laboratory.

*Student population.* The courses differed in student makeup with ETE 2210 offered to mechanical, aerospace, biological, environmental, and civil engineering students. The fundamentals of electronics course ETE 2300 was offered to students in the Engineering and Technology Education (ETE) Department and as a general education course. The students in the ETE department were pursuing bachelor's degrees in engineering and technology education, aviation maintenance management, and professional pilot.

### *Informed Consent*

This study's application was approved by the Institutional Review Board (IRB) in March of 2008 and is identified by the number 2028 (Appendix M). The research data was protected according to the IRB recommendations and procedures. The collected data was password protected on the researchers' computers. Confidential information was only accessed by the researchers. This point was also reflected in the consent form (Appendix N) and reiterated in the survey. The confidential information will be stored for 3 years (2011) and then destroyed.

The students were asked to voluntarily participate in the study and sign a consent form prior to the laboratory activities. Participating students were randomly assigned to the treatment and control groups. Each participant was coded on the last four digits of an administrative number that is assigned to each student by USU that is referred to as the A-number. The random assignment was executed by sorting the code and assigning every other student to the treatment group. The random assignment helped to reduce differences between the control and the treatment groups. To address internal validity by reducing potential resentment of the groups, students were assured that one instrument was not superior to the other.

### *Laboratory Modules*

Schulz (1991) recommended showing relevance to the student's particular field to incite student motivation and these modules attempted to address this need. The three laboratory modules have been chosen due to their wide applicability and broad scope and are found in Appendices J, K, and L. The laboratories were assessed by the laboratory

instructors if the students completed the minimum performance specific to each laboratory. The three laboratories and their learning objectives were to:

1. Introduction to AC measurements – gain familiarity with the oscilloscope and measure electrical signals with respect to time.
2. Frequency Response of RC and RL Networks – plot the voltage/current versus frequency, calculate phase angles, and calculate the critical frequency of the network.
3. Resonances of an RLC Circuit – plot voltage/current versus frequency, demonstrate how input impedance varies with frequency, understand the quality factor and bandwidth, and validate the equations for the resonant frequency of a series resonant circuit.

The participants were required to receive a laboratory instructor sign-off for each laboratory activity. The laboratory activities and results were evaluated by the laboratory assistant or professor. Then a signature was given if the student demonstrated proficiency with the laboratory tools and content. All of the participants finished the three laboratory activities within the allotted 3-hour time-frame.

### *Study Methodology*

This research was performed using a quasi-experimental pretest-posttest nonequivalent control group design. As the university course registration process is not fully random, a true experiment was not possible. The researchers were not able to assign students randomly to the courses. The students chose their own class schedule and are not assigned to any course. Therefore, a true experiment was not possible. Since the participants had potentially distinct characteristics by course enrollment, validity



concerns were mitigated by randomly assigning the treatment and control groups without regard to course enrollment.

### *Independent Variable*

The laboratory activities in this research required an oscilloscope with a peak-to-peak input voltage range of 20 volts, a 10 kS/s sampling rate, and variable volts and time per division. Student achievement will be measured varying on the type of oscilloscope used. The independent variable in this study was the type of oscilloscope used in the laboratory, traditional or software. The “traditional” oscilloscope was a Tektronix model 2235 100 MHz oscilloscope. The traditional oscilloscope’s capabilities surpassed the needs of the courses in this study, as these oscilloscopes were designed by the manufacturer to meet the demands of 4-year Bachelor’s degree in electronics and beyond. The software oscilloscope had a graphical user interface (GUI) that closely mimicked a traditional oscilloscope. The software oscilloscope used in this study was supported by a National Instrument data acquisition unit NI USB6008 DAQ and LabVIEW software due to its flexibility, ease of implementation, low cost, and it meets the requirements of the laboratory activities. The software routines were developed by Spexarth (2007) and can be found on the internet as freeware. The oscilloscope interfaces and specification tables are shown in Figure 1 and Table 2, respectively.

### Methods Relevant to Research Question One

Student achievement was the dependent variables in this portion of the study. Within this study, student achievement was a measure of cognition reflected by the extent

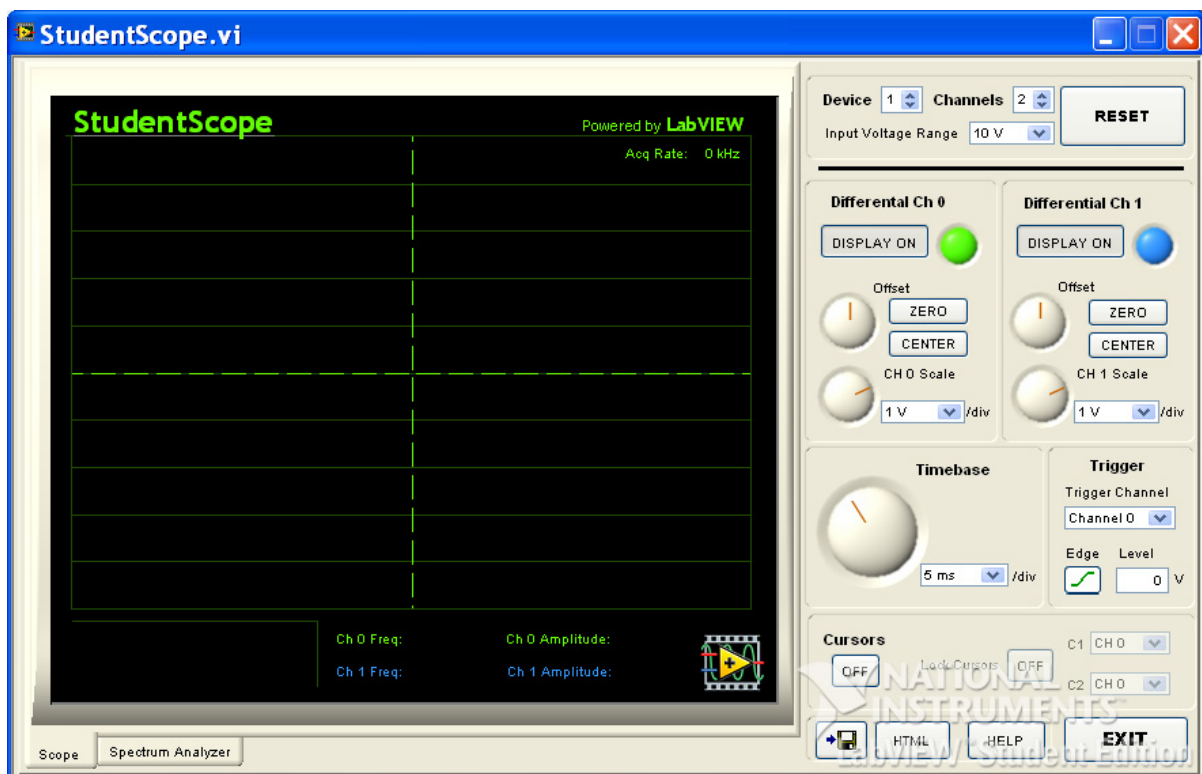
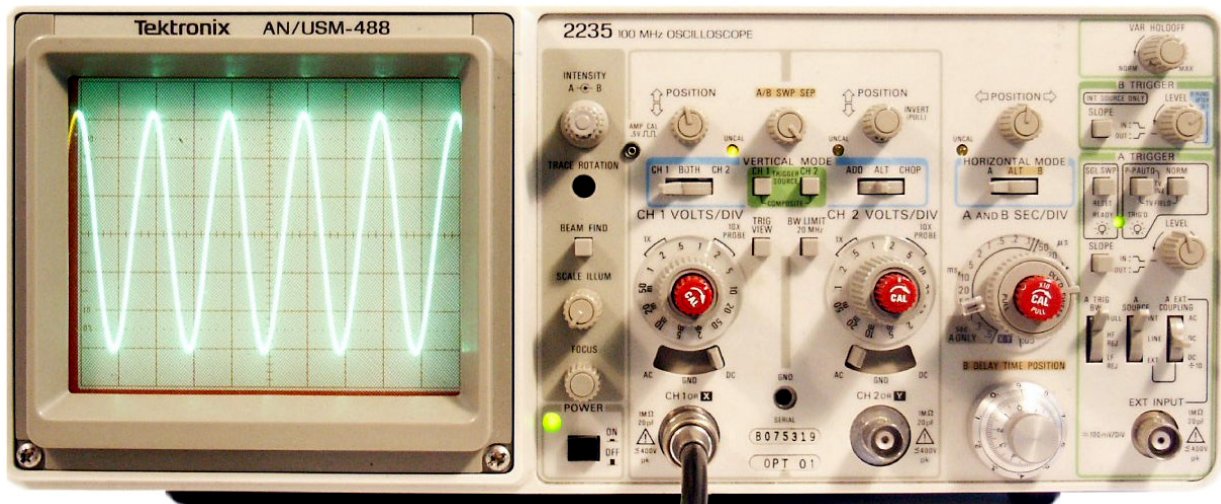


Figure 1. Traditional and software oscilloscopes user interfaces (Test Equipment Depot, 2008). Both oscilloscopes have two inputs, variable voltage and time scales, a basic trigger function, and offsets. The software oscilloscope also has digital voltage and frequency displays and a cursor. The traditional oscilloscope has more complex mathematical functions, an advanced trigger function, and a frequency range up to 100 MHz versus 25 KHz for the 6009 software oscilloscope.

Table 2

*Oscilloscope Comparison Table*

Oscilloscope	Tektronix	Computer-based	Laboratory needs
Number of inputs	2	2	2
Voltage range (V)	100	20	20
Voltage resolution	2mV sensitivity	5 mV sensitivity	10 mV sensitivity
Bandwidth	DC to 100 MHz	DC to 25 kHz	DC to 10 kHz
Trigger function	Yes	Yes	No
Offset function	Yes	Yes	Yes
Digital voltage readout	No	Yes	No
Cursors	No	Yes	No
Mathematical functions	Yes	No	No
Digital frequency readout	No	Yes	No
Appearance	35 knobs/switches	21 knobs/switches	N/A

to which students attain a specific learning objective or goal.

*Achievement Assessment Instruments*

*Pretest.* The students' achievement was assessed by a pretest-posttest design. The pretest was given during a lecture period to all the study participants prior to covering the specific topics. The pretest was also given before the laboratory activities. The pretest established a baseline to be later compared against the posttests. The pretest consisted of 30 items randomly ordered covering three topic areas in electrical engineering: alternating current (AC) measurements, the frequency response of resistive/capacitive (RC) and resistive/inductive (RL) circuits, and resonance in a resistive-inductive-capacitive (RLC) circuit. The items on the pretest were drawn from multiple sources: Boylestad's *Introductory Circuit Analysis*, 11<sup>th</sup> edition (Boylestad, 2007) and Floyd's

*Electronics Fundamentals*, 7<sup>th</sup> edition (Floyd, 2007), Boylestad's test item generator (Boylestad), and Lindburg's 2002 FE Exam preparation book (Lindeburg, 2002). The items were chosen if they were found in more than one source, well written, and germane to the topic. Although the questions were not identical, they were similar in scope and purpose. The items consisted of 26 multiple-choice questions and four true/false questions. Instructions were printed at the beginning of the test to clarify procedures. The students were assured that the pretest would have no bearing on their grade. The pretest and the item sources are found in Appendix C.

*Posttest.* The posttest was given as three separate quizzes consisting of ten items each. The posttest quizzes were administered during a lecture period within three days of completing each laboratory activity. The total score on the three quizzes was combined and compared to the pretest scores for later analysis. The quizzes are found in Appendices D, E, and F.

### Methods Relevant to Research Question Two

An additional assessment included a survey (Appendix G) of student affective traits. The survey collected demographics and measured the students' attitudes and preferences relevant to the laboratory. The survey consisted of questions that would be answered on a 5-point Likert scale along with open-ended questions, see Table 3.

The first section collected student demographics such as age, gender, and year in school, Table 4. These demographic data were later included in the data analyses of general applicability. The second section related to the student's preferences towards

Table 3

*Likert Scale Description and Score Conversion*

Score	Agreement <sup>a</sup>	Satisfaction <sup>b</sup>
1	Strongly disagree	Very unsatisfied
2	Disagree	Unsatisfied
3	Neutral	Neutral
4	Agree	Satisfied
5	Strongly agree	Very satisfied

<sup>a</sup> Agreement was used on items 2.1 to 2.7

<sup>b</sup> Satisfaction was used on items 2.8a to 2.8d, 3.2a to 3.2e, and 4.1a to 4.1e

Table 4

*Survey Questions of Affected Traits—Demographics*

Section 1	Demographics
1.1	What is your name?
1.2	What is your age group?
1.3	What is your class?
1.4	What is your gender?
1.5	What is your ethnicity?
1.6	What kind of community were you living in prior to your entrance to the university?
1.7	What is your major?
1.8	What is the highest level of education of your parents?
1.9	Which course are you currently taking?
1.10	In which laboratory section are you enrolled?

laboratories in general, comfort level with software, rating of the laboratory activities, and the perception of support from the instructors and their laboratory partners (see Table 5). This controlled for the confounding variable of the laboratory activities themselves and if the student had previous dispositions for laboratory work. The last sections address

Table 5

*Survey Questions of Affected Traits—Laboratory Activities*

Section 2	Laboratory activities (5-point Likert scale)
2.1	I am comfortable learning new computer skills and solving problems using a computer.
2.2	I am comfortable performing experiments and analyzing the resulting data.
2.3	I am comfortable designing new things.
2.4	I am comfortable learning new laboratory skills and working in a laboratory.
2.5	I am comfortable taking a leadership role in groups.
2.6	I am comfortable identifying, formulating, and solving engineering problems.
2.7	I prefer solving problems and working on projects alone.
Rate your satisfaction of the following:	
2.8a	Overall experience with the laboratory activities.
2.8b	Support from the instructor(s).
2.8c	Your lab partner's teamwork.
2.8d	How well the laboratory activities helped you meet the objectives.
2.9	What would you change to improve the laboratory experience?

the students' satisfaction and preferences for the computer-based and traditional oscilloscopes (Tables 6 and 7). The results did not only serve to describe the students' attitudes but also were used in the analysis of the error term.

The survey was broad and drew from existing surveys (Corter et al., 2007; Nickerson et al., 2007; Rutherford, 2007) that have analyzed students' perceptions of course delivery and pedagogy in engineering laboratories. The survey was offered in the laboratory after all the laboratory modules were completed. The data was then transcribed into a computer database for later analysis.

Table 6

*Survey Questions of Affected Traits—Software-Based Oscilloscope*

Section 3 Computer-based oscilloscope (5-point Likert scale)	
Rate your satisfaction of the virtual oscilloscope on the following items:	
3.2a	Overall experience
3.2b	Reliability
3.2c	Ease of use
3.2d	Sensation of reality
3.2e	Instruction/training
3.3	What would you change to improve the virtual oscilloscope?

Table 7

*Survey Questions of Affected Traits—Traditional Oscilloscope*

Section 4 Traditional oscilloscope (5-point Likert scale)	
Rate your satisfaction of the traditional oscilloscope on the following items:	
4.1a	Overall experience
4.1b	Reliability
4.1c	Ease of use
4.1d	Sensation of reality
4.1e	Instruction/training
4.2	What would you change to improve the traditional oscilloscope?
4.3	Which oscilloscope would you prefer using?

### Data Analysis

This study aimed to collect and analyze data from which conclusions may be drawn regarding student achievement and affective traits in engineering laboratories. This section will explain how the collected data were analyzed.

The data was analyzed using a common statistical package, Statistical Package for the Social Sciences (SPSS version 16, SPSS Inc., Chicago, IL). The alpha level was set to  $\alpha = .05$  to reject the null hypothesis. The null hypotheses state that there is no statistically significant difference in student achievement or affective traits in engineering laboratories utilizing software-based versus traditional instrumentation.

The first analysis verified that the data fit parametric statistical assumptions. This was performed by visually reviewing the data in histograms and box plots. Additionally, analyses of skewness and kurtosis were performed. Descriptive statistics were run on the data such as the mean, standard deviation, and other measures of central tendency. Effect sizes and confidence intervals were analyzed and reported (Cohen, 2007).

As the survey data included multiple question types, varying analyses were performed. These data were also visually inspected before running any statistical analysis (Gall et al., 2007). Some of the questions with the Likert scale were analyzed using the Mann Whitney U test. The open-ended questions were collected but there was not enough of responses to be statistically coded. However, the open-ended questions shed light on some of the students' perceptions. Additionally, some of the survey data were summed into subscales and analyzed as covariates in an ANCOVA. The subscale was also analyzed by an independent samples *t* test.

The achievement data was analyzed using one-way ANCOVA. The ANCOVA evaluates whether means on the dependent variable are the same across levels of a factor, adjusting for differences on the covariate. The covariates were held constant while the factor is tested for significance. This study included three covariates. The independent



variable, oscilloscope used, included two levels: traditional and software-based oscilloscopes. The dependent variable was the difference score between the posttest and the pretest. A preliminary analysis evaluating the homogeneity-of-slopes assumption was performed.

This study included three covariates: course, overall experience, and laboratory propensity. The covariate “course” was the course in which the participant was enrolled. The covariate “overall experience” was taken from the participants’ responses to their overall experience with the distinct type of oscilloscopes. The last covariate “laboratory propensity” was a subscale that was derived from the self-report survey that described the participant’s attitude towards engineering laboratories.

## CHAPTER IV

### RESULTS

The purpose of this study was to: (a) determine if there was a difference in student achievement in an engineering laboratory when a traditional and software-based oscilloscope was used; and (b) determine if there was a difference in student affective traits in an engineering laboratory when a traditional and software-based oscilloscope was used; and (c) if there were differences between the traditional and software-based oscilloscope, determine how they compare.

#### Description of Sample

The sample was comprised of 61 students enrolled during the spring semester of 2008 from two courses, ETE 2210 Electrical Engineering for Nonelectrical Engineers and ETE 2300 Electronic Fundamentals. There were 31 students in the computer-based oscilloscope group and 30 students in the traditional oscilloscope group. Table 8 is a table of the demographic information of the participants from this study. Figure 2 is a graph of the genders and ethnicities of the sample compared to the National average (American Society for Engineering Education [ASEE], 2007). Ninety-seven percent of the students were under the age of 30 with a median age of 22. Twenty-five (41%) students came from rural communities prior to entering the university. Forty-two (69%) students' parents received at least a bachelors degree or higher. The computer-based and traditional groups were similar across the demographics with no statistical significance found on any component of the demographics. Both courses were taught by the same instructor. Each

Table 8

*Demographics of the Sample, Computer-Based, and Traditional Groups*

Categories	Sample		Treatment group		Comparison group	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Total <i>N</i>	61	100.0	31	50.8	30	49.2
Gender						
Female	10	16.4	4	40.0	6	60
Male	51	83.6	27	52.9	24	47.1
Ethnicity						
White	54	88.5	27	50.0	27	50.0
Asian/Pacific Islander	5	8.2	2	40.0	3	60.0
Hispanic	1	1.6	1	100.0	--	--
Black	--	--	--	--	--	--
Other	1	1.6	1	100.0	--	--
Age						
17 or less	--	--	--	--	--	--
18-19	13	21.3	4	30.8	9	69.2
20-21	13	21.3	5	38.5	8	61.5
22-23	18	29.5	11	61.1	7	38.9
24-25	7	11.5	2	28.6	5	71.4
26-27	7	11.5	6	85.7	1	14.3
28-29	1	1.6	1	100.0	--	--
30-34	1	1.6	1	100.0	--	--
35-39	--	--	--	--	--	--
40-44	--	--	--	--	--	--
45-49	--	--	--	--	--	--
50-54	1	1.6	1	100.0	--	--
55+	--	--	--	--	--	--
Communities						
Rural	25	41.0	12	48.0	13	52.0
Suburban	23	37.7	13	56.5	10	43.5
Urban—less than \$1,000,000	7	11.5	3	42.9	4	57.1
Urban—over 1,000,000	6	9.8	4	66.7	2	33.3
Military base	--	--	--	--	--	--

*(table continues)*

Categories	Sample		Treatment group		Comparison group	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Parents' education						
Some high school	1	1.6	1	100.0	--	--
High school/GED	3	4.9	1	33.3	2	66.7
Some college	10	16.4	4	40.0	6	60.0
Associates degree	5	8.2	3	60.0	2	40.0
Bachelors degree	20	32.8	9	45.0	11	55.0
Masters degree	16	26.2	11	68.8	5	31.3
Doctoral degree	6	9.8	2	33.3	4	66.7
Years in school						
Freshman	6	9.8	2	33.3	4	66.7
Sophomore	33	54.1	16	48.5	17	51.5
Junior	15	24.6	8	53.3	7	46.7
Senior	7	11.5	5	71.4	2	28.6
Masters student	--	--	--	--	--	--
Doctoral student	--	--	--	--	--	--

student in the different laboratory sections received the same laboratory activities. During the intervention, all students had access to the same laboratory instructors. All sections had access to laboratory demonstrations instructor guidance, readings, and handouts.

### Results Relevant to Research Question One

The first research question sought to discover if there were differences in student achievement in engineering laboratories utilizing traditional versus software-based instrumentation. The null hypothesis for this question was that there was no statistical significance in student achievement between engineering laboratories utilizing traditional instrumentation and laboratories utilizing software-based instrumentation.

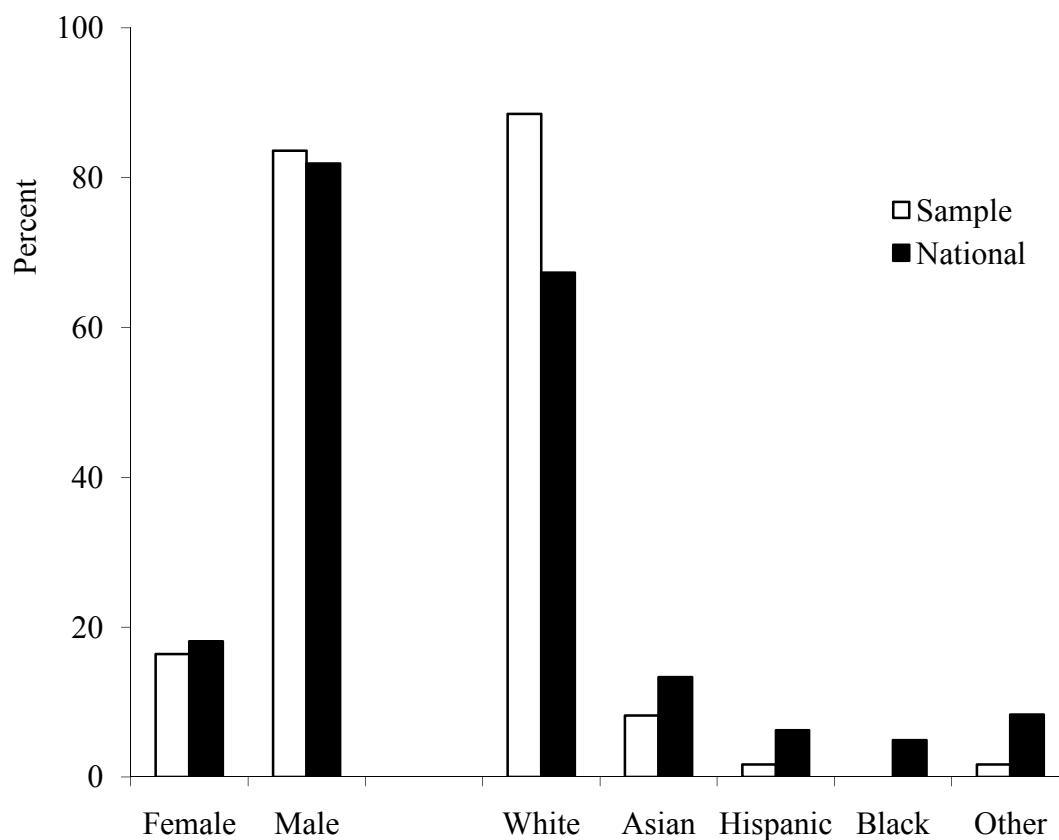


Figure 2. Sample versus national engineering student demographics (ASEE, 2007).

The effect size was also analyzed for this study. Effect size is an estimate of the measure of the strengths in two variables (Cohen, 2007). Similar to effect sizes, for analysis of variance and covariance measures of association are calculated. A common measure of association method is partial  $\eta^2$ . This is calculated by subtracting the ratio of Mean Squares<sub>within</sub> to Mean Squares<sub>total</sub> from 1.0. The range for  $\eta^2$  is from 0 to 1. The range 0.01 to 0.06 is considered small; 0.06 to 0.14 is medium; > 0.14 is large (Fargo, 2008).

Reliability was analyzed using Cronbach's alpha for the achievement test and two subscales within the survey instrument: the laboratory propensity and the attitude towards

the oscilloscopes. The 30 item achievement instrument demonstrated high reliability with a Cronbach's alpha ( $\alpha$ ) = .82. The survey instrument subscales for laboratory propensities and the oscilloscopes yielded Cronbach's alpha of ( $\alpha$ ) = .78 and .83 respectively. From these results, it is suggested that the instruments have acceptable internal consistency.

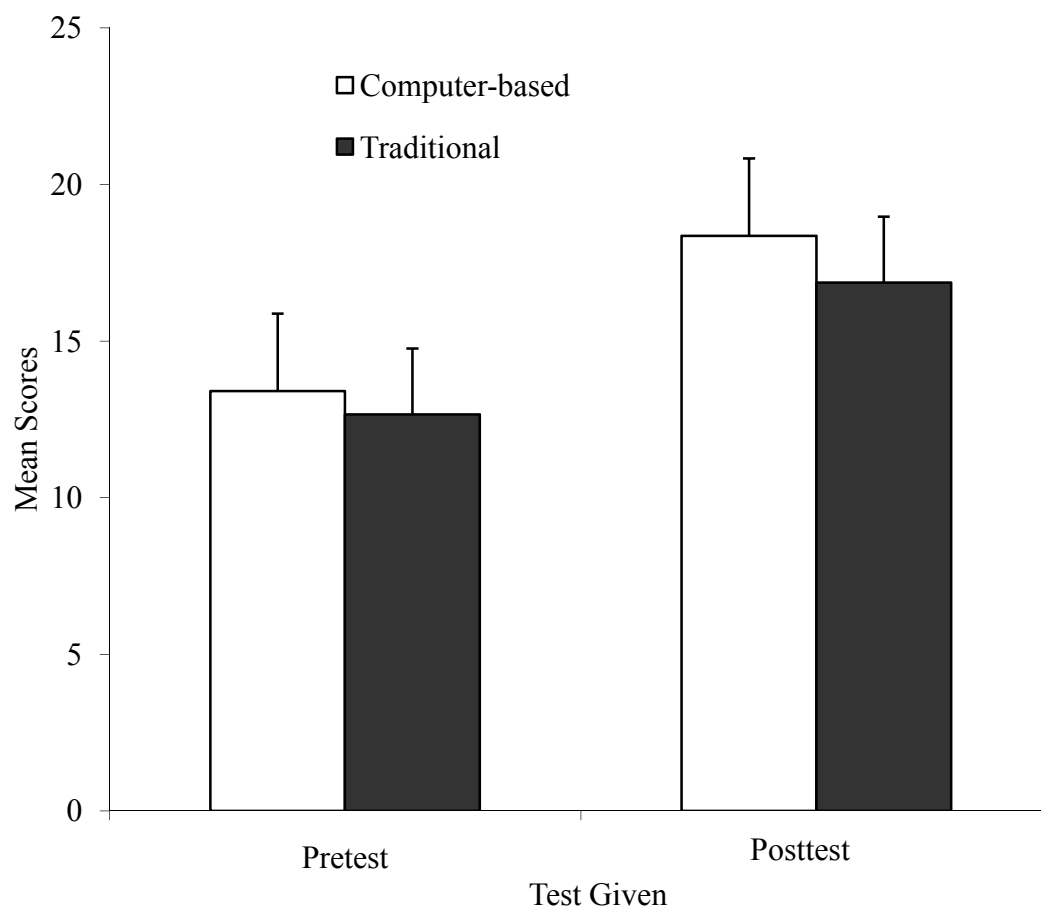
#### *Achievement Data Descriptive Statistics*

The descriptive statistics for achievement are found in Table 9. The mean score for the pretest for the computer-based group were higher ( $M = 13.40 \pm 0.44$ ) than the traditional group ( $M = 12.65 \pm 0.61$ ). The mean score for the posttest was also higher for the computer-based group ( $M = 18.35 \pm 0.69$ ) than for the traditional group ( $M = 16.87 \pm 0.87$ ). The effect sizes for the pretest ( $d = .16$ ) and the posttest ( $d = .22$ ) were small. Figure 3 displays the mean scores of the pretest and posttest for both the computer-based and traditional groups. The white bars represent the computer-based group means and the dark bars represent the traditional group means. Figure 3 indicates that the computer-based group achieved higher mean scores for both the pretest and posttest. Tests for kurtosis and skew were not significant for the achievement data.

Table 9

#### *Descriptive Statistics for the Achievement Tests*

Variable	<i>M</i>	<i>SEM</i>	<i>d</i>	<i>n</i>
Mean scores (pretest)				
Computer-based	13.40	.44	.16	31
Traditional	12.65	.61		30
Mean scores (posttest)				
Computer-based	18.35	.69	.22	31
Traditional	16.87	.87		30



*Figure 3.* Means scores on the pretest and posttest for both the computer-based and traditional groups. No statistical significance was found between groups. Statistical difference was found between pretest and posttest within each group at  $p < .001$ . Error bars represent standard error of the mean.

#### *One-Way ANCOVA*

A one-way ANCOVA was performed on the achievement data. The independent variable, oscilloscope used, included two levels: traditional and software-based oscilloscopes. The dependent variable was the difference score between the posttest and the pretest. A preliminary analysis evaluating the homogeneity-of-slopes assumption indicated that the relationship between the covariates and the dependent variable did not

differ significantly as a function of the independent variable, see Table 10. The covariate “course” was the course in which the participant was enrolled with an  $F(1, 56) = 1.80$ ,  $MSE = 25.39$ ,  $p = .18$ , partial  $\eta^2 = .03$ . The covariate “overall experience” was taken from the participants’ response to their overall experience with the distinct type of oscilloscopes and had an  $F(1, 56) = .89$ ,  $MSE = 25.39$ ,  $p = .35$ , partial  $\eta^2 = .02$ . The covariate “laboratory propensity” is a subscale derived from the self-report survey that described the attitude towards engineering laboratories had an  $F(1, 56) = .75$ ,  $MSE = 25.39$ ,  $p = .39$ , partial  $\eta^2 = .01$ . The two groups did not significantly vary statistically even while holding variables constant. The ANCOVA was not significant,  $F(1, 56) = .08$ ,  $MSE = 25.39$ ,  $p = .78$ , partial  $\eta^2 = .001$ . The results failed to reject the null hypothesis. The results for the achievement data indicated that there was no statistical significance found in the means of the difference scores between the participants who used the computer-based oscilloscopes and those who used the traditional oscilloscopes.

Table 10

*One-Way ANCOVA Summary Table for Achievement Tests*

Descriptor	SS	df	MS	F	Sig.	Partial $\eta^2$
Course	45.73	1	45.73	1.80	.18	.03
Overall experience	22.58	1	22.58	.89	.35	.02
English lab propensity	18.91	1	18.91	.75	.39	.01
Treatment	2.08	1	2.08	.08	.78	.001
Error	1421.68	56	25.39			
Total	3468.00	61				
Corrected total	1528.07	60				

*Note.* No statistical significance was found for any covariate or main factors.



## Results Relevant to Research Question Two

Is there a significant difference in student affective traits in engineering laboratories utilizing traditional versus software instrumentation? This question was addressed by a self-report pencil and paper survey given to the participants during a class period. The survey was divided into three sections: demographics, attitudes towards engineering laboratories, and experience with the oscilloscopes. All 61 study participants completed the survey.

### *Engineering Laboratory Propensity Subscale*

There were six questions included in a subcategory to assess students' propensity and comfort of working in engineering laboratories. The participants answered the questions using a 5-point Likert scale based on agreement, Table 11. These questions

Table 11

### *Students' Propensities and Comfort with Engineering Laboratories*

Item	Description	Computer-based		Traditional	
		<i>M</i>	SEM	<i>M</i>	SEM
2.1	Learning and solving problems using a computer.	4.12	.14	4.26	.11
2.2	Performing experiments and analyzing the resulting data.	3.90	.13	4.16	.09
2.3	Designing new things.	3.77	.13	3.76	.14
2.4	Learning new laboratory skills and working in a laboratory.	3.90	.12	4.23	.11
2.5	Taking a leadership role in groups.	3.74	.13	4.00	.13
2.6	Identifying, formulating, and solving engineering problems.	3.67	.15	3.90	.16
	Total Propensity and Comfort Scale	3.77	.15	3.93	.15
2.7	Solving problems and working on projects alone.	3.16	.16	3.13	.17

*Note.* Based on a 5-point Likert scale with a higher mean score representing a more positive student response. There was no significant difference on any item between groups.

were taken from a previous engineering education survey conducted by Rutherford (2007). The survey questions can be found in Tables 4-7.

Table 11 suggests that the students were comfortable with laboratories and the associated tasks. The lowest mean score within the subscale 3.77 was on item 2.3: “I am comfortable designing new things.” The highest mean score was 4.20 on item 2.1 “I am comfortable learning new computer skills and solving problems using a computer.” The lowest mean of this section 2.85 was on item 2.7 “I prefer solving problems and working on projects alone.”

The engineering laboratory propensity subscale was analyzed using an independent samples  $t$  test with an alpha level of  $p < .05$ . The results of the analysis were not significant  $t(59) = 1.55, p = .126$ , failing to reject the null hypothesis. The 95% confidence interval ranged from  $-0.35$  to  $2.76$

### *Laboratory Experiences*

There were five questions included in this subcategory to assess students' towards the laboratory activities and their experiences, Table 12. Four of the questions were answered using a 5-point Likert scale based on satisfaction, (see Table 3), with one open-ended question. Table 12 suggests that the students were satisfied with their laboratory experience.

The highest mean in the sample was 4.41 on item 2.8c: “Your lab partner’s teamwork.” The lowest mean in the sample was 3.74 on item 2.8a: “Overall experience with the laboratory activities.” The total mean score was 4.00 for the students’ laboratory experiences. Item 2.9 was an open-ended question, “What would you change to improve

Table 12

*Students' Satisfaction with the Laboratory Experience*

Item	Description	Computer-based		Traditional	
		<i>M</i>	SEM	<i>M</i>	SEM
2.8a	Overall experience with the laboratory activities.	3.72	.15	3.97	.13
2.8b	Support from the instructor(s).	4.03	.14	3.93	.17
2.8c	Your lab partner's teamwork.	4.39	.14	4.43	.13
2.8d	How well the laboratory activities met the objectives.	3.74	.12	4.00	.14

*Note.* There was no statistical difference on any item between groups.

the laboratory experience?" There were 38 (62%) responses with varying categories.

Thirty-seven percent ( $n = 14$ ) of the responses addressed instruction before the laboratory activities. Mann-Whitney U tests were run on the satisfaction of the laboratory experiences between the treatment and comparison groups. The results of the analysis did not show significance,  $U = 368.5$ ,  $p = .159$ .

*Satisfaction with the Oscilloscopes*

The participants were asked to rate their satisfaction on five items pertaining to both the software-based and traditional oscilloscopes. There was also an open-ended question for both oscilloscopes. The final question of the survey asked the participants who used the software-based oscilloscope which oscilloscope they preferred as the treatment group was also able to use the traditional oscilloscope in other laboratory activities.

Both oscilloscopes were rated on five separate items using the satisfaction scale, (see Table 3). The items with their mean scores are listed in Table 13 for both

Table 13

*Satisfaction with the Software-based and Traditional Oscilloscopes*

Item	Computer-based		Traditional	
	<i>M</i>	<i>SEM</i>	<i>M</i>	<i>SEM</i>
Overall experience	3.94	.13	3.96	.11
Reliability	3.71	.14	3.93	.15
Ease of use	3.87	.15	3.61	.14
Sensation of reality	3.84	.14	3.71	.15
Instruction/training	3.90	.13	4.00	.11

oscilloscopes. The mean of the overall experience for the software-based oscilloscope was 3.94 while the traditional oscilloscope was 3.96. The mean of reliability for the software-based oscilloscope was 3.71 while the traditional oscilloscope was 3.93. The mean of ease of use for the software-based oscilloscope was 3.87 while the traditional oscilloscope was 3.61. The mean of the sensation of reality for the software-based oscilloscope was 3.84 while the traditional oscilloscope was 3.71. The mean of the instruction and training for the software-based oscilloscope was 3.90 while the traditional oscilloscope was 4.00. The lowest mean score for the software-based oscilloscope was 3.71 for reliability. The lowest mean score for the traditional oscilloscope was 3.61 for ease of use. The highest mean score for the software-based oscilloscope was for the overall experience with an  $M = 3.94$ . The highest mean score the traditional oscilloscope was the instruction and training with an  $M = 4.00$ . Both groups had similar experiences and satisfaction with their oscilloscopes.

Figure 4 suggests that the students were satisfied with both oscilloscopes. The

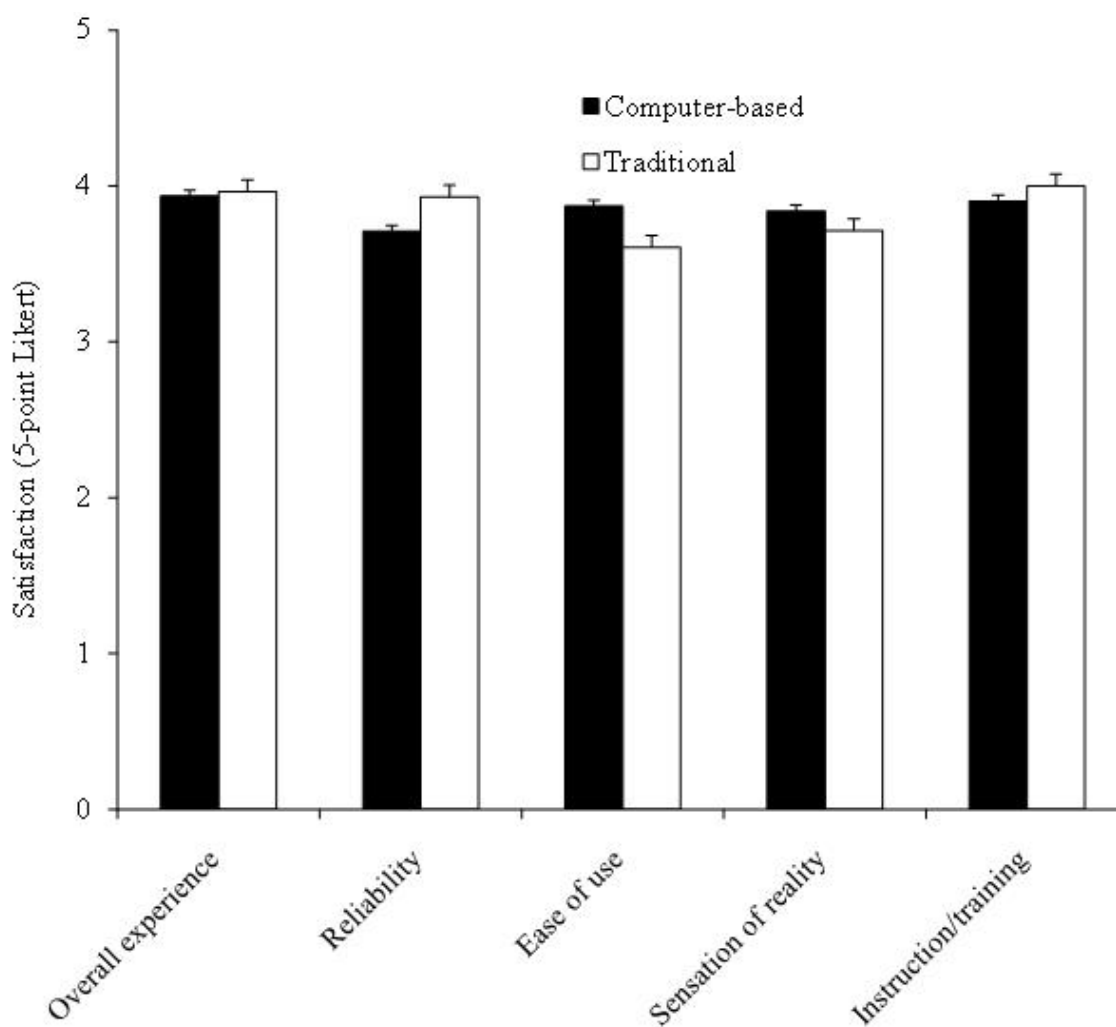


Figure 4. Satisfaction with the computer-based and traditional oscilloscopes.

Note. No statistical significance was found. Error bars represent standard error of the mean.

participants were also asked to respond to an open-ended question regarding how the oscilloscopes could be improved. The response rate was 33% ( $n = 20$ ). Over 33% of the responses stated “nothing” or “not much.” The final question answered by the treatment group was if they preferred the software-based or traditional oscilloscope. Eleven participants from the treatment group preferred the software-based oscilloscope while

eight participants from the treatment group preferred the traditional oscilloscope. These numbers are too small to make any statistical inferences.

### Summary

This quasi-experimental study consisted of a pretest-posttest design for student achievement and a self-report survey for student affective characteristics. There were 61 participants in this study from two undergraduate courses in electrical engineering and electronics. The average student was a 22-year-old white male in his sophomore year majoring in engineering and came from an urban settings with parents who obtained at least a bachelor's degree from a university.

An ANCOVA was performed to test the null hypothesis for the achievement data. Even while holding the covariates of the enrolled course, the overall experience, and engineering laboratory propensity constant, the analysis failed to reject the null hypothesis. The results were not significant with a  $p < .05$ . Additionally, the effect sizes were small for the study.

A survey was administered to measure student affective traits. The survey included demographics, engineering laboratory propensities, experience with the laboratory activities, and satisfaction with both the software-based and traditional oscilloscopes. The mean scores between the treatment and comparison groups were not statistically significant and the null hypothesis was not rejected with a  $p < .05$ .

## CHAPTER V

### DISCUSSION

The purpose of this study was to: (a) determine if there was a difference in student achievement in an engineering laboratory when a traditional versus software-based oscilloscope was used; and (b) determine if there was a difference in student affective traits in an engineering laboratory when a traditional and software-based oscilloscope was used; and (c) if there were differences between the traditional and software-based oscilloscope, determine how they compare. These findings may then be applied to the role of software-based instruments in distance education laboratories

This chapter will discuss the results from the findings of this research. Discussion will pertain to generalizability, research question one, and research question two.

#### Generalizability and Demographics

The participants in this study completed a self-report demographic survey. The demographic results were analyzed and compared to national engineering student demographics (ASEE, 2007). The study included 61 students from a land-grant research university. The demographics were analyzed between treatment and comparison groups by independent sample  $t$  tests. The two randomly assigned groups did not differ significantly on any demographic.

#### *National Comparison*

The genders of the study participants were less than 2% different from the

national percentage of graduating engineering students, Figure 5. The ethnicity of the sample was overwhelming White at 88.5% versus the national average at 67.3%. Although there may be a high number of White people in this study, the sample ethnicities more closely followed the state of Utah ethnicities as the sample was drawn from a state run university (United States Census Bureau, 2000).

*Sample Demographics*

The majority of the students 54.1% were in their sophomore year of school. The courses from which the sample was drawn were sophomore level courses. Furthermore,

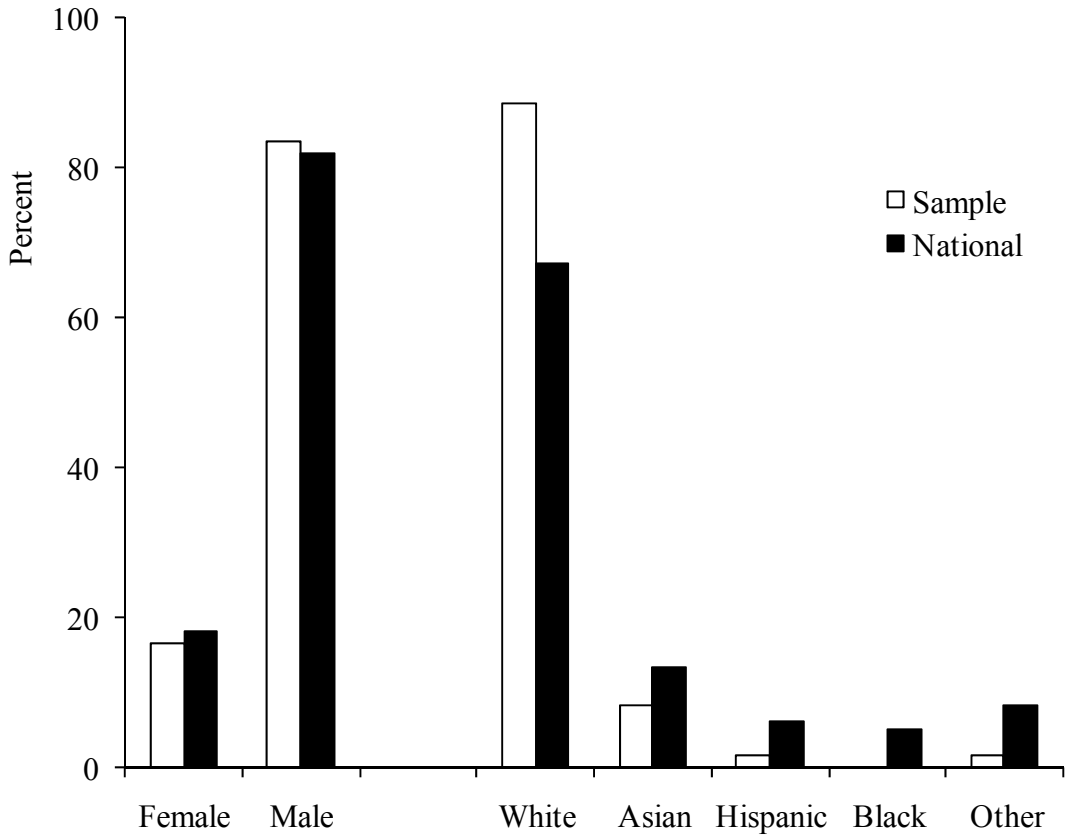


Figure 5. Sample versus national engineering student demographics (ASEE, 2007).



the electrical engineering courses were also prerequisites to junior level courses for a portion of the majors. The median age of the participants was 22.3 years. Data from the university suggest that a large portion of the participants served missions for The Church of Jesus Christ of Latter-day Saints for 2 years between the ages of 19 and 21 (Utah State University, 2008b). Therefore, most students only completed their freshman year of college before serving a mission. Although mission service was not included in the survey, using the university demographics helps explain the average age of the students. Ninety-eight percent of the participants were from the College of Engineering. One of the courses is also offered for general education credit and included one student from the college of humanities. Forty-one percent of the students came from rural communities. The land-grant university from which the sample was taken is situated among many rural communities and attracts students with agricultural backgrounds. Assumably, agricultural backgrounds include the use of manual education. Therefore, a hands-on component to learning would be welcome by these students. Sixty-nine percent of the students' parents received a bachelor's degree or beyond. The parents' education suggests that the students, and/or their families, placed schooling as a high priority.

#### Discussion Relevant to Research Question One

The mean scores for the pretest of both groups were similar. Both groups had similar gains from their difference scores. The ANCOVA results were not statistically significant for the differences scores between the treatment and comparison groups. Three covariates were introduced and held constant in the ANCOVA analysis. None of

the covariates were statistically significant.

#### *ANCOVA Covariates*

One of the covariates was analyzed based on the course in which the students were enrolled. Each course had distinct audiences, engineers (ETE 2210 Electrical Engineering for nonmajors and nonengineering majors (ETE 2300 Electronic Fundamentals)). Therefore, the course was analyzed as a possible confound. The analysis of covariance for the course was not significant. Analysis showed that the pseudorandom assignment of the treatment and comparison group was sufficient. The covariate of laboratory propensity was also included in the ANCOVA. Prior to running the ANCOVA, an independent samples *t* test was performed on the subscale without any statistical significance. The results of the analysis were congruent with the previous analyses. The last covariate was the overall experience with each of the oscilloscopes expressed by the participants in the self-report survey. The experiences with each scope shared similar means and this was reflected in the ANCOVA. Even while holding other variables constant no significant differences were found, alluding to a similar encounter with either oscilloscope. The results suggest that the experience, achievement, and satisfaction with the computer-based oscilloscope and the traditional oscilloscope were equivalent. Previous studies have found distance delivery and computer-based instrumentation to be at least equivalent to traditional delivery (Campbell et al., 2002; Corter et al., 2007; Ko et al., 2005; Ringwood & Galvin, 2002).

## Discussion Relevant to Research Question Two

An attitudinal survey was completed by all participants in this study. The purpose of this instrument was to investigate if there was a significant difference in student affective traits in engineering laboratories utilizing traditional versus software-based instrumentation

### *Engineering Laboratory Propensity and Comfort*

The participants answered seven questions regarding their propensity for and comfort with engineering laboratory components. Six of these questions were used in the engineering laboratory propensity subscale. The seventh question, item 2.7, was the converse of question 2.5, asking the participant their level of comfort while taking the lead in a group. This subscale was developed to investigate the impact of the participants' propensity for engineering laboratories, instruments, and the use of a new tools facilitated by the computer. The results of the independent samples  $t$  test were not significant while comparing the treatment and comparison group.

The items in this portion of the survey are well aligned with the objectives put forward by Feisel and Rosa (2005) and ABET (2007). The survey items spanned at least five objectives found in each of the aforementioned authors' objectives. Table 14 displays which of the objectives were matched with the survey items.

According to the results of item 2.1 to 2.7, the participants ranged from comfortable to very comfortable with learning new computer skills and solving problems with a computer. The students' comfort with computers and laboratories was a potential

Table 14

*Engineering Laboratory Objective Alignment with the Survey*

Topic	Survey item	ABET (2007)	Feisel & Rosa (2005)
Collaborative Work	5	D	11
Data analysis	2	B	4
Design	3	B, C	5
Engineering problems	1, 6	E	--
Engineering tools	1, 4	K	1
Experimentation	2	B	3

confound in determining the students' experience with a computer-based oscilloscope. The participants were comfortable with using laboratory equipment, performing experiments, analyzing data, and learning new laboratory skills. Students were slightly under comfortable in taking leadership roles in groups. Although designing new things was the lowest component of the subscale, the mean was closer to "comfort" than "neutral" along with solving engineering problems. These results were not surprising as a portion of the participants were not engineering students. The final question, item 2.7 was the converse of item 2.5, stating "I prefer solving problems and working on projects alone." The results suggest that the majority of the students disagree with this statement, congruent with the findings of item 2.5. Overall, the subscale mean suggests that students were comfortable with engineering laboratories and their associated tasks.

*Laboratory Experience*

This section of the instrument included five questions: four multiple choice and one open-ended. The overall experience of the laboratories was rated close to, but below, "satisfied." The open-ended question was completed by 62% of the participants. The

responses varied between open suggestion of what might be further included in the laboratories to criticism of the lack of instruction. Most responses suggested that the laboratory activities and equipment needed better explanations. The traditional and software-based oscilloscopes were introduced to the students at the same time as alternating current AC theory. The topic of AC theory has traditionally been a challenging concept to the students. Furthermore, the software-based oscilloscope was new to the laboratory instructors and they expressed some reticence in supporting both oscilloscopes in the laboratory activities. This might partially account for the request of improved support. However, item 2.8b suggests that the students were satisfied with the instructor support. Although the laboratory objectives were explained at the beginning of each activity and written on each activity handout, the mean satisfaction rating was just under “satisfied.” Not surprisingly, the participants rated their laboratory partner’s teamwork quite high between satisfied and very satisfied as they were allowed to choose their laboratory partners for each activity.

### *Satisfaction with Oscilloscopes*

The participants were asked to rate certain aspects and the overall experience with the oscilloscopes. The study participants rated both oscilloscopes as satisfactory. The difference of the overall rating means was less than 1%. The results of the Mann-Whitney U test were not statistically significant. The null hypothesis failed to be rejected. All responses for each of the questions were rated close to or above satisfactory.

The software-based oscilloscope was rated lowest on reliability. One of the eight software-based oscilloscopes frequently encountered issues and forced the students to

move to another station. Eventually, the problem was resolved. Therefore, it was no surprise that the software-based oscilloscope mean was rated 6% less than the traditional scope mean respective to reliability. The software-based oscilloscope was rated higher by 7% on ease of use than the traditional oscilloscope. The traditional oscilloscope was intended to meet much greater needs than the software-based oscilloscope. Therefore, the software-based oscilloscope had less complexity and the students were already familiar with a “software” interface mediated by a computer. Additionally, prior to the laboratory activities, most students did not have experience with an oscilloscope. Interestingly, the software-based oscilloscope was rated higher by 4% for sensation of reality. This result is counter intuitive and could not be explained by the researcher. The training for the traditional oscilloscope was rated higher by 3% than the software-based oscilloscope. The results from the survey suggest that students found the oscilloscopes to be equivalent. The students rated both oscilloscopes favorably in each of the questions. Like Campbell and colleagues (2002) and Corter and colleagues (2007), the results found the students did not have a significant preference for either oscilloscopes or methods.

The participants were also asked to comment on how both the software-based and traditional oscilloscopes could be improved. The response rate was less 33% with 1/3 of the response stating that “not much” could be done to improve the oscilloscopes. The ultimate question asked the treatment group which oscilloscope they preferred. Only a few of the participants responded to this question. Of the 19 responses, 11 participants choose the software-based oscilloscope. The number of responses was low, but the results were noteworthy.

## Summary

This intent of this study was to find if there were differences in student achievement and affective traits while using a computer-based and traditional oscilloscope. If differences were found, describe how the two types of oscilloscopes might compare. The results infer that the two types of oscilloscopes were equivalent for the laboratory activities in this study. Student gain scores were similar as were the student attitudes towards the oscilloscopes.

## CHAPTER VI

### CONCLUSIONS, IMPLICATIONS, FURTHER RESEARCH

#### Conclusions

Although there was no statistical significance found between the traditional and software-based oscilloscope, the results of this study were promising. The results suggest that computer-based oscilloscopes can be equivalent to traditional oscilloscopes for electrical engineering courses delivered to nonmajors. Computer-mediated laboratory instruments are foundational to distance educational courses. Distance engineering courses may use computer instrumentation as part of the curriculum when much of the engineering courses offered via distance delivery currently are limited to electronic blackboards and e-material.

One of the purposes of this study was to assess the viability of software-based instrumentation. In addition to distance laboratories, the current engineering laboratories could also benefit from computer-based instrumentation. If the software-based oscilloscope were intended to be an improvement solely to the laboratory, the statistics would suggest that all else being equal, neither scope would be preferred. Additionally, the software-based oscilloscope costs a fraction  $\sim (1/10^{\text{th}})$  of the traditional oscilloscope. Furthermore, the size of the software-based oscilloscope is smaller than the traditional oscilloscope. The computer-based instrumentation could be a promising and viable option in current laboratory settings.



## Implications

Distance education engineering laboratories are often mediated by the computer. The students interface with software-based instruments as part of that mediation. This study has shown for an electrical engineering service course and a fundamentals electronics course that software-based instrumentation is a viable alternative. There are programs that desire to introduce engineering laboratories into their programs but are limited by costs and perceived instrument availability within their constraints. Not only would a software-based oscilloscope fit well within distance education, but also for programs that are limited by costs, such as rural and urban schools.

## Further Research

Further research recommendations would include taking the software-based oscilloscopes into a distance setting. The instruction would no longer be given with a laboratory instructor readily available in person. The instructor could be available by other forms of communication such as the telephone, email, or a chat session. The research could also be performed on more than three activities and include an entire course. The research design could include counter balancing and a delayed posttest to strengthen the findings. Lastly, a larger sample would add to the validity of the findings.

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APPENDICES



Appendix A

Thirteen Laboratory Objectives (Feisel & Rosa, 2005)

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 13 Laboratory Objectives
 

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Objective	Name	Description
1	Instrumentation	Apply appropriate sensors, instrumentation, and/or software tools to make measurements of physical quantities.
2	Models	Identify the strengths and limitations of theoretical models as predictors of real-world behaviors. This may include evaluating whether a theory adequately describes a physical event and establishing or validating a relationship between measured data and
3	Experiment	Devise an experimental approach, specify appropriate equipment and procedures, implement these procedures, and interpret the resulting data to characterize an engineering material, component, or system.
4	Data Analysis	Demonstrate the ability to collect, analyze, and interpret data, and to form and support conclusions. Make order of magnitude judgments and use measurement unit systems and conversions.
5	Design	Design, build, or assemble a part, product, or system, including using specific methodologies, equipment, or materials; meeting client requirements; developing system specifications from requirements; and testing and debugging a prototype, system, or proc
6	Learn from Failure	Identify unsuccessful outcomes due to faulty equipment, parts, code, construction, process, or design, and then re-engineer effective solutions.
7	Creativity	Demonstrate appropriate levels of independent thought, creativity, and capability in real-world problem solving.
8	Psychomotor	Demonstrate competence in selection, modification, and operation of appropriate engineering tools and resources.
9	Safety	Identify health, safety, and environmental issues related to technological processes and activities, and deal with them responsibly.
10	Communication	Communicate effectively about laboratory work with a specific audience, both orally and in writing, at levels ranging from executive summaries to comprehensive technical reports.
11	Teamwork	Work effectively in teams, including structure individual and joint accountability; assign roles, responsibilities, and tasks; monitor progress; meet deadlines; and integrate individual contributions into a final deliverable.
12	Ethics in the Laboratory	Behave with highest ethical standards, including reporting information objectively and interacting with integrity.
13	Sensory Awareness	Use the human senses to gather information and to make sound engineering judgments in formulating conclusions about real-world problems.

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Appendix B

ABET Program Outcomes (2007)

### Criterion 3. Program Outcomes (ABET, 2007)

Engineering programs must demonstrate that their students attain the following outcomes:

- (a) an ability to apply knowledge of mathematics, science, and engineering
- (b) an ability to design and conduct experiments, as well as to analyze and interpret data
- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- (d) an ability to function on multidisciplinary teams
- (e) an ability to identify, formulate, and solve engineering problems
- (f) an understanding of professional and ethical responsibility
- (g) an ability to communicate effectively
- (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- (i) a recognition of the need for, and an ability to engage in life-long learning
- (j) a knowledge of contemporary issues
- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Manufacturing and Mining Engineering:

Students must demonstrate an ability to conduct laboratory experiments and to critically analyze and interpret data in more than one major environmental engineering focus areas; laboratory experience: graduates must be able to measure manufacturing process variables in a manufacturing laboratory and make technical inferences about the process.

Appendix C

Student Achievement Pretest

## Electrical Engineering Pretest

Note: This pretest was offered two weeks before the material was covered in lecture and three weeks prior to the laboratory activities. The pretest was offered during a lecture period.

### Objectives:

1. Demonstrate understanding of frequency responses of RC and RL networks.
2. Explain how to plot voltage and current versus frequency in an RC and RL network.
3. Describe how to calculate the phase angle of the input impedance versus frequency.
4. Describe voltage-current versus frequency for an RLC circuit.
5. Explain how input impedance varies with frequency.
6. Explain quality factor and bandwidth.
7. Describe resonant frequency in a parallel resonant circuit.
8. Describe how an oscilloscope is used in electronics.
9. Explain how a function generator is used electronics.

## Item Sources:

Boylestad, R. L. (2007). *Introductory Circuit Analysis* (11 ed.). Upper Saddle River, NJ: Pearson/ Prentice Hall.

Floyd, T. L. (2007). *Electronics Fundamentals* (7 ed.). Upper Saddle River, NJ: Pearson/Prentice Hall.

Lindeburg, M., R. (2002). *FE Review Manual* (3rd ed.). Belmont: Professional Publications, Inc.

Buchla, T. (2007). *Lab Manual to Accompany Electronic Fundamentals* (7 ed.). Upper Saddle River, NJ: Pearson/Prentice Hall.

## AC Measurements

- 1 (Floyd p.361 #7)
- 2 (Boylestad p. 582 #4)
- 3 (Boylestad p. 558)
- 4 (Boylestad p. 582 #5)
- 5 (Boylestad p. 582 #13)
- 6 (Floyd p. 365 #28)
- 7 (Floyd p. 366 #37)
- 8 (Boylestad p. 583 #36b)
- 9 (Boylestad p. 583 #36c)
- 10 (Boylestad p. 583 #36d)

## RC &amp; RL Frequency Response

- 1 (Floyd p.471 #1)
- 2 (Buchla p. 211 #1)
- 3 (Floyd p.471 #1)
- 4 (Boylestad Testgen Chapter 15)
- 5 (Boylestad Lab Manual p. 290)
- 6 (Boylestad Lab Manual p. 310)
- 7 (Buchla p. 202 #5a)
- 8 (Buchla p. 202 #5b)
- 9 (Buchla p. 202 #5c)
- 10 (Buchla p. 202 #5e)

## Parallel Resonance

- 1 (Boylestad Testgen Chapter 20)
- 2 (Floyd p.610 #4)
- 3 (Boylestad Testgen Chapter 20)
- 4 (Lindeburg, p 41-9 #3)
- 5 (Boylestad Testgen Chapter 20)
- 6 (Lindeburg p.41-9 #1)
- 7 (Boylestad Testgen Chapter 20)
- 8 (Floyd p.613 #26)
- 9 (Boylestad Testgen Chapter 20)
- 10 (Lindeburg p. 41-10#10,17)

## Item Answers:

1. T
2. T
3. T
4. T
5. A
6. B
7. D
8. A
9. D
10. B
11. A
12. B
13. C
14. A
15. D
16. D
17. B
18. B
19. C
20. B
21. A
22. C
23. A
24. C
25. D
26. A
27. B
28. D
29. A
30. B



Name \_\_\_\_\_

Course \_\_\_\_\_

Laboratory section \_\_\_\_\_

### Electrical Engineering Assessment

#### Instructions

This assessment will NOT count towards your grade. This test will help us better analyze student learning and instructor teaching.

This assessment contains True/False and multiple choice questions. Please place your answer on the line to the left of the question. If you do not know the answer to the question or even know to approach it, give your best attempt.

Example:

  F   2. (T/F) University of Utah's mascot is a poodle.

  B   3. What are the three basic units of measurement included in Ohm's Law?

- |                                       |                         |
|---------------------------------------|-------------------------|
| a) Volts, Ohms, Farads                | b) Volts, Amperes, Ohms |
| c) Admittance, Susceptance, Reactance | d) Ohms, Henries, Volts |

---

**TRUE/FALSE Write "T" if the statement is true, "F" if the statement is false.**

       1. (T/F) Bandwidth is the range of frequencies between the half-power frequencies.

       2. (T/F) The total impedance of a series RLC circuit at resonance is equal to the resistance of the circuit.

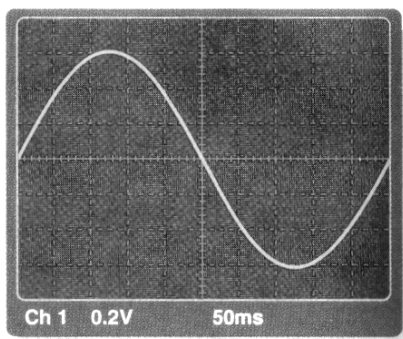
       3. (T/F) Impedance is the combination of capacitive reactance, inductive reactance, and dc resistance.

       4. (T/F) Current and voltage are in phase in series resonant circuits.

**MULTIPLE CHOICE** Chose the one alternative that best completes the statement or answers the question.

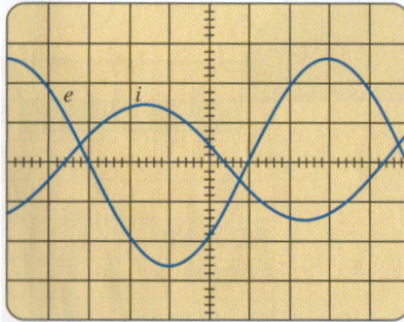
- \_\_\_ 5. If the peak value of a sine wave,  $V_p = 20V$ , then the rms value is  
 a) 14.14 V    b) 6.37 V    c) 7.07 V    d) 0.707 V
- \_\_\_ 6. What is the period of the waveform whose frequency is 1160 KHz?  
 a) 1160 ns    b) 862 ns    c) 0.087 us    d) 0.707 V
- \_\_\_ 7. The oscilloscope displays  
 a) frequency vs. current    b) voltage vs. resistance  
 c) time vs. current    d) voltage vs. time
- \_\_\_ 8. What is the frequency of the repeating waveform whose period is 16.7 ms?  
 a) 60 Hz    b) 6.01 KHz    c) 6.1 mHz    d) 0.006 MHz
- \_\_\_ 9. The angular velocity of a waveform with the frequency of 600 Hz is  
 a) 3768 Hz    b) 1884Hz    c) 1884 rad/s    d) 3768 rad/s
- \_\_\_ 10. A 6 Vp sine wave is riding on a dc voltage of 8 V. If the dc voltage is lowered to 5 V, how far will the lower peak of the sine wave go?  
 a) 3 V    b) -1 V    c) -3 V    d) 1 V

Refer to Figure 1 for question #11



- \_\_\_ 11. Given an oscilloscope with a vertical sensitivity = 0.2 V and a horizontal sensitivity = 50ms, the rms value and the frequency are:  
 a) 0.424 V, 2 Hz    b) 3 V, 0.5 Hz    c) 6 V, 5 Hz    d) 0.6 V, 2 Hz

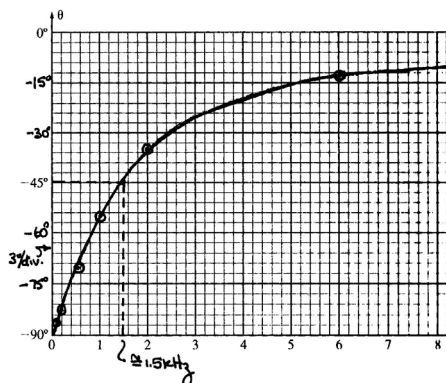
Refer to figure 2 for questions #12 - 14



Vertical Sensitivity = 0.5 V/div  
Horizontal Sensitivity = 1ms/div

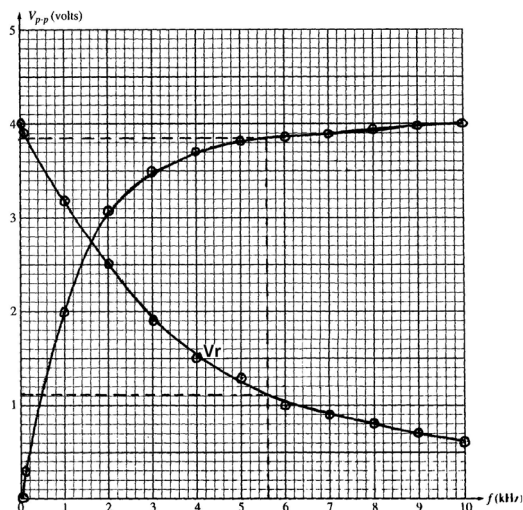
- \_\_\_ 12. The frequency of the waveforms is  
a) 8 Hz      b) 125 Hz      c) 4 Hz      d) 8 KHz
- \_\_\_ 13. The rms value of the waveform is  
a) 1.25 V      b) 0.88 mV      c) 0.88 V      d) -1.25 V
- \_\_\_ 14. The voltage leads the current with a phase shift of  
a) 207°      b) 45°      c) 3.14 radians      d) 153°
- \_\_\_ 15. 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°  
c) lagging the source voltage by 90°      d) in phase with the current
- \_\_\_ 16. If a sinusoidal voltage wave is applied to an inductor, the current in the inductor  
a) leads the voltage by 45°      b) leads the voltage by 90°  
c) lags the voltage by 45°      d) lags the voltage by 90°
- \_\_\_ 17. In a series RC circuit, 10 V rms is measured across the resistor and 10V rms is also measured across the capacitor. The rms source voltage is  
a) 20 V      b) 14.14 V      c) 28.28 V      d)- 10 V

Refer to Figure 3 for question number 18



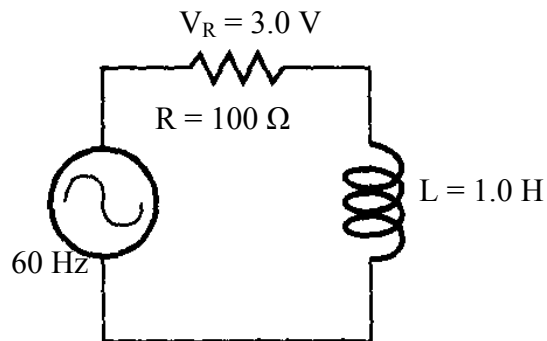
18. Figure 3 represents frequency versus
- phase angle  $\theta$  for an RL circuit
  - phase angle  $\theta$  for an RC circuit
  - $V_R$  for an RC circuit
  - $V_R$  for an RL circuit

Refer to figure 4 for question #19



19. Figure 4 represents frequency versus
- $V_R$  with a positive slope;  $V_L$  with a negative slope
  - $V_R$  with a positive slope;  $V_C$  with a negative slope
  - $V_R$  with a negative slope;  $V_L$  with a positive slope
  - $V_C$  with a positive slope;  $V_L$  with a negative slope

Refer to Figure 5 for questions 20 - 23



- \_\_\_ 20. The current in the inductor is  
 a) 30 A      b) 30 mA      c) 0.30 A      d) 60 mA
- \_\_\_ 21. The inductive reactance is  
 a) 377  $\Omega$       b) 188  $\Omega$       c) 600  $\Omega$       d) 1.8 k $\Omega$
- \_\_\_ 22. The voltage across the inductor is  
 a) 1.25 V      b) 0.88 mV      c) 11.3 V      d) 1.13 V
- \_\_\_ 23. The phase angle between  $V_R$  and  $V_S$  is  
 a) 75°      b) 45°      c) 3.14 rads      d) 283°
- \_\_\_ 24. What is the Q of a 1 mH coil at 1 kHz if its series resistance is 10 $\Omega$ ?  
 a) 0.8      b) 1.59      c) 0.63      d) 1.0
- \_\_\_ 25. Frequencies that define the points on the resonance curve that are 70.7% of the peak current or voltage value are known as the frequencies that determine  
 a) resonance      b) average      c) selection      d) bandwidth
- \_\_\_ 26. The reactance of a 10mH inductor and 0.2  $\mu$ F capacitor are equal when the frequency is  
 a) 3.54 kHz      b) 7.12 kHz      c) 14 kHz      d) 21 kHz
- \_\_\_ 27. What is the resonant frequency of a series circuit consisting of a 100 pF capacitor, a 10 k $\Omega$  resistor, and a 1 mH inductor?  
 a) 3.16 MHz      b) 503 kHz      c) 1.58 MHz      d) 159 Hz



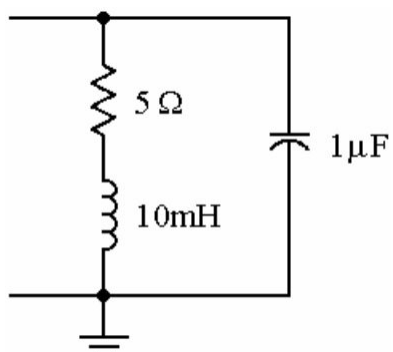


Figure 8

- \_\_\_ 30. See Figure 8. What is the resonant frequency of this parallel network?  
a) 15.9 MHz   b) 1.59 kHz   c) 15.9 Hz   d) 159 Hz

Appendix D  
AC Measurements Quiz



## AC Measurements Quiz

Note: This quiz was given the week the associated laboratory was administered.

### Objectives:

1. Describe how an oscilloscope is used in electronics.
2. Explain how a function generator is used electronics.

### Item Sources

Boylestad, R. L. (2007). *Introductory Circuit Analysis* (11 ed.). Upper Saddle River, NJ: Pearson/ Prentice Hall.

Floyd, T. L. (2007). *Electronics Fundamentals* (7 ed.). Upper Saddle River, NJ: Pearson/Prentice Hall.

(Floyd p. 361 #7)

(Boylestad p. 582 #4)

(Boylestad p. 558)

(Boylestad p. 582 #5)

(Boylestad p. 582 #13)

(Floyd p. 365 #28)

(Floyd p. 366 #37)

(Boylestad p. 583 #6b)

(Boylestad p. 583 #36c)

(Boylestad p. 583 #36d)

### Item Answers

1. A
2. B
3. D
4. A
5. D
6. B
7. A
8. B
9. C
10. A

Name \_\_\_\_\_

Course \_\_\_\_\_

Laboratory section \_\_\_\_\_

## AC Measurements Quiz

*This quiz contains multiple choice questions. Please place your answer on the line to the left of the question.*

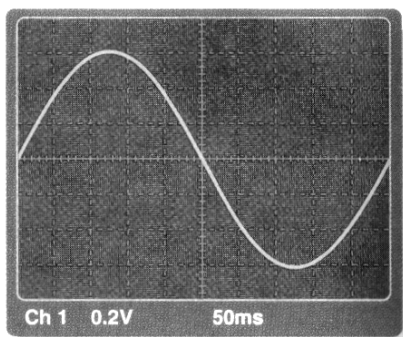
Example:

- B   3. What are the three basic units of measurement included in Ohm's Law?  
 a) Volts, Ohms, Farads                      b) Volts, Amperes, Ohms  
 c) Admittance, Susceptance, Reactance    d) Ohms, Henries, Volts

**MULTIPLE CHOICE** Chose the one alternative that best completes the statement or answers the question.

- \_\_\_\_ 1. If the peak value of a sine wave,  $V_p = 20V$ , then the rms value is  
 a) 14.14 V    b) 6.37 V    c) 7.07 V    d) 0.707 V
- \_\_\_\_ 2. What is the period of the waveform whose frequency is 1160 KHz?  
 a) 1160 ns    b) 862 ns    c) 0.087 us    d) 0.707 V
- \_\_\_\_ 3. The oscilloscope displays  
 a) frequency vs. current                  b) voltage vs. resistance  
 c) time vs. current                          d) voltage vs. time
- \_\_\_\_ 4. What is the frequency of the repeating waveform whose period is 16.7 ms?  
 a) 60 Hz    b) 6.01 KHz    c) 6.1 mHz    d) 0.006 MHz
- \_\_\_\_ 5. The angular velocity of a waveform with the frequency of 600 Hz is  
 a) 3768 Hz    b) 1884Hz    c) 1884 rad/s    d) 3768 rad/s
- \_\_\_\_ 6. A 6 V<sub>p</sub> sine wave is riding on a dc voltage of 8 V. If the dc voltage is lowered to 5 V, how far will the lower peak of the sine wave go?  
 a) 3 V    b) -1 V    c) -3 V    d) 1 V

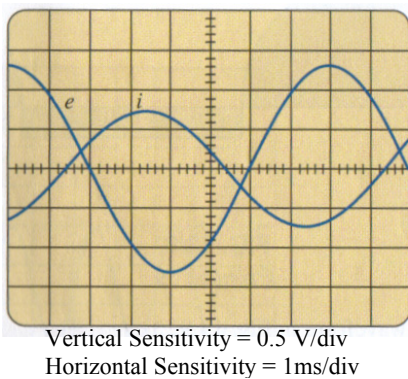
Figure 1



Refer to figure 1 for question #7

- \_\_\_ 7. Given an oscilloscope with a vertical sensitivity = 0.2 V and a horizontal sensitivity = 50ms, the rms value and the frequency are:  
 a) 0.424 V, 2 Hz      b) 3 V, 0.5 Hz      c) 6 V, 5 Hz      d) 0.6 V, 2 Hz

Figure 2



Refer to figure 2 for questions #8 – 10

- \_\_\_ 8. The frequency of the waveforms is  
 a) 8 Hz      b) 125 Hz      c) 4 Hz      d) 8 KHz
- \_\_\_ 9. The rms value of the waveform is  
 a) 1.25 V      b) 0.88 mV      c) 0.88 V      d) -1.25 V
- \_\_\_ 10. The voltage leads the current with a phase shift of  
 a) 207°      b) 45°      c) 3.14 radians      d) 153°

## Appendix E

### Frequency Response of RC and RL Networks Quiz

## Frequency Response of RC & RL Networks Quiz

Note: This quiz was given the week the associated laboratory was administered.

### Objectives

1. Demonstrate understanding of frequency responses of RC and RL networks.
2. Explain how to plot voltage and current versus frequency in an RC and RL network.
3. Describe how to calculate the phase angle of the input impedance versus frequency.

### Item Sources

Boylestad, R. L. (2007). *Introductory Circuit Analysis* (11 ed.). Upper Saddle River, NJ: Pearson/ Prentice Hall.

Floyd, T. L. (2007). *Electronics Fundamentals* (7 ed.). Upper Saddle River, NJ: Pearson/Prentice Hall.

Buchla, T. (2007). *Lab Manual to Accompany Electronic Fundamentals* (7 ed.). Upper Saddle River, NJ: Pearson/Prentice Hall.

(Floyd p.471 #1)

(Buchla p. 211 #1)

(Floyd p.471 #1)

(Boylestad Testgen Chapter 15)

(Boylestad Laboratory Manual p. 310)

(Boylestad Laboratory Manual p. 290)

(Buchla p. 202 #5a)

(Buchla p. 202 #5b)

(Buchla p. 202 #5c)

(Buchla p. 202 #5e)

### Item Answers

1. T
2. D
3. D
4. B
5. B
6. C
7. B
8. A
9. C
10. A

Name \_\_\_\_\_

Course \_\_\_\_\_

Laboratory section \_\_\_\_\_

### Frequency Response of an RC & RL Network Quiz

*This quiz contains True/False and multiple choice questions. Please place your answer on the line to the left of the question.*

Example:

  F   2. (T/F) University of Utah's mascot is a poodle.

  B   3. What are the three basic units of measurement included in Ohm's Law?

- |                                       |                         |
|---------------------------------------|-------------------------|
| a) Volts, Ohms, Farads                | b) Volts, Amperes, Ohms |
| c) Admittance, Susceptance, Reactance | d) Ohms, Henries, Volts |

**TRUE/FALSE Write "T" if the statement is true, "F" if the statement is false**

       1. (T/F) Impedance is the combination of capacitive reactance, inductive reactance, and dc resistance.

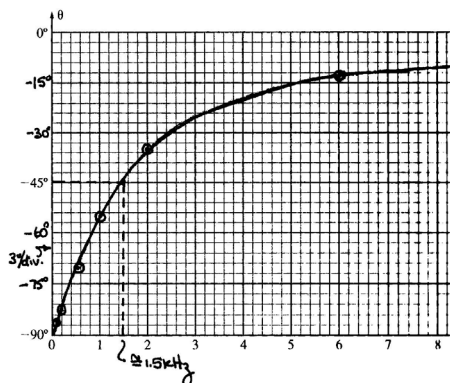
**MULTIPLE CHOICE Chose the one alternative that best completes the statement or answers the question.**

       2. 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) lagging the source voltage by  $90^\circ$     d) in phase with the current

       3. If a sinusoidal voltage wave is applied to an inductor, the current in the inductor  
 a) leads the voltage by  $45^\circ$     b) leads the voltage by  $90^\circ$   
 c) lags the voltage by  $45^\circ$     d) lags the voltage by  $90^\circ$

       4. In a series RC circuit, 10 V rms is measured across the resistor and 10V rms is also measured across the capacitor. The rms source voltage is  
 a) 20 V    b) 14.14 V    c) 28.28 V    d) - 10 V

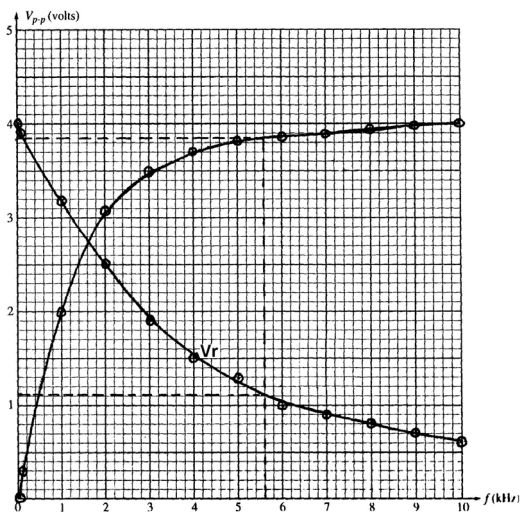
Figure 1



Refer to Figure 1 for question number 5

5. Figure 1 represents frequency versus
- a) phase angle  $\theta$  for an RL circuit
  - b) phase angle  $\theta$  for an RC circuit
  - c)  $V_R$  for an RC circuit
  - d)  $V_R$  for an RL circuit

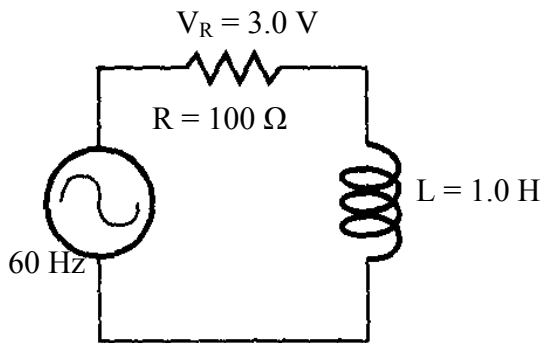
Figure 2



Refer to figure 2 for question #6

6. Figure 2 represents frequency versus
- a)  $V_R$  with a positive slope;  $V_L$  with a negative slope
  - b)  $V_R$  with a positive slope;  $V_C$  with a negative slope
  - c)  $V_R$  with a negative slope;  $V_L$  with a positive slope
  - d)  $V_C$  with a positive slope;  $V_L$  with a negative slope

Figure 3



Refer to Figure 3 for questions 7-10.

- \_\_\_ 7. The current in the inductor is  
 a) 30 A      b) 30 mA      c) 0.30A      d) 60 mA
- \_\_\_ 8. The inductive reactance is  
 a) 377 Ω      b) 188 Ω      c) 600 Ω      d) 1.8 kΩ
- \_\_\_ 9. The voltage across the inductor is  
 a) 1.25 V      b) 0.88 mV      c) 11.3 V      d) 1.13 V
- \_\_\_ 10. The phase angle between  $V_R$  and  $V_S$  is  
 a) 75°      b) 45°      c) 3.14 rads      d) 283°



Appendix F  
Resonance Quiz

## Resonance Quiz

Note: This quiz was given the week the associated laboratory was administered.

### Objectives

1. Describe voltage-current versus frequency for an RLC circuit.
2. Explain how input impedance varies with frequency.
3. Explain quality factor and bandwidth.
4. Describe resonant frequency in a parallel resonant circuit.

### Item Sources

Boylestad, R. L. (2007). *Introductory Circuit Analysis* (11 ed.). Upper Saddle River, NJ: Pearson/ Prentice Hall.

Floyd, T. L. (2007). *Electronics Fundamentals* (7 ed.). Upper Saddle River, NJ: Pearson/Prentice Hall.

Lindeburg, M., R. (2002). *FE Review Manual* (3rd ed.). Belmont: Professional Publications, Inc.

(Boylestad Testgen Chapter 20)

(Floyd p.610 #4)

(Boylestad Testgen Chapter 20)

(Lindeburg, p 41-9 #3)

(Boylestad Testgen Chapter 20)

(Lindeburg p.41-9 #1)

(Boylestad Testgen Chapter 20)

(Floyd p.613 #26)

(Boylestad Testgen Chapter 20)

(Lindeburg p. 41-10#10,17)

### Item Answers

1. T
2. T
3. T
4. C
5. D
6. A
7. B
8. D
9. A
10. B

Name \_\_\_\_\_

Course \_\_\_\_\_

Laboratory section \_\_\_\_\_

### Frequency Response of an RC & RL Network Quiz

*This quiz contains True/False and multiple choice questions. Please place your answer on the line to the left of the question.*

Example:

  F   2. (T/F) University of Utah's mascot is a poodle.

  B   3. What are the three basic units of measurement included in Ohm's Law?

- |                                       |                         |
|---------------------------------------|-------------------------|
| a) Volts, Ohms, Farads                | b) Volts, Amperes, Ohms |
| c) Admittance, Susceptance, Reactance | d) Ohms, Henries, Volts |

**TRUE/FALSE Write "T" if the statement is true, "F" if the statement is false.**

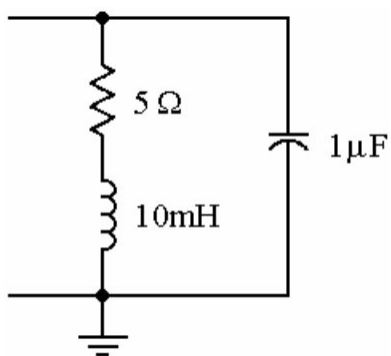
1. (T/F) Bandwidth is the range of frequencies between the half-power frequencies.
2. (T/F) The total impedance of a series RLC circuit at resonance is equal to the resistance of the circuit.
3. (T/F) Current and voltage are in phase in series resonant circuits.

**MULTIPLE CHOICE Chose the one alternative that best completes the statement or answers the question.**

4. What is the Q of a 1 mH coil at 1 kHz if its series resistance is 10Ω?  
 a) 0.8                      b) 1.59                      c) 0.63                      d) 1.0
5. Frequencies that define the points on the resonance curve that are 70.7% of the peak current or voltage value are known as the frequencies that determine  
 a) resonance      b) average      c) selection      d) bandwidth
6. The reactance of a 10mH inductor and 0.2 uF capacitor are equal when the frequency is  
 a) 3.54 kHz      b) 7.12 kHz      c) 14 kHz      d) 21 kHz



Figure 3



- \_\_\_ 10. See Figure 3. What is the resonant frequency of this parallel network?  
a) 15.9 MHz    b) 1.59 kHz    c) 15.9 Hz    d) 159 Hz

Appendix G  
Survey of Affective Traits

## Software-based Instrumentation

This survey is intended to help better understand software-based instrumentation in electronics laboratories. While completing this survey is safe and confidential, you may choose not to participate at any time. Your personal information, including your name, will not be published or used in this analysis and will be destroyed following the study.

### SECTION 1 DEMOGRAPHICS

1.1. What is your name?

1.2. What is your age group?

17 or less

18-19

20-21

22-23

24-25

26-27

28-29

30-34

35-39

40-44

45-49

50-54

55+

1.3. What is your class?

Freshman

Sophomore

Junior

Senior

Masters Student

Doctoral Student

1.4. What is your gender?

Female

Male

- 1.5. What is your ethnicity?  
African American  
Asian American or Pacific Islander  
Hispanic  
International Student  
Mixed Racial  
Native American  
White  
Other, Please Specify:
- 1.6. What kind of community were you living in prior to your entrance to the University?  
Rural  
Suburban  
Urban - big city over 1,000,000  
Urban - small city less than 1,000,000  
Military Base
- 1.7. What is your major?  
Biological/Irrigation Engineering  
Civil/Environmental Engineering  
Engineering & Technology Education  
Mechanical/Aerospace Engineering  
Professional Pilot/Maintenance Management  
Other, Please Specify:
- 1.8. What is the highest level of education of your parents?  
Some High School  
High School/GED  
Some College  
Associates Degree  
Bachelors Degree  
Masters Degree  
Doctoral Degree  
Other, Please Specify:
- 1.9. Which course are you currently taking?  
ETE 2210 Electrical Engineering for Non-majors  
ETE 2300 Electronic Fundamentals
- 1.10. In which laboratory section are you enrolled?  
Monday 1:30 pm  
Tuesday 1:30 pm  
Wednesday 8:30 am  
Wednesday 2:30 pm



## SECTION 2 LABORATORY ACTIVITIES

2.1. I am comfortable learning new computer skills and solving problems using a computer.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

2.2. I am comfortable performing experiments and analyzing the resulting data.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

2.3. I am comfortable designing new things.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

2.4. I am comfortable learning new laboratory skills and working in a laboratory.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

2.5. I am comfortable taking a leadership role in groups.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

2.6. I am comfortable identifying, formulating, and solving engineering problems.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

2.7. I prefer solving problems and working on projects alone.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

2.8. Rate your satisfaction of the following.

a. Overall experience with the laboratory activities

b. Support from the instructor(s)

c. Your lab partner's teamwork

d. How well the laboratory activities helped you meet the objectives

2.9. What would you change to improve the laboratory experience?

### SECTION 3 SOFTWARE-BASED OSCILLOSCOPE

This section is only for those who used the software-based oscilloscope during the labs. All others please go to section 4 “Traditional Oscilloscope”.

3.1. Did you use the software-based oscilloscope for any of your laboratory activities? If “no”, then go to section 4.

3.2. Rate your satisfaction of the software-based oscilloscope on the following items.

a. Overall experience

b. Reliability

c. Ease of use

d. Sensation of reality

e. Instruction/training

3.3. What would you change to improve the software-based oscilloscope?

### SECTION 4 TRADITIONAL OSCILLOSCOPE

4.1. Rate your satisfaction of the traditional oscilloscope on the following items.

a. Overall experience

b. Reliability

c. Ease of use

d. Sensation of reality

e. Instruction/training

4.2. What would you change to improve the traditional oscilloscope?

4.3. Which oscilloscope would you prefer using?

Software-based Oscilloscope or Traditional Oscilloscope

Appendix H  
ETE 2210 Syllabus

ETE 2210  
Section 001 – EE for Non-Majors

Dr. Ward Belliston  
4 credits  
Spring 2008

Catalog Description

A study and application of DC and AC concepts which includes circuit fundamentals, theorems, laws, analysis, components, equipment and measuring devices. The laboratory will include circuit design, construction and analysis of AC/DC circuits, and the use of measuring instruments, power supplies and signal generators.

Course Objective

1. To demonstrate an understanding and application of Ohm's Law
2. To build electronic circuits on a proto board
3. To demonstrate an understanding and application of resistance
4. To demonstrate the ability to use a DMM, power supply and frequency generator
5. To demonstrate an understanding and application of Series, parallel and compound circuits
6. To understand the principles of capacitance and inductance in modern electronic and electricity DC and AC circuits
7. To demonstrate the ability to use an oscilloscope to measure voltage and frequency
8. To build a power supply
9. To understand the application of modern analog circuits like operational amplifiers and instrumentation amplifiers

Textbook

*Introductory Circuit Analysis*, Robert L. Boylestad, Prentice Hall, 2003 (11<sup>th</sup> edition)

Fees

The laboratory experiments for this course will require electronic supplies. You have three options in purchasing parts:

1. You may purchase all of the parts *on your own*. The list of parts can be obtained from sources such as Radio Shack, past students or any other source you might know about.
2. You may purchase the proto board on your own and get the remaining parts from Dr. Belliston. You will need to pay a parts fee of \$18.00 in the registrar's office; deposit into account number MITE (A02363-525500). Bring the receipt to Dr. Belliston, and he will provide you with all the parts except the proto board.
3. You may purchase all of the parts, including proto board, from Dr. Belliston. Pay a parts fee of \$38.00 in the registrar's office; deposit into account number MITE (A02363-525500). Bring the receipt to Dr. Belliston, and he will provide you with all of the parts, including the proto board.

Note: Do not confuse the parts fee with the \$20 course fee which is paid with registration. The course fee is used for the maintenance and repair of equipment.

### Instructor

Dr. Ward Belliston                      Office: IS 112D

Phone:                      797-1801

E-mail:                      [ward@cc.usu.edu](mailto:ward@cc.usu.edu)

Office hours:              MF 9:30-10:30am

TR 11:30-12:30pm

### Class Time

Lecture:                      MWF -                      11:30am – 12:20pm – EL 248

Lab:                              W                              -                              2:30pm – 5:20pm – IS 119

### Homework

Homework will be assigned to be due at the beginning of the next class period unless otherwise stated. Late homework will not be accepted for credit. Homework is to be submitted on Engineering computation paper. The class number, assignment number, and your name should appear, in that order, across the top of the page. The page number should appear in the upper right-hand corner of EACH page as N/total pages, where N=1 for first page, N=2 for second page, etc. Each answer should be distinctively marked by such things as an arrow, an underline, a circle, a box, etc. Your work should be clearly shown so that others can easily follow your work. Although not required, you may find it helpful to write out the problem stated and then the solution to the problem. Submit homework flat and stapled in the upper left hand corner.

### Grading Policy

	10%
	30%
	5%
Laboratory (11 labs) and lab quizzes	25%

1. Homework will be assigned and graded.
2. Tentative dates for the hourly exams are:
  - Exam #1 – Friday, Jan. 25, 2008
  - Exam #2 – Friday, Feb. 15, 2008
  - Exam #3 – Friday, March 7, 2008
  - Exam #4 – Friday, April 4, 2008
  - Exam #5 – Friday, April 18, 2008

Material found on exam #1 could be on exam #2 and so on...

3. It is mandatory that each student attend each and every lecture and laboratory period. Lack of attendance will result in a failure grade.
4. The comprehensive final examination is scheduled for:
  - Date: Friday, May 2, 2008
  - Time: 9:30 a.m. - 11:20 p.m.
  - Place: EL 248
5. Cheating on quizzes or exams will not be tolerated and will result in a grade of "F" for that particular test.

### Accommodations for Persons with Disabilities

If a student has a disability that requires some accommodation by the instructor, the student must contact the instructor and document the disability through the Disability Resource Center during the first week of the course. Any request for special considerations must be discussed with and approved by the instructor.

### Class Schedule:

- A. DC Circuits
  - a. Current and Voltage
  - b. Resistance
  - c. Ohm's Law
  - d. Power and Energy
  - e. Series Circuits
  - f. Parallel Circuits
  - g. Series Parallel Networks
  - h. Thevenin's Theorem
  - i. Superposition Theorem
  - j. Norton's Theorem
  - k. Kirchhoff's Laws
  - l. Capacitance
  - m. Magnetism
  - n. Inductance
- B. AC Circuits
  - a. Sinusoidal Alternative Waveforms
  - b. Single phase
  - c. Three phase
  - d. Transformers
  - e. Power supplies
  - f. Delta-Wye Transformation
  - g. Series Circuits
  - h. Parallel Circuits
  - i. Compound Circuits
  - j. Power

- k. Power Factor
- l. Resonance

### C. Analog Circuits

- a. Operational Amplifiers

### **TENTATIVE LABS**

1. Electronics Laboratory Introduction and Equipment Familiarization
2. Ohm's Law
3. Series Circuits
4. Superposition
5. Thevenin's Theorem
6. Capacitance
7. Rectifiers
8. Power Supplies
9. AC Measurements
10. Frequency Response of RC and RL Circuits
11. Resonance
12. Operational Amplifiers
13. Capstone Project

### Tentative Schedule

The schedule shown may be adjusted from time to time as necessary. (Note: It is assumed that each student will study the summary, self-examination, and review questions at the end of each chapter. No late assignments are accepted.)

<u>Date</u>	<u>Days</u>	<u>Section</u>	<u>Topic</u>	<u>Problems</u>
Mon		Class Instruction		
Wed		Assignment #1 2, 3, 5, 7, 10, 11, 12, 13, 14, 18, 24, 34, 35	Current & Voltage	Page 59
Fri		Assignment #2 1, 2, 3, 4, 7, 14, 15, 16, 23, 24	Resistance	Pg 97-98
Mon		Assignment #3 40a, 40b, 41, 42, 44, 45a, 45b, 49, 52, 53, 54	Resistance	Pg 98-99
Wed		Assignment #4 Power & Energy	Ohms Law, 1, 2, 4, 6, 9, 13, 14, 20, 26	Pg 127 - 129
Fri		Assignment #5 Power & Energy	Ohms Law, Pg 128 - 129 28, 30, 32, 43, 44, 48a, 48c	
Mon		NO CLASS/Martin Luther King Day		
Wed		Assignment #6 5.2	Series Circuits Pg 172 - 176 1, 2, 4, 5, 7, 8, 10, 11a,b,c, 12, 16, 18, 20, 22, 26,	28
Fri		Exam #1		
Mon		Assignment #7 22, 24, 26, 28, 30, 33, 38	Advanced Problems 5.6 – 5.11 Pg 177 - 183	17, 18, 20,
Wed		Assignment #8 2, 3, 4, 10, 14, 16, 20, 22 Handout	Parallel Circuits Pg 232-237	
Fri		Assignment #9 24, 26, 28, 30, 38, 43 Handout	Parallel Circuits Pg 238 - 242	
Mon		Assignment #10 2, 4, 7, 10, 12, 18, 22, 24, 25, 29	Series Parallel Pg 274-281	
Wed		Assignment #11 9.1 – 9.2	Superposition Theorem Pg 388 – 389 1, 2, 4 & Handout	



Fri	Assignment #12	Thevenin's Theorem & Wheatstone Bridge	Pg 389-391	
Mon	Assignment #13	Norton's Theorem & Maximum Power Handouts	Pg 392	
Wed	Assignment #14	Capacitance 1, 4, 8, 14, 21, 23, 27, 32, 36, 51, 52, 54	Pg 453 - 458	
Fri	Exam #2			
Mon	NO CLASS/President's Day			
Tuesday	Attend Monday Classes:			
	Assignment #15		AC Circuits	Pg 581 - 584
	1, 2, 4, 5, 6, 9, 10, 11, 14, 17, 20			29, 30, 42
Wed	Assignment #16	Capacitors in AC 13.1 – 13.9	Pg 632 - 633 4, 13, 14, 15, 16a, 16b	
Feb 22	Fri	Assignment #17 11.2 – 11.12	Inductors	Pg 504-511 7, 12, 14, 15,
				22, 41
Mon	Assignment #18	Magnetic Circuits 12.1 – 12.13	Handout	
Wed	Assignment #19	Inductance and Inductance in AC Pg 510 - 511	Pg 632- 633	42, 43, 44
Fri	Assignment #20	Transformers	Pg 1025 - 1027 2a, 8, 13, Handout	
Mon	Assignment #21	Series RC Circuits 15.2 – 15.3	Pg 702-706 2a, 2b, 2c, 4b, 21, 24a, 24c, 24e Handout	
Wed	Assignment #22	Parallel RC Circuits 15.8	Pg 708	29, Handout
Mar 7	Fri	Exam #3		
Mar 10-14	Mon-Fri	SPRING BREAK/NO CLASSES		
Mar 17	Mon	Assignment #23	Series – Parallel RC Circuits	Handout
Mar 19	Wed	Assignment #24	Series – RL Circuits 4a, 4c, Handout	Pg 703
		15.3		

Mar 21	Fri 15.8	Assignment #25	Parallel RL Circuits 28, 30, Handout	Pg 708
Mar 24	Mon	Assignment #26	Series-Parallel RL Circuits	Handout
Wed	Assignment #27 23, Handout	Series RLC Circuits	Pg 707	
Mar 28	Fri	Assignment #28 5.5 – 5.8	Parallel RLC Circuits	Pg 707 25, 26,
		Handout		
Mar 31	Mon 20.2	Assignment #29	Resonance 1, 2, 3, 13, 14, Handout	Pg 911
Wed	Assignment #30	Op-Amp Circuits	Handout	
Fri	Exam #4			
Mon	Assignment #31	Op-Amp Circuits	Handout	
Wed	Assignment #32	Op-Amp Circuits	Handout	
Fri	Assignment #33	Instrumentation Amplifier	Handout	
Mon	Assignment #34	Instrumentation Amplifier	Handout	
Wed	Review	Handouts		
Fri	Exam #5			
Mon	Review	Handouts		
Wed	Review	Handouts		
Fri	LAST DAY OF CLASS			
Fri	Final Exam (Comprehensive)			
	Room: El 248			
	Time: 9:30 am – 11:20 am			

## PARTS FOR ETE 2210 – EE FOR NON-MAJORS

All parts may be procured from [jameco.com](http://jameco.com)

RESISTORS ¼ Watt, 5% tolerance, axial

11 – 150 OHM Resistors  
1 – 1k OHM Resistor  
1- 10K OHM Resistor  
1 – 1K OHM Potentiometer

INDUCTOR

1 – 10 mh

CAPACITORS

2 – 470 Microfarad 50 V  
1 – 0.01 Microfarad  
1 – 0.1 Microfarad

SEMICONDUCTORS

Diodes: 4 – IN4007

DIGITAL

1 – 7 segment display  
1 – BCD 7 segment 7447  
1 – 7490  
1 – 7404  
4 – red LED's  
1 – 7805  
1 – Proto Board

ANALOG

741 Op Amp

IT IS NOT REQUIRED, BUT GREATLY RECOMMEND:

1. Needle nose pliers
2. Wire strippers
3. Diagonal cutters

Appendix I  
ETE 2300 Syllabus

## ETE 2300 - ELECTRONIC FUNDAMENTALS

Dr. Ward Belliston

4 credits

Spring 2008

### Catalog Description

A study and application of DC and AC concepts, semiconductors, digital electronics, and microcomputers. Prerequisite: Math 1050 or equivalent. **NOTE: Student will be dropped if they do not meet the prerequisite.**

### Course Objective

1. To demonstrate an understanding and application of Ohm's Law
2. To build electronic circuits on a proto board
3. To demonstrate an understanding and application of resistance
4. To demonstrate the ability to use a DMM, power supply and frequency generator
5. To demonstrate an understanding and application of Series, parallel and compound circuits
6. To solve problems and show applications of network theorems
7. To understand the principles of capacitance and inductance in modern electronic and electricity circuits
8. To demonstrate the ability to use an oscilloscope to measure voltage and frequency
9. To understand the basics of semiconductors
10. To build a power supply
11. To understand the application and characteristics of digital circuits
12. To solve a problem using modern digital logic gates

### Textbook

Electronics Fundamentals, Thomas Floyd, Prentice Hall, 2007 (Seventh Edition)

### Fees

The laboratory experiments for this course will require electronic supplies. You have three options in purchasing parts:

1. You may purchase all of the parts *on your own*. The list of parts can be obtained from sources such as Radio Shack, past students or any other source you might know about.
2. You may purchase the proto board on your own and get the remaining parts from Dr. Belliston. You will need to pay a parts fee of \$24.00 in the registrar's office; deposit into account number MITE (A02363-525500). Bring the receipt to Dr. Belliston, and he will provide you with all the parts *except the proto board*.
3. You may purchase all of the parts, *including proto board*, from Dr. Belliston. Pay a parts fee of \$46.00 in the registrar's office; deposit into account number MITE

(A02363-525500). Bring the receipt to Dr. Belliston, and he will provide you with *all* of the parts, including the proto board.

Note: Do not confuse the parts fee with the \$20.00 course fee which is paid with registration. The course fee is used for maintenance and repairs of equipment.

### Instructor

Dr. Ward Belliston                      Office: IS 112D  
 Phone:                      797-1801  
 E-mail:                      [ward@cc.usu.edu](mailto:ward@cc.usu.edu)  
 Office hours:      MF 9:30–10:30a.m. & TR 11:30-12:30pm  
 Personal appointments may be made.

### Class Time

Lecture TR – 9:00 – 10:15am in Room Engr 103  
 Laboratory A - Monday 1:30 - 4:20 p.m. in Room IS 119  
 Laboratory B - Tuesday 1:30 - 4:20 p.m. in Room IS 119  
 Laboratory C – Wednesday 8:30 a.m. –11:20 p.m. in Room IS 119

### Homework

Homework will be assigned to be due at the beginning of the next class period unless otherwise stated. Late homework will not be accepted for credit. Homework is to be submitted on Engineering computation paper. The class number, assignment number, and your name should appear, in that order, across the top of the page. The page number should appear in the upper right-hand corner of EACH page as N/total pages, where N=1 for first page, N=2 for second page, etc. Each answer should be distinctively marked by such things as an arrow, an underline, a circle, a box, etc. Your work should be clearly shown so that others can easily follow your work. Although not required, you may find it helpful to write out the problem stated and then the solution to the problem. Submit homework flat and stapled in the upper left hand corner.

### Grading Policy

	10%
	30%
5%	
Laboratory (11 labs) and lab quizzes	30%
25%	

1. Homework will be assigned and graded.

2. Tentative dates for the hourly exams are:  
 Exam #1 – Thursday, January 24, 2008  
 Exam #2 – Thursday, February 14, 2008  
 Exam #3 – Thursday, March 6, 2008  
 Exam #4 – Thursday, April 3, 2008  
 Exam #5 – Thursday, April 17, 2008

NOTE: Material found on exam #1 could be on exam #2 and so on...

3. It is mandatory that each student attend each and every lecture and laboratory period.

4. The comprehensive final examination is scheduled for:

Date: Tuesday, April 29, 2007

Time: 7:30 a.m. - 9:20 a.m.

Place: Engr 103

5. Cheating on quizzes or exams will not be tolerated and will result in a grade of “F” for that particular test.

### Accommodations for Persons with Disabilities

If a student has a disability that requires some accommodation by the instructor, the student must contact the instructor and document the disability through the Disability Resource Center during the first week of the course. Any request for special considerations must be discussed with and approved by the instructor.

Class Schedule:

#### DC & AC Electronics

Ohm's Law  
 Resistance  
 Series & parallel circuits  
 Electromagnetic induction  
 Inductance  
 Capacitance

#### AC Electricity

Single phase  
 Three phase  
 Transformers  
 Rectifiers  
 Power supplies

#### Semiconductors

Diodes  
 Transistors  
 SCR  
 TRIAC

Digital Electronics

Number systems

Binary

Hexadecimal

Logic gates

AND

OR

NOT

NAND

NOR

Combinational logic

Microcomputers

Basic computer architecture

Computer interfacing

Labs (Tentative)

1. Ohm's law
2. Series circuits
3. Parallel circuits
4. Inductance
5. Capacitance
6. AC Measurements
7. Power supplies
8. RC & RL circuits
9. Transistors
10. Resonance
11. Logic gates
12. Combinational logic
13. PLD's



## PARTS FOR ETE 2300

All parts may be procured from [jameco.com](http://jameco.com)

### RESISTORS ¼ Watt, 5% tolerance, axial

11- 150 OHM Resistors  
1- 1k OHM Resistor  
1- 1k OHM Potentiometer

### INDUCTOR

1- 10 mh

### CAPACITORS

2- 470 Microfarad 50 V  
1- 0.01 Microfarad  
1- 0.1 Microfarad

### SEMICONDUCTORS

Diodes:

4 - IN4007

Triac:

1 - SC146M

### DIGITAL

1- 7 segment display  
1- BCD 7 segment • 7447  
1- 7490  
1- 7404  
4- red LED's  
1- yellow LED  
1- green LED  
1- dip switch  
1- GAL22V10  
1- 7400  
1- 7408  
1- 7432  
1-7427  
1- 7805  
1-MOC 3010  
1-PROTO BOARD

IT IS NOT REQUIRED, BUT GREATLY RECOMMEND:

1. Needle nose pliers
2. Wire strippers
3. Diagonal cutters

### Tentative Schedule

The schedule shown may be adjusted from time to time as necessary. (Note: It is assumed that each student will study the summary, self-examination, and review questions at the end of each chapter. No late assignments are accepted.)

<u>Date</u>	<u>Days</u>	<u>Section</u>	<u>Topic</u>	<u>Problems</u>
Tues Quiz		Class Instruction	Study Chapter 1	Basic Math
Thursday  23, 25, 26	Assignment #1 1, 2, 4, 6, 8, 10, 12, 14, 16, 2-4, 2-5		Quantities and Units	Page 19-20  20, 21, 22,
Tues	Assignment #2 2-6, 2-7	Resistance	Voltage Current and 1, 2, 3, 4, 7, 8, 11, 13, 14, 17, 19, 20, 25, 26, 27, 29, 30, 31	Pg 65-68
Thurs  10, 12, 14, 17,  24	Assignment #3  3-1, 3-2, 3-3, 3-4		Ohm's Law & Power	Pg 102-105  1, 2, 4, 6, 8,  18, 22, 23,
Tuesday  33, 35, 36, 37 41, 43	Assignment #4		Ohm's Law & Power	Pg 105-106 27, 28, 32, 39, 40,
Thurs	Exam #1			
Tues  50, 51, 52, 54, 56, 57, 60	Assignment #5	Ohm's Law & Power 3-8	Pg 106-108	44, 46, 49,
Thurs 1-18	Assignment #6		Series Circuits	Pg 152 - 154
Tues  24, 26, 28, 30	Assignment #7	Series Circuits 4-5, 4-6, 4-7, 4-8, 4-9	Pg 154-158  33, 35, 38	18, 20, 22,
Thurs 1-14	Assignment #8		Parallel Circuits	Pg 202-204

Tues	Assignment #9	Parallel Circuits	Pg 204-207	
		17, 18, 19, 21, 25, 31, 32, 34		
Thur	Exam #2			
Tues	No Class – Attend Monday’s Schedule			
Thurs	Assignment #10		Magnetism and	Pg 310-312
	Electromagnetism	1, 4, 7, 8, 9, 10, 12, 16, 17, 7-5, 7-6		18, 19
Tues	Assignment #11	Inductance	Pg 512-514	11-1,
		11-2, 11-3, 11-4	1, 3, 4, 8, 9., 12, 13, 14, 15	
Thurs	Assignment #12		Capacitors	Pg 417-420
		1, 2, 4, 13, 14, 16, 17, 20, 28		22, 23, 26,
Tues	Assignment #13	Alternative Voltage and Current	Pg 363-366	
		8-1, 8-2, 8-2, 8-4, 8-5, 8-6	1, 3, 5, 6, 7, 8, 14, 16, 21, 22, 23, 24,	22, 23, 24,
Mar 6	Thurs	Exam #3		
Tues/Thur	No Classes – Spring Break			
18	Tues	Assignment #14	Inductors and Capacitors in	Pg 514
	AC Circuits	17, 18, 19, 20, 21		Pg 420 31, 32, 33, 38, 40,
		34, 35, 36, 41		
Thurs	Assignment #15		Transformers	pg 645-648
		3, 4, 5, 6, 10, 11, 13, 14, 15, 17, 18, 19, 23, 24, 32		
Tues	Assignment #16	Diodes and Applications	Pg 746-749	
		16-1, 16-2, 16-3, 16-4	Pg 695-725	1, 2, 4, 7, 8,
		10, 13, 16-5		20, 21, 22, 23, 24, 25
Mar 27	Thurs	Assignment #17	Diodes and Applications Thyristors SCR and Triac Applications	Pg 749 29, 30 Handout
Tues	Assignment #18	Digital Electronics	Handout	
Thurs	Exam #4			

Tues	Assignment #19	Digital Electronics	Handout	
Apr 10	Thurs	Assignment #20	Digital Electronics	Handout
Tues	Assignment #21	Combinational Logic	Handout	
Thurs	Exam #5			
Tuesday	Assignment #22		Microcomputers	Handouts
Thur	Last Day of This Class			
Apr 29	Tues	Comprehensive Final Exam		
		Time: 7:30 – 9:20 am		
		Place: Engr 103		

Appendix J  
AC Measurements Laboratory

## AC Measurements Laboratory

### Objectives:

1. Become familiar with the fundamentals and operation of an oscilloscope.
2. Learn how to set the amplitude and frequency of a function generator.
3. Understand how to use an oscilloscope to measure both dc and ac voltage levels.
4. Understand the impact of the AC/DC/GND switch on the display waveform.

### Required Equipment:

1. Oscilloscope, Traditional or Computer-based (see Table and Figure 3.1)
2. Function Generator Agilent 3320A 20 MHz

## AC Measurements Laboratory

Name \_\_\_\_\_ Lab Day \_\_\_\_\_ Lab Time \_\_\_\_\_

## Objectives:

1. Become familiar with the fundamentals and operation of an oscilloscope.
2. Learn how to set the amplitude and frequency of a function generator.
3. Understand how to use an oscilloscope to measure both dc and ac voltage levels.
4. Understand the impact of the AC/DC/GND switch on the display waveform.

## Procedure:

1. Turn on the oscilloscope and establish a horizontal line centered on the face of the screen.
2. Adjust the following controls and note their effect:
3. a. Focus\* b. Intensity\* c. X-position\* d. Y-position, position, or Offset  
a. = *not included on software-based oscilloscope*
4. Measure a DC voltage from the power supply.

**WARNING**

**Make certain the function generator is set to -20 dB attenuation unless specified in the lab instructions. Otherwise the equipment may be severely damaged and you may be held liable. If you have questions, please ask the instructor for further directions.**

5. Set the signal generator to a frequency of 1 kHz at an amplitude less than 5 V<sub>pp</sub>. Measure the peak-to-peak voltage.
6. Measure the time for one cycle by first adjusting the seconds/division to display one or two cycles on the screen and then figuring the time. Time = sec/div \* # of divisions for one cycle.
7. Divide the time for one cycle into 1 to obtain the frequency. Note the frequency on the signal generator.
8. Set the signal generator for a 2 V<sub>pp</sub> signal at a frequency of 1 kHz. Measure the voltage with a DMM. What voltage do you read and why?
9. Demonstrate to the instructor the following:
10. Read a DC voltage with the oscilloscope.
11. Read an AC voltage with the oscilloscope.
12. Read time for one cycle with the oscilloscope.
13. Calculate frequency from the time in step 3.

## Problems

1. Write the sinusoidal expression for the waveform appearing in Figure. 1

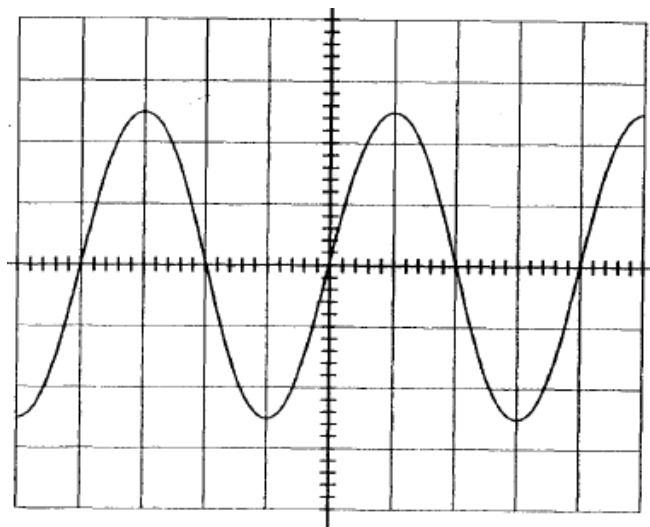


Figure 1. Vertical sensitivity = 4 V/div.  
Horizontal sensitivity = 5  $\mu$ s/div

2. Sketch the waveform defined by  $v = -1.5 + 2.5 \sin 2\pi(20 \times 10^3)t$  on the scope in Figure 2. Include the vertical and horizontal sensitivities.

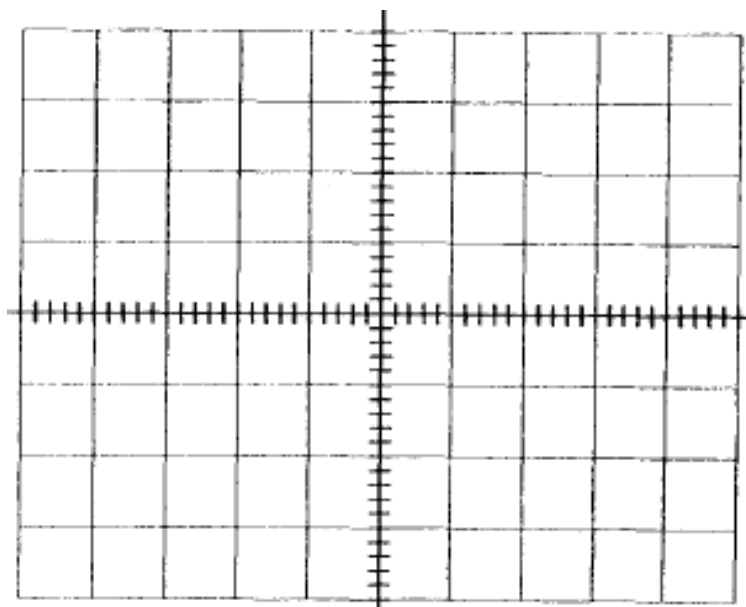
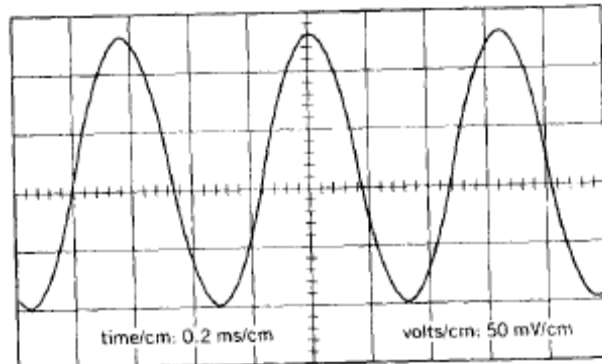


Figure 2. Vertical Sensitivity :



Horizontal Sensitivity:

3. Find the period of the periodic waveform with a frequency of 1160KHz.
4. In which frequency band is the frequency 1160 KHz located?
5. a. VLF b. LF c. MF d. HF e. VHF f. UHF g. SHF
6. Determine the frequency of a waveform if it has a period of 3 msec.
7. Determine the angular velocity of a sine wave with  $f = 610$  KHz.
8. What is the half wave average value of 20 Volts?
9. What is the RMS voltage value for a signal with a  $V_{pp}$  of 300 volts?
10. If  $e = 300 \sin 157t$ , how long (in seconds) does it take this waveform to complete  $\frac{1}{2}$  cycle?
11. For the waveform pattern below determine the following:



12. Peak amplitude:
13. Period of the wave:
14. Frequency of the waveform:
15. Find the amplitude and frequency of the following waves:
16.  $5 \sin 800t$
17.  $10^6 \sin 10,500t$
18. What is the instantaneous value of a voltage 20 msec after the wave goes through "0" with the equation  $e = 30 \sin 1300t$

## Appendix K

Frequency Response of RC/RL Networks Laboratory

## Frequency Response of RC/RL Networks Laboratory

### Objectives:

1. Become familiar with the frequency responses of RC and RL networks.
2. Plot the voltage and current of RC and RL network versus frequency.
3. Calculate and plot the phase angle of the input impedance versus frequency.

### Required Equipment:

1. Oscilloscope, Traditional or Computer-based (see Table and Figure 3.1)
2. Function Generator Agilent 3320A - 20 MHz
3. 100  $\Omega$  resistor -  $\frac{1}{2}$  Watt
4. 1k  $\Omega$  resistor -  $\frac{1}{2}$  Watt
5. 10 mH inductor - 50 V
6. 0.1  $\mu$ F capacitor - 50 V

## Frequency Response of RC & RL Networks Lab

Name \_\_\_\_\_ Lab Day \_\_\_\_\_ Lab Time \_\_\_\_\_

### Objectives:

1. Become familiar with the frequency responses of RC and RL networks.
2. Plot the voltage and current of RC and RL network versus frequency.
3. Calculate and plot the phase angle of the input impedance versus frequency.

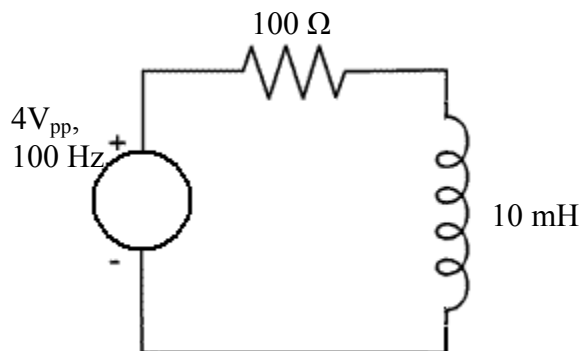
### Required Equipment:

1. Oscilloscope, Traditional or Computer-based (see Table and Figure 3.1)
2. Function Generator Agilent 3320A - 20 MHz
3. 100  $\Omega$  resistor - 1/2 Watt
4. 1k  $\Omega$  resistor - 1/2 Watt
5. 10 mH inductor - 50 V
6. 0.1  $\mu\text{F}$  capacitor - 50 V

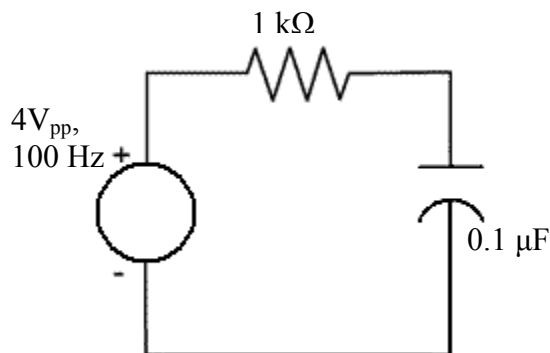
### Procedure:

1. Annotate the measured values of your components.
2. Construct the networks below.

*Figure 1.* RL Network



*Figure 2.* RC Network



3. Maintain the function generator output at 4 Volts<sub>pp</sub> and record the voltage across the inductor at the following frequencies. 100 Hz, 500 Hz, 1kHz, 2kHz, 3kHz, 4kHz, 5kHz, 6kHz, 7kHz, 8kHz, 9kHz, 10kHz.  
*Note:* the area in which the voltage across the inductor starts to level off is near what is termed the critical frequency.
4. Interchange the position of R and L and measure the voltage across the resistor for the frequencies in step 2.
5. Plot the magnitude of the peak-to-peak voltages across both R and L found in the steps above on a graph using engineering paper.
6. Calculate the phase angle for each frequency in Step 3 above.
7. Plot on a separate graph the frequency versus phase angle for the frequencies in Step 3.
8. Calculate the critical frequency and phase angle for the circuit.
9. Calculate the magnitude of the peak-to-peak current for the frequencies in Step 3 and plot them on a separate graph. Compare this graph to the voltage across the resistor versus frequency graph.
10. Does the magnitude of the voltage across R and L equal the supply voltage at the frequency of 5 kHz? Comment as to how they relate.
11. Calculate the reactance of the inductor at 8 kHz. How does this compare to the calculated value of the inductive reactance found by the inductor voltage divided by the inductive current at this same frequency?
12. Repeat Steps 3 through 9 for the RC network in Figure 2.

### Problems

1. Impedance is the combination of which three components?
2. In a series RC circuit, 10 V<sub>rms</sub> is measured across the resistor and 10V<sub>rms</sub> is also measured across the capacitor. The rms source voltage is  
a) 20 V    b) -10 V    c) 28.28 V    d) 14.14 V
3. If a sinusoidal voltage wave is applied to an capacitor, the current in the capacitor  
a) leads the voltage by 45°    b) leads the voltage by 90°  
c) lags the voltage by 45°    d) lags the voltage by 90°

4. In a series RC circuit, the voltage across the resistance is
- a) in phase with the current
  - b) lagging the source voltage by  $90^\circ$
  - c) lagging the source voltage by  $90^\circ$
  - d) in phase with the source voltage

Appendix L

Resonance of RLC Circuit Laboratory

## Resonance of RLC Circuit Laboratory

### Objectives:

1. Plot voltage/current versus frequency.
2. Demonstrate how input impedance varies with frequency.
3. Understand the quality factor and bandwidth.
4. Validate the equations for the resonant frequency of a series resonant circuit.

### Required Equipment:

1. Oscilloscope, Traditional or Computer-based (see Table and Figure 3.1)
2. Function Generator Agilent 3320A - 20 MHz
3. 47  $\Omega$  resistor -  $\frac{1}{2}$  Watt
4. 1k  $\Omega$  resistor -  $\frac{1}{2}$  Watt
5. 10 mH inductor - 50 V
6. 0.1  $\mu$ F capacitor - 50 V



## Resonance of RLC Circuit Laboratory

Name \_\_\_\_\_ Lab Day \_\_\_\_\_ Lab Time \_\_\_\_\_

## Objectives:

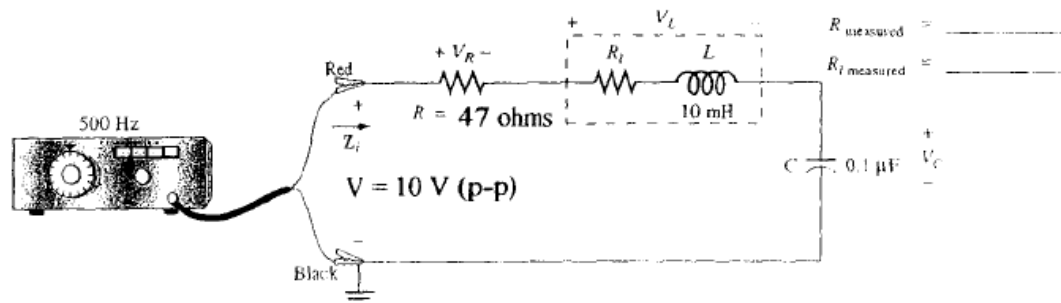
1. Plot voltage/current versus frequency.
2. Demonstrate how input impedance varies with frequency.
3. Understand the quality factor and bandwidth.
4. Validate the equations for the resonant frequency of a series resonant circuit.

## Required Equipment:

1. Oscilloscope, Traditional or Computer-based (see Table and Figure 3.1)
2. Function Generator Agilent 3320A - 20 MHz
3. 47  $\Omega$  resistor - 1/2 Watt
4. 1k  $\Omega$  resistor - 1/2 Watt
5. 10 mH inductor - 50 V
6. 0.1  $\mu\text{F}$  capacitor - 50 V

## Procedure:

1. Construct the circuit below. Measure the resistor value and the inductor resistance.



2. Using the given values compute the radian frequency and the resonant frequency.
3. Energize the circuit and set the generator frequency at every 5 kHz. At each frequency reset the input voltage to be 10 Volts peak to peak. Take a reading.,
4. Interchange the positions of the capacitor and inductor and take all the voltage readings across the inductor.
5. Finally, interchange the positions of the inductor and resistor and measure voltage.
6. Calculate the current at each frequency using Ohm's law. Current:  $V/R$
7. Calculate the input impedance  $Z$  by dividing the 10 volt (p-p), (or the rms equivalent) by the current in step 6 above.
8. Plot  $Z$  versus frequency on a graph.
9. At resonance, compare the input impedance  $Z$  to the total resistance of the circuit.
10. Describe in a few sentences how the input impedance of a series resonant circuit varies with frequency.

Appendix M  
IRB Application

## IRB Application

### Study Background

1. How does student achievement and affective traits in engineering laboratories utilizing traditional instrumentation compare with laboratories utilizing virtual instrumentation?
2. March 2008 to April 2009
3. N/A
4. Masters Thesis and journal article in the Institute of Electrical and Electronic Engineers (IEEE) Transactions on Education

### Participant Information

1. Undergraduates students in the ETE 2210 Electrical Engineering for Non-Majors and ETE 2300 Electronic Fundamentals courses.
  - a. 100 participants
  - b. Typically 18-35 years of age
  - c. 70 Males
  - d. 30 Females
  - e. Students will be asked to participate by the research team at the beginning of a class session using a informed consent letter.
  - f. Participate in the class with the treatment group using a virtual (software) oscilloscope in addition to the traditional oscilloscope. All participants will fill out a web survey.
  - g. Nine contacts over the semester
  - h. All student volunteers from the ETE 2210 and ETE 2300 courses during the Spring 2008 semester.
  - i. N/A
  - j. No
2.
  - a. 18 years older – initial contact may include students under 18. They will be removed from the study once identified.
  - b. Older than 65 – no
  - c. No cognitively impaired
  - d. No know physical/mental illness
  - e. Yes, may be potentially pregnant. We want to include all students in the class. No attempt will be made to identify or exclude pregnant students.
  - f. No prisoners
  - g. No institutionalized or adjudicated
  - h. Yes risks for coercion. As stated in the letter of consent, the students' grades will not be affected by participation.

### Risks & Benefits

1. Student achievement and affective traits will be better understood for distance laboratories using virtual instrumentation.
2. The student might be uncomfortable disclosing attitudes towards the course activities

and the instructors. The researchers will make clear that the information is confidential and will not be shared outside the research team.

#### Informed Consent

1. The informed Consent will be obtained by a letter given to the students and will be signed and dated.
2. PI or research assistant

#### Confidentiality

1. Yes, they will be coded using the last six digits of the A-number.
2. The data analysis will be performed on the code only.
  - a. They will be stored in a locked filing cabinet with only the researchers having access.
  - b. Three years
3. Yes, the students' scores and their survey results will be stored on a hard drive.
  - a. The records will be maintained on password protected computers and password protected files.
  - b. Three years

#### 4. Deception

No

#### 5. Health Records

No

#### 6. Conflict of Interest

No

Appendix N  
Informed Consent Letter



## INFORMED CONSENT

### A Comparison of Student Achievement and Affective Traits in Electrical Engineering Laboratories Using Traditional and Virtual Instrumentation

**Introduction/ Purpose** Professor Schreuders in the Department of Engineering and Technology Education at Utah State University (USU), and Matthew Lammi the research assistant, are conducting a research study to find out more about student learning and attitudes with virtual instrumentation. You have been asked to take part because you are enrolled in a course where the research will be performed. There will be approximately 100 participants in this research here at USU.

**Procedures** Participating in this survey is considered minimal risk and your participation is voluntary. You will be asked to participate in an online survey describing your experiences in the laboratory with the traditional and virtual oscilloscopes. The responses will be compared to the grades you receive on the quizzes relating to the laboratory materials. Your participation in this study will only be for Spring semester 2008.

**Voluntary nature of participation and right to withdraw without consequence** If you choose not to participate, you will not be penalized. If you begin the study and decide that you want to withdraw, all data pertaining to you will be removed from the research study.

**Risks/Benefits** There is minimal risk in participating in this research. While there is no direct benefit for you in participating, the results from this study may improve student success within the College of Engineering.

**Explanation and Offer to Answer Questions** If you have any other questions or research related problems, you may reach Paul Schreuders at (435) 797-7559 or Matthew Lammi at (435) 797-1796.

**Confidentiality** Research records will be kept confidential, consistent with federal and state regulations. To protect your privacy, you will be assigned a code number for use in all analyses and reporting of the data. Paul Schreuders and Matthew Lammi will be the only researchers who have access to the data collected and it will be kept in a locked filing cabinet in Dr. Schreuders office. The data will also be stored on a computer with a protected password. Personal, identifiable information will only be retained for three years and it will then be destroyed.

**IRB Approval Statement** The Institutional Review Board for the protection of human participants at USU has approved this research study. If you have any questions or concerns about your rights, you may contact the IRB at (435) 797-1821.

**Copy of consent** You have been given two copies of this Informed Consent. Please sign both copies and retain one copy for your files.

**Investigator Statement** "I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."

\_\_\_\_\_  
Dr. Paul Schreuders, (435) 797-5559

\_\_\_\_\_  
Matthew Lammi, (435) 797-1796

**Signature of Participant** By signing below, I agree to participate.

\_\_\_\_\_  
Participant's signature

\_\_\_\_\_  
Date