A QUASI-EXPERIMENTAL EVALUATION AND COMPARISON OF TWO LABORATORY INSTRUCTIONAL SYSTEMS FOR TEACHING SELECTED INTEGRATED CIRCUIT CONCEPTS

by

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DEDICATION

This research is dedicated with my deepest appreciation to my parents, and for their love and never ending encouragement throughout my life.

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Chapter 1

INTRODUCTION

Change in the electronics industry during the past decade has occurred at a phenomenal rate. With the introduction of solid state technology the entire industry has moved into an era of rapid technological advancement. When J. S. Kilby of Texas Instruments developed the first integrated circuit in 1958, little did he know that this technological advancement would instigate an electronic revolution. The magnitude of this impact was exemplified by the fact that Kilby was awarded the "Medal of Science" by the President of the United States (Curry, 1970). The effects of this contribution on the market are best illustrated by the introduction of the hand-held integrated circuit electronic calculator. The drastic reduction of weight and cost of this product illustrate two of the major advantages of integrated circuits and the reason for the industry shift to this technology (Leeds, 1968:8). "Today IC's (integrated circuits) account for over 50 percent of the semiconductor market and, therefore, represent a significant portion of the total field of electronics" (Ingram, 1972:2).

In education there has not been the degree or rate of change that has occurred in industry (Maness, 1969). Educators have found it increasingly difficult to stay abreast of technological advances, especially in the area of electronics (Slater, 1970). This is not a new problem in education as Deck (1955) indicated that the literature in the

field of electronics had not been developed and that, after it is developed, frequent revisions would have to be made to keep pace with the rapid rate of advancement in industry. Schmitt and Pelly (1966) concluded that staying abreast of technological advancements and applying modern concepts of industry to teaching are two major problems of national concern to industrial arts teachers. These existing conditions in education are a result of the high cost of research and development (Maness, 1969). The problems of incorporating new technology into curriculums and improving instruction has been the focus of many research efforts. However, much remains to be done. "Research is needed to identify fundamental factors for improvements in effectiveness and economy of instruction" (Lumsdaine, 1963:669,670). Brown stated that "Additional research must be conducted to find out the most effective methods of teaching and what teaching aids and materials are needed" (1963:38).

There has been a lack of instructional materials for use in electronics education programs dealing with recent integrated circuit technological advancements (Rigby, 1972:4). If industrial education programs are to depict what is going on in industry, then those things that have had an impact on industry should be incorporated into the curriculum (Maness, 1969:123). Therefore, "...industrial education programs must look to industry for direction in developing and up-dating course content" (Maness, 1969:126). Brook (1974), Tuttle (1974), Rigby (1972), Ingram (1971), and Maness (1969) surveyed industry to determine the integrated circuit concepts that should be taught in industrial and

vocational electronics courses at various educational levels. Slater (1970) surveyed electronics educators for similar recommendations. Industry and electronics educators from selected educational institutions recommended and placed the highest priority on the following integrated circuit instructional areas: (1) introduction to integrated circuits, (2) digital integrated circuitry, (3) linear integrated circuitry, and (4) digital and linear integrated circuit applications. Concepts under each of these instructional areas were also priority rated and recommended by both industry and electronics educators.

STATEMENT OF THE PROBLEM

Although industry has identified high priority integrated circuit concepts that should be taught in industrial and vocational education electronics programs, a review of the related literature revealed that no research has been conducted to evaluate or compare systems for teaching these concepts. In addition the review revealed three pressing needs in electronics education which should be met. (1) Strategies need to be developed so that electronics educators can stay abreast of advances in technology. (2) Additional research is needed to identify fundamental factors for improvements in effectiveness of current instruction, the most effective method of teaching, and effective teaching aids and materials. (3) Instructional materials are needed for industrial and voactional education electronics programs which cover the area of integrated circuits. Industry has recommended and placed a high priority on selected integrated circuit concepts. However, no research

could be found which dealt directly with these expressed needs as related to integrated circuits.

PURPOSE OF THE STUDY

The purpose of this study was to evaluate and compare two laboratory training systems for teaching integrated circuit concepts which surveys of industry have indicated as having a high priority in industrial education electronics programs. More specifically, the study sought to determine if either system could be effectively used to teach those concepts which industry recommended. Data were also analyzed to determine if any significant differences existed between the two systems. Student achievement was used as the criterion measure. System A consisted of existing laboratory equipment and System B consisted of an integrated circuit laboratory training system. Both systems are described in Appendix A.

The following hypotheses were investigated in this study:

Hypothesis 1. There is no significant difference between pretest and posttest scores when selected integrated circuit concepts are taught using the lecture method supplemented by either System A or System B.

Hypothesis 2. The participants' median posttest score in either experimental group A or experimental group B will be less than the cut off score of 75.

Hypothesis 3. There is no significant difference between the two laboratory training systems in terms of overall student achievement

on the complete instructional series when selected differences are controlled.

Hypothesis 4. There is no significant difference between the two laboratory training systems in terms of the students' overall retention of information taught during the integrated circuit instructional series.

Hypothesis 5. There is no significant difference between the two laboratory training systems in terms of student achievement on individual units when selected student differences are controlled. More specifically, there is no significant difference in student achievement on (a) introductory concepts of integrated circuits, (b) digital integrated circuitry including gates and flip-flops, (c) linear integrated circuitry including operational amplifiers and timers, and (d) digital and linear integrated circuit applications.

ASSUMPTIONS

This study was based on the following assumptions:

1. The intact class chosen as the sample was considered to be typical of those in the recent past and future who have taken or will take the industrial education electronics course.

2. The membership of the experimental groups had similar educational backgrounds and abilities.

3. The experiment was conducted under essentially the same conditions for all participants.

4. The instructional units selected for the study were

representative of the broad base of information associated with integrated circuits.

5. A cut off score of 75, with 50 percent of the participants in either group attaining this score, represented an acceptable industry performance level.

LIMITATIONS

The limitations of this study were:

1. The participants in this study were enrolled in an industrial education electronics course at Mississippi State University, and for this reason randomization of the sample was not possible.

2. The research was oriented toward integrated circuit subject matter only.

3. The experiment involved only those instructional units identified by industry as having a high priority when teaching integrated circuits.

4. The experimental groups were limited to a combined total of 35 male students.

IMPORTANCE OF THE STUDY

Advances in integrated circuit technology have created problems for the electronics educator. It is important that action be taken to solve these problems. Maness concluded that if industrial education programs are to be in tune with the times and relevant, "then the curriculum must be kept up-to-date" (1969:123). Cheshier emphasized this

point again in 1976:

> Since integrated circuits are dominating new designs and since indications are that they will be the predominant active electronic device over the next decade, all electronics programs from high school through college must teach their fundamentals (1976:52).

The 1975 edition of the Electronic Market Data Book illustrates how rapidly the electronics industry is moving toward IC technology. Factory sales of integrated circuits were reported to have increased from 13.4 percent to 49.3 percent of the total solid state component sales for the period 1966 through 1972. At the same time factory sales of transistors have dropped from 44.3 percent of the total sales in 1966 to 24.6 percent of the total solid state component sales in 1972. It appears that this trend can be expected to continue.

Industry has recommended that industrial education curriculums include "laboratory activities using linear, digital, and memory integrated circuits" (Rigby, 1972:53). This seems to indicate that industry feels that laboratory activities are very worthwhile and should be used to facilitate learning. Educators do not disagree; however, "The role of the laboratory as a technique to increase the achievement of students...needs further investigation" (Hurlebaus, 1970:109). A review of the literature revealed that no research could be found which determined the best approach to teaching integrated circuits in the classroom or laboratory. This is disturbing, especially when one considers that industry and educators have recommended that integrated circuit concepts be taught at various educational levels (Slater, 1970 and Rigby, 1972).

Maness recommended that "A study should be made to determine the cost of implementing a course in ICs" and that "Facilities and equipment should be of major concern in this study" (1969:124,126). Manufacturers of ICs considered breadboarding and the complete project approach to be the two best instructional techniques for teaching integrated circuits (Ingram, 1971). A review of past research revealed that two studies have been conducted to determine the value of the breadboarding technique when used in an electronics laboratory situation. Schuler concluded that "The circuit board (breadboard) technique appears to be an effective method of laboratory instruction" (1966:3377). Fowler (1965) concluded that students prefered the project method over the quick disconnect (breadboard) method, judging the quick disconnect (breadboard) method to be of more value in producing a better understanding of electrical theory. Based upon these two studies, it appears that the breadboarding technique is an effective method of laboratory instruction for basic electronics and electrical theory. However, no research could be found that determined if this method is effective when dealing with ICs.

Tuttle concluded that "Training systems are one of the most valuable educational vehicles in the teaching of digital logic circuits" (1974:67). This conclusion was based upon data gathered in a survey of electronics educators and digital logic manufacturers. Tuttle asked that educators and manufacturers rate a list of concepts or topics on the basis of their being used to aid a teacher in the purchase of a digital logic training system and for inclusion in a college level

industrial arts course. Thus, the above conclusion was not based upon an evaluation of various training systems. However, this does not mean that training systems are not effective; rather, the data did not support such a conclusion. Kindel pointed out:

> Well constructed teaching aids are beneficial to teaching. If a device is so constructed that students can understand better and remember the information presented longer, then the teaching aid is worthwhile (1961:1).

The present study investigated the value of training systems in teaching integrated circuit concepts.

It appears that educators have three choices for teaching electronics concepts in the laboratory. They may: (1) purchase commercial laboratory training systems of the type studied by Tuttle (1974); (2) design and construct a laboratory training system that meets their specific needs (Brook, 1974); or (3) use traditional or existing laboratory equipment. The present study was designed to evaluate the effectiveness of these last two choices for teaching high priority, integrated circuit concepts.

The results of this study should indicate whether either laboratory training system is effective in teaching those integrated circuit concepts recommended by industry. Thus, this will provide one possible approach for solving part of the problems facing the electronics educator. The findings will also increase the quantity of information available to industrial and vocational education teachers concerned with teaching integrated circuit concepts. In addition, this research should provide a basis for future studies of instructional

materials, methods, and laboratory equipment for teaching advanced integrated circuitry.

ORGANIZATION AND PROCEDURE

An intact class of 35 students enrolled in an industrial education electronics course was selected as the sample for the study. The sample was randomly divided into two groups, an experimental group A and experimental group B. Both groups received instruction in integrated circuitry through the conventional lecture technique supplemented by laboratory exercises. However, experimental group A utilized existing laboratory equipment while experimental group B utilized a teacher constructed laboratory training system to conduct the assigned laboratory activities.

Scores on the pretest were used to control statistically for selected student differences which existed in the intact class chosen as the sample. Six criterion measures were used to measure student achievement and retention on integrated circuit subject matter material. These were four unit tests, a posttest, and a retention test. Unit tests were administered at the completion of each unit and a posttest was administered upon completion of the total instructional series. The retention test was administered two weeks after the completion of the experiment without being announced in advance.

The t-test for correlated samples, median confidence interval, and the analysis of covariance were chosen as the statistical procedures for use in the study. These statistical procedures were chosen on the

basis of the experimental design selected for the study, the research hypotheses under investigation, and the conditions which existed at the research site.

DEFINITION OF TERMS

The terms listed below are defined in relation to the context of this study.

Clock--A stable oscillator that produces a train of equispaced pulses used for synchronization (Rodgers, 1970:14).

Clock Pulse--Any of the pulses produced by a clock (Rodgers, 1970:14).

Conventional Lecture Technique--A method of instruction whereby instructional units are presented through a presentation supported with the use of audio visual materials, question and answer sessions, and discussions.

Digital Integrated Circuit--An integrated circuit whose function is to handle digital information by means of switching circuits (Texas Instruments Learning Center, 1972:203).

Flip-Flop--A digital building block that, upon command from a "clock pulse" received at one input, stores (remembers) at its output a bit of information received at another input (Texas Instruments Learning Center, 1972:60).

Gate--Switching circuit building blocks which utilize yes and no statements as inputs to make certain simple decisions with the answer also expressed as yes or no (Texas Instruments Learning Center, 1972:42).

Hawthorne Effect--The behavior of a subject in an experiment which is influenced or produced by the subject's perception of the

experiment and how he should respond to the experimental stimuli (Ary, Jacobs, and Razavieh, 1972:237).

Initial Learning--Intellectual growth of the student directly following the learning experience (Yeager, 1965:8).

Instructional Series--A sequence of instructional units used to present integrated circuit concepts by the conventional lecture and laboratory techniques.

Integrated Circuit--An electronic circuit containing transistors and perhaps diodes, resistors, and capacitors, along with interconnecting electrical conductors processed and contained entirely within a single chip of silicon (Texas Instruments Learning Center, 1972:188).

Integrated Circuit Laboratory Training System--A teacher-designed and constructed instructional device containing the necessary supportive circuitry and breadboarding capabilities to study modern integrated circuit technology (Brook, 1974).

Integrated Circuit Timer--An integrated circuit which upon receiving a precise electrical signal activates or deactivates its output to control additional electronic circuits for a prescribed period of time.

Linear Integrated Circuit--An amplifying type integrated circuit which is used to increase the power, current, or voltage applied to its input (Texas Instruments Learning Center, 1972:234).

Operational Amplifier--A common form of linear integrated circuit that serves as an unspecialized amplifier which is characterized

by extremely high voltage gain and differential inputs (Texas Instruments Learning Center, 1972:226).

Retention--Student comprehension and/or recollection of previously learned instructional material (Yeager, 1965:8).

System A--Existing laboratory equipment used by students in the completion of assigned laboratory activities.

System B--A non-commercial teacher designed and constructed integrated circuit laboratory training system used by students to complete assigned laboratory activities.

Chapter 2

REVIEW OF RELATED LITERATURE

A literature review was conducted to determine the extent of prior research pertinent to the present study. The search for literature concerned with integrated circuit technology extended from 1960 onward as this technology was initiated by the introduction of the integrated circuit into the American market in 1960. There was an abundance of information available on electronics in general; however, only a limited number of studies pertinent to integrated circuit technology was found.

Although six studies were identified which concentrated on integrated circuits, none dealt with the aspects of teaching this new and expanding body of information. Even fewer studies were found which dealt with the area of semiconductor electronics. A synopsis of the review of the related literature is presented in four parts: literature related to integrated circuits, electronics teaching techniques, laboratory equipment, and the use of analysis of covariance in research associated with electronics education programs.

INTEGRATED CIRCUITS

Tuttle (1974) determined the criteria an educator should use in selecting a digital logic training system. He first surveyed the digital logic manuals which accompanied a wide variety of digital logic trainers marketed in 1974. The comprehensive list of selected topics he developed

was introduced to a cross section of digital logic, industrial education, university instructors and to integrated circuit manufacturers. Both the instructors and manufacturers' representatives were asked to rate each topic in one of two areas: selection for purchase of a digital training system and inclusion in a college level industrial arts electronics course. Based on findings, Tuttle developed a criteria list and topical outline which could be compared with those topics presented in any given instructional manual that accompanies a commercial digital training system. This gave the instructor a method of determining which commercial training system would meet specific requirements of a program, both in offering the digital logic concepts and in the alloted dollar value. Prior to this time no such criteria existed to aid an instructor in the selection of digital logic training equipment.

The major areas of concern in instructional materials for teaching digital logic were defined as: "Binary Logic and Boolean Algebra, Rules of Logic, Logic Families, Flip-Flops, Counters and Binary Numbers, Code and Code Conversion, Binary Arithmetic Operations, Core Memory Elements, and Related Circuits" (Tuttle, 1974:68). Tuttle suggested that the topical outline developed in the study could also be used in the development of an instructional monograph. Used as such, it could help meet the needs of college level industrial arts electricity and electronics instructors in providing instruction in digital logic circuitry.

Two conclusions were drawn by Tuttle from the data compiled in his study which are pertinent to this research.

1. Due to the unique nature of digital logic circuitry, new information must be added to industrial education programs for an understanding of it.

2. Training systems are one of the most valuable educational vehicles in the teaching of digital logic circuitry (1974: 67).

In view of these conclusions, Tuttle made several recommendations which have a bearing upon this study.

1. Industrial education programs on the secondary level should include an introduction to digital logic circuitry.
2. Institutions of higher education that offer graduate programs in industrial teacher education should implement a course in digital logic circuitry for graduate credit.
3. A study should be made to determine the cost of implementing a course of digital circuitry. Facilities and equipment should be of major concern in this study (1974:69).

Rigby (1972) identified instructional topics in the area of integrated circuits which were relevant to the industrial education curriculum. He used selected readings, data from previous studies, and consultations with advisory persons to compile fifty-five instructional topics on integrated circuits. These were submitted to leading manufacturers of integrated circuits to be rated on the level of desirability for use in a college level industrial arts electricity and electronics course. The data obtained in the survey were analyzed to establish the necessary information to develop an up-to-date and relevant program of instruction for integrated circuits.

An instructional monograph was also developed on integrated circuits which could be used in an industrial education electricity and electronics course. The monograph was written around suggested course content and was designed to fulfill the needs of educators for materials of this type to use in the industrial education curriculum.

Rigby's conclusions which are pertinent to this study were:

1. Integrated circuits command a significant portion of the

field of electronics and, therefore, should be included in industrial education programs at both the secondary and the college level.

2. Based on manufacturers' recommendations, the following instructional topic clusters dealing with integrated circuits should be included in an industrial education electronics course:

> Development and impact of integrated circuits
> Basic semiconductor theory
> Introduction to monolithic integrated circuits
> Integrated circuit processing and fabrication
> Linear integrated circuits
> Digital integrated circuits
> Memory integrated circuits
> Future capabilities and applications of integrated circuits (1972:52)

Industrial respondents made the recommendation that the industrial education curriculum should include "laboratory activities using linear, digital, and memory integrated circuits" (Rigby, 1972:53). Recommendations pertinent to this research were:

1. Integrated circuits should be among industrial offerings at the secondary and college level.
2. Teacher preparation institutions should modify their course offerings to include integrated circuits and offer workshops to update those teachers already in the field (Rigby, 1972: 53).

Ingram (1971) identified a body of knowledge that could be utilized as high school industrial arts curriculum materials. The study focused upon four major objectives, the first of which was to present an historical perspective of integrated circuits. The second objective was to determine what effect integrated circuits had upon the high school electronics curriculum. The third was the development of instructional

materials which reflected current technology in integrated circuitry, and the final objective was to recommend curriculum changes for the future. A survey of integrated circuit manufactureres was conducted to ascertain the relative industrial value of active devices, to recommend instructional time for various instructional areas, and to suggest curriculum materials for integrated circuits.

The survey for a second year industrial arts electronics course led Ingram to the following conclusions:

1. Instructional time for integrated circuits, with emphasis on monolithic structures, should be divided on the basis of digital integrated circuits, 21 percent; linear integrated circuits, 19 percent; and fabrication, 10 percent.
2. With reference to digital integrated circuits, gates and flip-flops were considered to be the most representative circuit type for instructional content.
3. The emphasis of instructional content on digital integrated circuits should be placed on the transistor-transistor logic configuration as it is most widely used.
4. When linear integrated circuits are to be considered for inclusion into instructional content, operational and differential amplifiers were considered most representative of circuit types.
5. In projecting to the future, the survey indicated that there should be a move to increase the time devoted to digital and linear circuit instruction.
6. Emphasis on medium and large scale integrated circuitry

should be increased with less emphasis being placed on special purpose tubes.

The following recommendations were made with regard to instructional techniques for teaching integrated circuits:

1. Instruction in transistor technology and integrated circuit technology should be mutually overlapping and interacting.
2. A complete set of curriculum materials should be developed and tested for the integrated circuitry portion of a high school level and a college level course (Ingram, 1971:106).

Survey data also revealed that manufacturers considered the top four instructional techniques for teaching integrated circuits to be breadboarding, complete project, modeling, and pictorial drawing, respectively.

Slater (1970) asked four year college and university industrial education instructors to rate specific needs for updating educational experiences. The study focused on selected electronics concepts as identified in previous studies. Emphasis was placed on identifying course content for in-service and graduate level training in the industrial education electronics curricula. Data obtained from 133 industrial education electronics instructors were categorized on the basis of baccalaureate degree, relative need, and priority. An analysis of the data indicated that needs existed for an increased emphasis on theories, recent advances in electronics technology, and practical applications in the service of electronics devices. The data supported the fact that many college level electronics instructors recognize the need to stay abreast of technological developments through specific types of in-service programs. Slater concluded that "Educators responsible for the design and implementation of in-service programs should include the content areas of integrated circuits and transistors..."

It was also concluded that courses of study should be designed to include appropriate concepts related to: "...recent advances in electronics" (1970:4510).

Maness (1969) investigated the present status of integrated circuits in American industry and asked integrated circuit manufacturers to identify the concepts they felt were essential for understanding integrated circuits. In addition, they were asked to identify the supplementary integrated circuit instructional content needed in industrial teacher education programs. He found that the advantages of integrated circuits over discrete components had caused industry to shift utilization patterns toward integrated circuits. Advantages of integrated circuits were identified as: "greatly reduced size and weight, lower cost, improved reliability, improved performance, decreased power requirements, and novelty and sales appeal" (Maness, 1969:123).

The data indicated that digital integrated circuits, linear integrated circuits, and introduction to integrated circuits and monolithic circuits were the most important topics identified by industry and were rated 87.5, 83.3, 91.7, and 75 out of a possible rating of 100, respectively (Maness, 1969).

It was concluded (Maness, 1969) that the impact of integrated circuits on the electronics industry has been tremendous and that electronics courses should be updated to provide a better understanding of integrated circuits. Two additional conclusions drawn were that course content in industrial teacher education programs should include integrated circuit material and that industry is willing to work with industrial teacher education programs in up-dating course content.

Several recommendations were made by Maness about future implications for teaching integrated circuitry and conducting future research.

1. At least one course in integrated circuits should be implemented in industrial teacher education programs and required for those students specializing in electronics.
2. Some content pertaining to integrated circuits should be offered to all students enrolled in industrial arts programs.
3. Institutions of higher education that have graduate programs in industrial teacher education should implement a course in integrated circuits for graduate credit.
4. A study should be made to determine the cost of implementing a course of integrated circuits. Facilities and equipment should be of major concern in this study (Maness, 1969:124, 126).

An historical study by Klienman (1966) traced the development of the integrated circuit from the transistor to its level of industrial utilization in 1966. Intensive research and extensive interviewing of industrial representatives, military personnel, consultants, and representatives of financial and academic institutions provided the information compiled by the study. Klienman found that it was a combined effort on the part of government and industry that eventually secured the development and introduction of the integrated circuit on the American market. Although major advances in integrated circuit technology cannot be attributed to the government, it was the governmental effort that acted as the stimulus that accelerated the development of the integrated circuit. Based on data collected, Klienman concluded that "integrated circuit technology eventually would have been developed by private industry" and that "major advances were not attributed to government support" (1966:217). It was an Air Force interest in modular electronics that struck the first spark and private industry that kindled the fire to the present non-extinguishable level. The fact

that "Those firms with a large stake in the semiconductor and IC business have been the most successful in the market place and have the best technical capability" (Klienman, 1966:218) supports this finding.

Summary of Research Related to Integrated Circuits

A review of the literature related to integrated circuits revealed several important factors which had implications for the future. Past research indicated that additional research is needed to make improvements in effectiveness and cost of instruction. In addition, research is needed to determine the most effective methods of teaching. Findings also indicated that a shift in program emphasis from transistor to integrated circuit technology is needed along with the development of instructional materials. This is especially true for industrial education programs at institutions of higher learning.

ELECTRONICS TEACHING TECHNIQUES

Holt (1972) compared student performance under the traditional lecture-demonstration method with an individualized packet method for teaching semiconductor theory. Under the individualized approach the students were allowed to select media, learning methods, behavioral objectives, and self tests. Data were collected and analyzed to determine any differences between groups in immediate achievement and in four-week retention. The emphasis of the study was on electronic problem solving ability and recall of electronic concepts and principles.

The findings of this study revealed that there was no significant difference between the two teaching methods. It was recommended that

further research be done to evaluate teaching methods based upon student performance as well as the cost, efficiency, and teacher/student attitudes.

Brown (1971) designed and evaluated an instructional program to teach basic semiconductor electronics concepts to college freshmen. The program consisted of a slide/tape series that covered both basic theory and the laboratory procedure that accompanied the coordinated experiments. A pretest/posttest instrument was developed and submitted to a jury of experts in the field of electronics and media. Thirty-four students enrolled in a basic semiconductor electronics course were randomly divided into two groups. One group received instruction through the conventional lecture-laboratory technique, while the other group received instruction from the slide/tape lecture and laboratory procedural instructions. At the midpoint in the course the two groups were rotated to eliminate instructor bias. Records were kept on the amount of time each group spent receiving instruction from the conventional lecture-laboratory technique and the slide/tape program.

The results indicated that there was a substantial savings in time for the students that received their instruction from individual carrels. The statistical treatment of analysis of covariance was used on the data obtained from the pretest and posttest. The results of this treatment indicated that there was no significant difference at the .01 level between the two groups. It was concluded that while there was no significant difference between the control and experimental groups, there was a substantial savings in student instructional time. Therefore, since the audio-visual technique was just as effective as the conven-

tional lecture laboratory technique the time saved would thus permit better use of facilities, equipment, and instructional time.

Dennison (1970) made an experimental comparison between the conventional method of instruction composed of lecture, demonstration, and discussion, and an experimental method. The experimental method was different from the conventional method in that it included the use of eight-millimeter, single-concept films. Five representative units of basic electronic subject matter material were selected by a jury of experts for use in the study. Seven evaluation tests were used which included a pretest, posttest, and five unit tests. Scores obtained on these tests were used to assess increases in initial learning and overall retention. An analysis of the data revealed that the experimental method was superior in producing greater increases in initial learning and overall retention.

Hurlebaus (1970) compared the conventional laboratory manual approach with an approach requiring students to design and detail the experimental format. The relative effectiveness of both approaches was determined by conducting the study in junior college electronics courses. The students of each class were asked to choose one of the two laboratory sections established for each class. Their choice was based upon their desire to participate in the specific type of laboratory activity offered. These two sections were then randomly assigned as the control and experimental groups. However participants received lectures and were evaluated as a total group. A posttest and a delayed posttest were used as the criterion measures for the null hypotheses. The analysis of the data by the analysis of covariance technique revealed that

the experimental group exhibited greater achievement in terms of overall electronics achievement, basic concepts achievement, and problem solving capabilities. The results also indicated that as students progress in an electronics course an increase in problem solving capability can be observed. Hurlebaus recommended that "The role of the laboratory as a technique to increase the achievement of students...needs further investigation" (1970:109).

Baker (1966) conducted a study to determine the effectiveness of a problem solving approach to project construction. This method was compared with the conventional practices used for teaching an introductory college level electricity laboratory. Students in the experimental group investigated an assigned study unit and developed practical applications of the principles illustrated in the unit. A project which utilized these principles was designed and constructed. The control group followed the conventional approach of constructing required projects and performing circuit board experiments during laboratory periods. The groups were combined for lectures, but the experimental group was released from the normal laboratory period to accomplish their tasks on an independent basis.

The study measured the initial learning and retention of factual information, manipulative skills, and student attitudes toward the course. Evaluation was done through unit tests, a comprehensive post-test, a manipulative performance test, a standardized attitude scale, and a student questionnaire. A panel of judges evaluated the projects constructed by the experimental group as compared with a typical project.

Baker found no significant difference when the two approaches

were compared. It was concluded that:

1. A laboratory activity does not contribute to learning but the specific type of activity is less important than the degree of organization of the activity.
2. Formal laboratory periods are not necessary (1966:3354).

Schuler (1966) compared the relative effectiveness of the circuit board and chassis laboratory instructional techniques at the college level. The experiment was conducted in a basic electronics course. Both groups received the same lectures and demonstrations, the only difference being the laboratory instruction treatment. The circuit board group performed experiments on circuit or breadboards using premounted components and solderless connections. Conventional construction procedures were used by the chassis group. Subject matter tests, a troubleshooting test, a laboratory exercise, and interest observation, and a student questionnaire were used to collect the data required for the comparison. An analysis of the data revealed that the circuit board technique was significantly more effective for reinforcing lecture material. The majority of both groups indicated that they prefered the circuit board technique over the conventional chassis technique. Greater mean scores were achieved by the circuit board group on the troubleshooting test, laboratory exercises, and interest observation. However this difference was not statistically significant. Thus it was concluded that "The circuit board technique appears to be an efficient method of laboratory instruction" (Schuler, 1966:3377).

Fowler (1965) compared the project method with the combination of the quick disconnect and project method. These laboratory activities were evaluated in introductory electricity courses at the college level.

The study evaluated the teaching methods, and overall retention of subject matter, assessed student attitudes toward the course, and ascertained the interaction between the teaching method and prior knowledge of the subject matter. Both groups received the same lectures, demonstrations, homework, and tests. The only difference between the groups was the type of laboratory activity in which the students were involved. The evaluation was based upon data obtained from subject matter tests, a manipulative performance test, a standardized attitude scale, and a student questionnaire.

An analysis of the data revealed that the higher score obtained by the quick disconnect method for teaching alternating current principles was significant at the .10 level. The quick disconnect group obtained higher mean scores on all other teacher constructed tests than did the control group. Data from the student questionnaire revealed that the majority of students felt that the laboratory activities were a valuable part of the course. They prefered the project method over the quick disconnect method, judging the quick disconnect method to be of more value in producing a better understanding of electrical theory.

It was concluded that this research, like past research, indicates "that a number of laboratory activities are equally effective for teaching basic electricity at the college level" (Fowler, 1965:6658). Fowler recommended that laboratory activities should be based upon "Cost to the school and student, laboratory facilities for conducting the activity, ease of administration, and teacher competence with the method" (1965: 6548).

Summary of Research Related to Electronics Teaching Techniques

A review of research in this area revealed that a variety of techniques have been studied. Slide tape presentations of lecture materials and laboratory procedures, when compared with conventional lecture laboratory prodecures, were found to be equally effective. However in another study, when teacher-constructed eight millimeter film loops were compared with the conventional lecture demonstration method, the eight millimeter film approach proved to be superior. Other studies revealed that the conventional laboratory manual approach, when compared to student designed experimental problems and formats, was found to be inferior. When the quick disconnect or laboratory breadboard technique for teaching electronics was compared with the conventional chassis or project method, it was found to produce superior results. An additional study revealed that student performance is equally good when instruction is given by the traditional lecture-demonstration method or by individualized instruction packets.

LABORATORY EQUIPMENT

The product of a study by Brook (1974) was the development of an IC course outline and laboratory trainer designed to meet the training needs of future employees in the Mississippi electronics industry. This study was the foundation for the present research. This two part study consisted of an industrial survey and the design, development, and construction of an integrated circuit laboratory training unit. A list of electronics concepts was developed through a review of curriculum and reference materials and was used as part of the survey instrument.

Industries in Mississippi which focused primarily upon electronics were asked to rate each concept on a scale extending from one to five representing the importance of teaching each concept. Space was provided on the survey instrument for additional topics to be added as deemed necessary by the respondent. From this, a list of topics was converted into an outline for an advanced electronics course with major emphasis on integrated circuits.

An integrated circuit laboratory training unit was designed and constructed on the basis of the information obtained from the industry survey, a review of the literature, and an evaluation of commercially available training units. The design of the trainer was based upon six criteria: "(1) Needs of the Student, (2) Industrial Requirements, (3) Adaptability to Industrial Applications, (4) Ease of Operation, (5) Versatility, and (6)Economics" (Brook, 1974:8). The modular design system of the trainer could be easily updated and modified to prevent early obsolescence. The total development cost was far below the purchase price of any comparable commercially produced training unit. It was concluded that a teacher designed training unit could be produced in the typically equipped electronics laboratory. It was also found that the instructional capabilities of the unit surpassed those of comparable commercially produced training systems.

An experimental study conducted by Yamauchi (1971) assessed student achievement when miniaturized and full size electronics laboratory equipment was utilized for instructional purposes. The study also included a survey of manufacturers and instructors using miniaturized equipment. They were asked to rate full size and miniaturized labora-

tory equipment with regard to producing the greatest student achievement. Participants in the study were divided into three groups, each receiving different treatments. The first group used miniaturized equipment, the second group utilized full size industrial laboratory equipment, and the last group did not use any laboratory equipment. Data for the evaluation were collected through the use of achievement tests and survey forms. Upon analyzing the data, Yamauchi found that no significant difference existed when full size and miniaturized equipment was compared for producing greater student achievement. The survey indicated that manufacturers of miniaturized laboratory equipment expected greater learner achievement than instructors when miniaturized equipment is utilized. These findings seem to support the fact that a change from full size to miniaturized laboratory equipment is made on the basis of economics and space utilization. This finding seems to refute the claim of manufacturers of miniaturized equipment that students using this equipment show greater achievement in the laboratory.

The design and construction of electrical equipment that would aid in teaching electrical concepts was the focus of Monteleone's (1952) work. This study was based upon the application of electrical apparatus or units to junior and senior high school industrial arts shops and teacher training institutions. It was stated that:

> The apparatus which have been developed in this study are those which are usually omitted from the school shop because of their cost or because the commercially built units are unsuitable for the teaching situation found in the school shop (1952:522).

An electrical apparatus was constructed for use with several instructional areas: electrical power, electroplating, anodizing, vacuum tube

characteristics, regulated power supplies, and induction heating. A lengthly development process yielded some units that were too costly, too complex, and did not fulfill the existing needs. The ultimate design for the units took into consideration safety, quietness, simplicity of design, construction, and compactness. Superior performance of these units as teaching vehicles was illustrated by the fact that they were chosen to be used by an industrial arts department of an Eastern teachers college.

The main thrust of Monteleone's study was on the design and construction of electrical apparatus for teaching. Strong emphasis was given to construction details and specifications. These units which were constructed by prospective teachers for use at future employment stations, served as the vehicles for teaching electrical concepts. Hope was expressed that this construction approach would lead to the development of other electrical apparatus of this type. Monteleone concluded that this teaching approach provides an excellent mechanism for teaching electrical principles.

Summary of Research Related to Laboratory Equipment

Research reviewed in this area revealed several important factors about laboratory equipment. Teacher developed laboratory training devices can be constructed at a cost far below comparable commercial training devices. These devices can also be designed in a manner so that they can be easily and cheaply updated as technology advances to combat obsolescence. Another study revealed that miniaturized laboratory equipment, when compared with standard size equipment for teaching

electronics concepts, does not produce greater student achievement levels. Research also proved that the construction of laboratory training devices, by students as part of their required laboratory activity, serves as an excellent mechanism for teaching electrical principles.

THE USE OF ANALYSIS OF COVARIANCE

The use of the statistical procedure of analysis of covariance in various fields of research has been wide and varied. It appears that this procedure has found major application in those situations where intact groups have been used in experimental studies. Redditt (1973) conducted a quasi-experimental study to compare the group lecture method and a self-directed method for teaching electricity. In this study, which was conducted at the college level, he used two intact sections of basic electricity operating during the same semester. The analysis of covariance proved to be successful in analyzing the data to determine the existence of differences between the two methods. Seguin (1973) successfully utilized the analysis of covariance to control for individual differences that existed in the backgrounds of electronics students. Here again, intact electronics laboratory classes were used in an experimental study to determine the effect of grouping on cognate and psychomotor achievement.

Landers (1972) also used this technique with his "Non-Equivalent Group" design. He used a pre-existing group to determine the effectiveness of two different approaches to laboratory teaching. This design

was chosen because randomization of subjects was not feasible and thus existing differences had to be adjusted statistically. Bockman (1971) successfully applied the statistical procedure of analysis of covariance when he used existing classes to determine the effectiveness of programmed instruction and the conventional lecture discussion method.

Summary of Research Related to the Use of Analysis of Covariance

The statistical procedure of analysis of covariance has been chosen for wide use in the area of electronics research as well as in other fields. It has primarily been applied in situations where intact classes or groups had to be used in experimental studies. In addition, it has been used to adjust statistically for differences which exist within established groups and classes. It was for these purposes that the analysis of covariance was developed (Wert, Neidt, and Ahmann, 1954) (Winer, 1962).

SUMMARY

The introduction of the integrated circuit to the American market opened an era in electronics which has taken on connotations far different from any of the past. Cheshier stated:

> Since integrated circuits are dominating new designs and since indications are that they will be the predominant active electronic device over the next decade, all electronics programs from high school through college must teach their fundamentals (1976:52).

This literature and research review was conducted to determine the present status of research related to integrated circuits, electronic teaching techniques, laboratory equipment, and the use of analysis of

covariance in electronics research. The main emphasis of the review was limited to electricity and electronics in the fields of industrial and vocational education. There was an abundance of information available in the area of electronics but very little research has been conducted on the more advanced concepts of electronics. Those studies which dealt with semiconductor electronics concentrated on the fabrication of semiconductor devices and associated teaching techniques. No studies were found which focused upon the teaching aspects of integrated circuitry. The major concentration of studies which dealt with integrated circuits was in the identification of instructional concepts. Findings emphasize the need for additional research in the area of teaching integrated circuit concepts to isolate the best instructional approach. Maness (1969:5) supports this by stating: "Since industrial education has often advocated the teaching of modern industrial processes, it may be that the area of integrated circuits should be emphasized to a greater degree."

Additional studies were reviewed which concentrated on electronic teaching techniques and laboratory equipment. Research supported the use of the quick disconnect or breadboarding techniques for laboratory instruction. The use of eight-millimeter film loops to supplement the conventional lecture techniques and the use of student designed experimental formats were also supported. Studies have indicated that laboratory training equipment can be constructed at a substantial savings by an electronics instructor and that the construction of such equipment serves as an excellent vehicle for teaching electrical concepts.

Research also revealed that standard size and miniaturized electronics laboratory equipment are both equally effective in producing student achievement.

This literature review has established the fact that the statistical procedure of analysis of covariance has been used successfully in electronics education research. It has been used when randomization was not possible and when intact classes had to be utilized in experimental studies. This technique statistically adjusts for differences, which exist within established groups, so that the resultant effect of the treatment variable can be measured accurately.

Market data (Electronics Industries Association, 1975:90) has established the fact that the integrated circuit is playing an ever increasing role in our lives. If, as Kindel's research (1961) indicates, teaching aids and devices are worthwhile in producing a better understanding of instructional material, then further research is needed to develop more effective teaching devices. The non-existance of research in teaching integrated circuit technology and the needs expressed by Maness (1969) and Tuttle (1974) exemplify this fact.

The author has used this literature review to establish a solid foundation for the present research. Existing needs in the field of electronics were identified in relation to the new and expanding instructional area of integrated circuits. In addition, the review of past research was utilized to identify those integrated circuit concepts which were included in the instructional series used in this research.

Chapter 3

RESEARCH DESIGN AND METHODOLOGY

The purpose of this study was to evaluate and compare two laboratory instructional systems for teaching high priority, industry-rated, integrated circuit concepts. More specifically, the study sought to determine if either system could be effectively used to teach those concepts which industry recommended to be included in an electronics program. These two systems were evaluated under laboratory teaching conditions using college level industrial education students.

To accomplish this objective, a quasi-experimental research design was utilized. This study was conducted in the Industrial and Occupational Education Department at Mississippi State University during the Spring Semester of 1977.

POPULATION AND SAMPLE

The population from which the sample was obtained consisted primarily of industrial arts and industrial technology majors in the Industrial and Occupational Education Department at Mississippi State University. Students in these two curriculums composed approximately eighty percent of the total departmental enrollment. The majority of the students in this population were enrolled in their sophomore, junior, or senior year of university level study. Historically, the departmental enrollment has consisted of a large number of transfer

students from the junior college system within the state and other departments on the campus. Only a small number of students have entered curriculums offered by the department during their freshman year. Therefore, the average age and maturity level found within the department appeared to be somewhat higher than would be found in other departments across the campus. Since the university is located in the northeast section of the state and draws its student body primarily from this area, the students enrolled in the department exhibit characteristics of persons with rural to semi-rural backgrounds. In the past few years there has been a noticable increase in the number of veterans enrolled within selected curriculums.

The sample selected for this experiment was an intact class enrolled in an industrial electronics course. The obvious limitation of using this class was imposed by the inflexibility of the educational system as the most desirable population (the total departmental enrollment) to be tested was not accessible. A random selection of subjects from the total departmental population was considered; however, it was quickly discarded as it would have been impossible to coordinate such a wide variety of student schedules. The sample consisted of 35 male industrial education majors who had similar educational background and abilities. Industrial arts and industrial technology majors composed the majority of the sample. The major difference between the two curriculums is the required coursework to be taken outside the Department of Industrial and Occupational Education. A description of these

and other curriculums may be found in the 1976-77 Mississippi State University catalog.

A biographical questionnaire was administered to all subjects prior to conducting the experiment. The purpose of this instrument was to describe the sample in terms of age, previous education, and demonstrated abilities on college entrance tests, etc. A synopsis of these data can be found in Appendix B.

SELECTION OF INSTRUCTIONAL UNITS

The instructional units selected for this study were considered to be representative of the broad base of information associated with integrated circuits. Four instructional units were selected rather than an entire course so that participating instructors and students did not have to relinquish more time than was necessary for the experiment.

A review of text books, curriculum materials, and courses of study revealed a long list of topics associated with integrated circuit technology. However, the basis for selecting the four units and associated concepts was found in recent research conducted by Tuttle (1974), Rigby (1972), Ingram (1971), Maness (1969), and Brook (1974). The data collected and analyzed in these studies indicated that industry and electronics educators placed the greatest importance on the following four instructional areas of integrated circuits:

1. Introductory concepts of integrated circuits.
2. Digital integrated circuitry including gates and flip-flops.

3. Linear integrated circuitry including operational amplifiers and timers.
4. Digital and linear integrated circuit applications.

DEVELOPMENT OF INSTRUCTIONAL MATERIALS

Electronics textbooks, current research, and curriculum materials were analyzed to locate all possible concepts or topics which should be included in the four selected instructional units. Detailed outlines were then developed for each unit. Various types of illustrations which could be used in conjunction with the associated integrated circuit concepts were located to coordinate with the unit materials. These materials were then submitted to a jury of experts to determine the content validity. The jury was composed of two university level electronics instructors holding the rank of Assistant Professor in the College of Arts and Sciences at Virginia Polytechnic Institute and State University who were involved in teaching integrated circuit theory and applications. The suggested changes made by the jury were incorporated into the final outline for each instructional unit. Illustrations approved by the jury were used as a guide to develop a coordinated set of color slides. The coordinated set of slides was used in conjunction with the outlines as the instructional guide for all presentations. Examples of these materials, except slides, have been included in Appendix C.

INSTRUMENTS

All test instruments used in the study were comprised of multiple choice questions. Questions were presented with four possible answers, only one of which was correct. The full array of tests used in the experiment included a pretest, four unit tests, a posttest, and a retention test which were administered in that order. The pretest, posttest, and retention tests were equivalent forms and were composed of fifty objective questions. Each unit test was composed of twenty-five questions. All instruments were submitted to the jury of experts along with the associated instructional unit outline for content validity evaluation. Suggested changes made by the jury were incorporated into the final draft of the measuring instruments. Reliability coefficients were calculated for the tests using TESTAT and DISTAT computer programs. Generalized reliability coefficients are reported with the instrument data in chapter four.

The pretest was used to determine the student's level of knowledge of integrated circuitry prior to conducting the experiment. It was composed of questions selected from each of the four instructional units.

A single test was developed for each instructional unit which consisted of twenty-five multiple-choice questions. The questions selected for these tests were considered to be representative of the major points illustrated in the unit presentation and applied in the laboratory activities. These instruments were administered at the

completion of the instructional presentation and the associated laboratory exercise to measure initial learning.

A posttest was used to measure student achievement at the completion of the four unit instructional series. The same multiple-choice format was used to provide for ease in scoring and to remove any possible source of subjectivity in the testing process.

Two weeks after the completion of the experiment and the administration of the posttest, a retention test was administered. It was designed to measure student retention after a definite time period had elapsed.

TESTING PROCEDURE

All tests were administered to all participants in the study at the same time to insure that different testing conditions did not exist for either group. Following this procedure eliminated any possible alteration in the results which could be produced by outside variables associated with testing conditions.

The pretest was administered prior to the beginning of the experiment in a scheduled testing period. Forty-five minutes were allowed for the participants to complete the test.

Since class periods were structured to a ninety minute time period, it became necessary that both a unit presentation and a unit test be completed within that time frame. A total of sixty minutes was allowed for the first lecture presentation with the remaining class time being utilized as part of the required laboratory period. The unit test

was then administered during the first twenty minutes of the next scheduled lecture period.

The posttest was administered at the completion of the experiment in a scheduled testing period. Forty-five minutes were designated to administer this test to all participants.

Two weeks after the completion of the experiment and posttesting, a retention test was administered to all participants. A forty-five minute time period was allowed for administering this instrument.

CONDUCTING THE EXPERIMENT

The experiment was begun by establishing an experimental group A and an experimental group B. Specific precautionary steps were taken to insure that a "Hawthorne Effect" did not intervene. Participants were not informed as to the identity of the experimental groups in the study. They were also separated for the laboratory exercise that was coordinated with each instructional unit presentation.

An intact class of 35 students enrolled in a junior level industrial electronics course was randomly divided by assigning a number to each student and consulting the random number table. Students were alternately assigned to the experimental group A and the experimental group B upon selection of their representative number.

The research design chosen for this study was a modified Non-Equivalent Control Group Design as illustrated by Campbell and Stanley (1968). The pre-existing conditions at the chosen study site were used as the basis for making this selection. Since it was determined that an intact class would be available for use in this study, it became

necessary to use the quasi-experimental design.

When a research design of this type is utilized, it is almost mandatory that the researcher administer a pretest to determine if differences exist between the two established groups. Both experimental groups were assembled as one group and given the pretest. This insured that testing conditions were the same for both groups. The scores obtained on this test were used as the covariant in the final statistical analysis of the data. Analysis of covariance was chosen as the major statistical tool for this study to allow statistical adjustment for differences that existed in the pre-existing groups.

Once the pretesting had been completed, both groups were asked to meet as one group for presentation of the first instructional unit. This same procedure was followed for all presentations as it insured that the conditions for the lecture portion of the experiment were the same for all participants. Upon completion of the lecture portion of the first instructional unit, both groups were given their laboratory activity assignment. The experimental group A was assigned the first laboratory exercise using existing laboratory equipment (system A). The experimental group B was assigned the same exercise using the integrated circuit laboratory training system (system B). Both groups were allowed the same amount of time to complete the laboratory activity.

Participants in both groups were asked to divide into lab teams of two people to conduct their assigned laboratory activity. To decrease interaction, each experimental group was assigned to a different laboratory. Both groups were asked not to intermix during the

laboratory period and not to discuss their lab activity with members of the other group for the duration of the experiment.

When the groups completed the laboratory activity, they were given a handout sheet that outlined the important points covered in the instructional units. A unit test was then administered at the beginning of the next scheduled lecture session when both groups were again combined. This procedure was repreated for the remaining three instructional units. Upon completion of the entire instructional series and the associated laboratory activities, a posttest was administered to all participants assembled as one group. This test was designed to measure overall student achievement on the total instructional series. Two weeks later a retention test was administered to all participants, again as a single group, to measure the retention of integrated circuit concepts. Participants were informed prior to the completion of each instructional unit that they could expect a twenty-five question objective type test upon its completion. However, they were not informed that they would be given a posttest and a retention test. All participants were instructed not to study with members of the opposite lab group in preparing for each of the unit tests.

Upon completion of the retention test, participants were given the opportunity to express their reactions to taking part in the experiment. A synopsis of their reactions toward taking part in the experiment can be found in Appendix D.

INSTRUMENT SCORING AND ANALYSIS

All tests used in the study were answered on standard, machine-readable, answer sheets. Each test was scored against the appropriate key and a composite score of the number of correct answers was printed on the student's answer sheet. An analysis of each test was made with TESTAT and DISTAT computer programs. This information is presented in chapter four.

TREATMENT OF DATA

The "t test" for correlated samples (Ferguson, 1976:166) was used as the statistical procedure to check for any significant difference between the pretest and posttest scores for both experimental groups, A and B. This procedure was chosen since it was necessary to determine the significant difference between two related measures (means). Bruning and Kintz support this choice by stating that this procedure "...is most commonly used in this way when two scores are recorded for the same individuals" (1968:12).

A confidence interval for the median score on the posttest for each group was calculated using the procedure described by Ferguson (1976:156). This procedure was chosen as the author desired to specify an interval within which it could be asserted with a known degree of confidence that the population median existed. Median scores were selected for the confidence interval calculations to insure that 50 percent of the participants would reach the accepted level of performance, thus indicating that the training system involved was effective.

The confidence interval for both groups was then checked against a cut-off score of 75. A score of 75, which was the acceptable level of performance, was based upon the Federal Communication Commission's required level of performance on certification examinations (Kaufman, 1973:iii). If 50 percent of either group obtained a score of 75 or greater on the posttest, the laboratory training system was considered to have been effective in teaching the integrated circuit concepts which industry recommended. Both laboratory systems were evaluated in this manner.

Analysis of covariance was the major statistical procedure chosen for this study. This procedure was chosen because the author desired to determine if a significant difference existed between the performance of the experimental groups using different laboratory training systems and because an intact class had to be utilized in the experiment, making true randomization impossible. Winer supports this choice by stating that:

> Direct control...is generally not possible when the experimenter is forced to work with intact groups. In such situations, statistical control is the only method available to the experimenter (1962:581).

There are three basic underlying assumptions that must be made if the analysis of covariance is expected to produce reliable results: the population is normally distributed, the variance of different groups is approximately equal, and the sample is a random representation of the true population.

In a study of this type it was desirable to maintain a high level of internal validity. Therefore in using an experimental design, it was imperative to ensure that any significant difference in the

results be attributed to the treatment variable. This provided a sound basis for the findings of the study.

Circumstances occur where a variable or variables are uncontrollable as a result of practical limitations associated with the experiment. Such is the case in this study where an intact group had to be utilized. The only means remaining to control for these variables or differences in the intact class is that of a statistical procedure, since the sample was not randomly selected. Wert, Neidt, and Ahman offer a solution: "To provide the investigator with a means of attaining a measure of control of individual differences, the statistical technique known a analysis of covariance was developed" (1954:343). This rationale served as the basis for the choice of this statistical procedure for this study. It was through the use of this statistical technique that a valid evaluation of the outcome of the experiment was accomplished. The general linear models procedure of the Statistical Analysis System (SAS), which is available at the Virginia Polytechnic Institute and State University Computing Center, was chosen as the prime computer program for data analysis.

The covariant selected for the statistical treatment was the participant's pretest score on integrated circuits. An alpha level of .05 was selected as the level of significance for use throughout the study. Six criterion measures were used for the analysis; the scores on the four unit tests, the posttest, and the retention test. These criterion measures were analyzed to evaluate and compare the two laboratory instructional systems. A cut off score of 75 was used as an acceptable industry performance level.

SUMMARY

Students enrolled in coursework in the Industrial and Occupational Education Department at Mississippi State University during the Spring Semester of 1977 composed the population for this study. The sample consisted of 35 students enrolled in an intact industrial education electronics course. Industrial arts and industrial technology majors made up the majority of the sample.

Participants in the study were randomly divided into two experimental groups. Both groups were combined for the lecture but were divided for the laboratory activities assigned with each instructional unit. The experimental group A conducted laboratory exercises using existing laboratory equipment (System A), while experimental group B conducted the same laboratory exercise with the integrated circuit laboratory training system (System B). Data were obtained from seven test instruments.

The conditions under which the experiment had to be conducted served as the basis for the selection of the analysis of covariance, an appropriate statistical treatment for this type of research. An alpha level of .05 was chosen for the level of significance throughout the study. The data from the instruments and the statistical procedure provided the results reported in the next chapter.

Chapter 4

PRESENTATION AND ANALYSIS OF DATA

INTRODUCTION

Data collected at the research site during the operation of the experiment has been presented and analyzed in this chapter. The analysis of the data was utilized as the basis to evaluate and compare the two laboratory training systems used in teaching the selected integrated circuit concepts which industry recommended. Five hypotheses were tested and the findings are reported in the order that the hypotheses were presented in Chapter 1. Experimental group A utilized existing laboratory equipment which did not include commercial training systems to complete assigned laboratory activities. Experimental group B utilized a non-commercial teacher designed and constructed integrated circuit laboratory training system to complete their assigned laboratory activities. Both experimental groups jointly attended lecture sessions and were assigned the same laboratory activities.

ANALYSIS OF DATA

Statistical procedures chosen for the analysis of the data included: the t-test for correlated samples, the median confidence interval, and the analysis of covariance. A .05 level of significance was chosen for use throughout the analysis. These statistical procedures were chosen on the basis of the experimental design selected for the

study, the research hypotheses under investigation, and the conditions which existed at the research site. Sixteen participants composed experimental group A when the experiment was begun. However, two participants were unable to complete the experiment due to illness and injury. Therefore, the scores for participants 2 and 7 have been omitted from the tables and calculations where they were unable to participate. Experimental group B was composed of nineteen participants, all of which completed the entire experiment. Thus the combined "n" for the experiment was thirty-three.

Generalized reliability coefficients for all instruments used in the experiment ranged from a low of 0.69 to a high of 0.82. These coefficients were calculated using TESTAT and DISTAT computer programs which were available at the Mississippi State University Computing Center. A modified Coefficient Alpha procedure developed by Cronback (1951) was used in the program to obtain the reliability coefficient for each instrument. Ary, Jacobs, and Razavieh (1972) state that a reliability coefficient of .70 and above is considered to be acceptable for test instruments by most test makers and researchers. Since the lowest test reliability coefficient calculated for the instruments used in the experiment was 0.69 and was not significantly different from the acceptable limit, all test instruments were considered to be reliable.

Hypothesis One

Hypotheses 1. There is no significant difference between pretest and posttest scores when selected integrated circuit concepts are

taught using the lecture method supplemented by either System A or System B.

Hypothesis one was tested in the null form using the t-test for correlated samples on the pretest and posttest scores for experimental groups A and B. Table I presents the pretest and posttest scores for experimental group A and t-test calculations. The highest score obtainable on the pretest and posttest was a score of 50. However, a review of the test scores revealed that neither a "floor" or a "ceiling" effect occurred as scores were not grouped at the low or high end of the scale. The mean scores for experimental group A on the pretest and posttest were 18.43 and 38.86 respectively. Median scores on the pretest and posttest were 19.30 and 41.30 respectively, while the standard deviations for these two tests were 4.297 and 5.22. Test reliability coefficients for the pretest and posttest were 0.69 and 0.77 respectively.

A "t" value of 15.93 was calculated for the pretest and posttest results of experimental group A. The critical value of "t" for 13 degrees of freedom at the .05 significance level is 2.16. Thus, there was a significant difference between the pretest and posttest scores for experimental group A at the .05 level of significance. Therefore, hypothesis one for experimental group A was rejected. In that the calculated "t" value was much larger than the critical value, the difference was considered to be important.

Table II presents the pretest and posttest scores for experimental group B and the t-test calculations. The mean scores for experimental group B on the pretest and posttests were 18.84 and 37.53 respectively, while the median scores on these tests were 17.83 and

TABLE I

Pretest/Posttest Performance for Experimental Group A

Participant	Pretest Score	Posttest Score	D	D^2
1	24	44	20	400
2	16	--	-	-
3	20	42	22	484
4	22	42	20	400
5	25	45	20	400
6	16	33	17	289
7	20	--	-	-
8	16	33	17	289
9	24	42	18	324
10	19	43	24	576
11	13	27	14	196
12	15	41	26	676
13	23	40	17	289
14	10	43	33	1089
15	14	35	21	441
16	17	34	17	289
Sum --	258	544	286	6142
$\bar{X}$ --	18.43	38.86	20.43	
Median --	19.30	41.30		
S --	4.297	5.222		
Test Reliability	0.690	0.77		

t = 15.93

TABLE II

Pretest/Posttest Performance for Experimental Group B

Participant	Pretest Score	Posttest Score	D	D^2
1	21	32	11	121
2	23	45	22	484
3	14	42	28	784
4	12	43	31	961
5	21	39	18	324
6	13	27	14	196
7	15	33	18	324
8	24	37	13	169
9	18	38	20	400
10	33	47	14	196
11	19	45	26	676
12	17	28	11	121
13	24	32	8	64
14	18	35	17	289
15	15	40	25	625
16	17	34	17	289
17	16	40	24	576
18	20	37	17	289
19	13	39	26	676
Sum --	358	713	360	7564
$\bar{X}$ --	18.84	37.53	18.95	
Median --	17.83	38.00		
S --	4.84	5.63		
Test Reliability	0.69	0.77		

t = 12.86

38.00. Standard deviations for the pretest and posttests were 4.84 and 5.63 respectively.

A "t" value of 12.86 was calculated for the pretest and posttest results of experimental group B. The critical value of "t" for 18 degrees of freedom at the .05 significance level is 2.101. Thus, there was a significant difference between the pretest and posttest scores for experimental group B at the .05 level of significance. Therefore, hypothesis one for experimental group B was rejected. This difference was considered to be important as the calculated "t" value was much greater than the critical value.

Hypothesis Two

Hypothesis 2. The participants' median posttest score in either experimental group A or experimental group B will be less than the cut off score of 75.

Hypothesis two was tested by calculating the confidence interval for the median score on the posttest for each experimental group and comparing the interval with the cut off score of 75. Median confidence intervals were calculated for each group after the posttest scores were converted to a 100 point scale by multiplying each score by a factor of two. Table III presents the posttest scores of experimental group A and the calculated limits for the median confidence interval. The confidence interval, at the .05 level, for the median posttest score extended from 76.571 (lower limit) to 88.628 (upper limit). Thus the lower limit of the confidence interval for the median score was above the industry accepted cut off score of 75. Therefore System A was

TABLE III

Confidence Interval for the Median Posttest Score-Group A

Participant	Post Test Score
1	44
2	--
3	42
4	42
5	45
6	33
7	--
8	33
9	42
10	43
11	27
12	41
13	40
14	43
15	35
16	34

$\overline{X}$ = 38.86

S = 5.22

Median = 41.3/50 or 83/100

df = 14-1 = 13

Alpha = .05

Lower Limit = 76.571

Upper Limit = 88.628

considered to be effective in teaching the integrated circuit concepts which industry recommended. Hypothesis two for experimental group A was rejected.

Table IV presents the posttest scores of the experimental group B and the calculated limits for the median confidence interval. The confidence interval, at the .05 level, for the median posttest extended from 72.912 (lower limit) to 79.08798 (upper limit). Since the lower confidence interval limit was calculated to be slightly less that the established cut off score of 75, it could only be concluded that the true median fell within these limits and was not 75 or larger. Therefore the data indicated that the instructional system used by experimental group B could not be considered effective or ineffective in teaching those integrated circuit concepts which industry recommended. Hypothesis two for experimental group B was retained.

At this point the author felt that it was necessary to take a closer look at the unit test performance of group B to determine if poor performance in one of the four instructional units had any effect on the composite posttest score. This was done by calculating the lower confidence interval limit for each of the median posttest scores. When the results of these calculations were reviewed to determine if the median scores were equal to or larger than the established cut off score, it was found that system B was effective in teaching units I and IV. The lower limit of the median confidence interval for the Unit I test was 76.9 and for the Unit IV test was 76.48. Therefore, system B was considered to be only effective in teaching introductory concepts

TABLE IV

Confidence Interval for the Median Posttest Score-Group B

Participant	Post Test Score
1	32
2	45
3	42
4	43
5	39
6	27
7	33
8	37
9	38
10	47
11	45
12	28
13	32
14	35
15	40
16	34
17	40
18	37
19	39

$\bar{X}$ = 37.5263

S = 5.4808

Median = 38/50 or 76/100

df = 19-1 = 18

Alpha = .05

Lower Limit = 72.912

Upper Limit = 79.087

of integrated circuits (Unit I) and applications of digital and linear integrated circuits (Unit IV). In addition it was considered to be effective in developing the performance level for these two units which industry accepts. System A was considered to be effective in teaching the integrated circuit concepts in all four instructional units and developing the same industry accepted level of performance.

Hypothesis Three

Hypothesis 3. There is no significant difference between the two laboratory training systems in terms of overall student achievement on the complete instructional series when selected differences are controlled.

Hypothesis three was tested in the null form by using the statistical procedure of analysis of covariance. The performance of both experimental groups A and B was compared by using the posttest results. Table V presents the performance of the experimental groups on the posttest. The highest obtainable score on the posttest was a score of 50. Mean posttest scores for experimental group A and experimental group B were 38.85 and 37.53 respectively. These mean scores were adjusted for differences which may have existed between the performance of experimental group A and experimental group B on the pretest. Pretest scores for the groups were used as the covariant in the procedure to adjust for differences which may have existed between the groups. Adjusted mean scores on the posttest were 38.97 and 37.43 for groups A and B respectively. The median posttest score for experimental group A was 41.3 and 38.00 for experimental group B. Standard deviations for

TABLE V

Comparison of Experimental Groups A and B
Posttest Performance

Participant	Group A Posttest	Group B Posttest
1	44	32
2	--	45
3	42	42
4	42	43
5	45	39
6	33	27
7	--	33
8	33	37
9	42	38
10	43	47
11	27	45
12	41	28
13	40	32
14	43	35
15	35	40
16	34	34
17		40
18		37
19		39
$\bar{X}$	38.85	37.53
$\bar{X}$ - Adjusted	38.97	37.43
S	5.22	5.48
Median	41.30	38.00

F = 0.74

the groups were similar in that the standard deviation for group A on the posttest was 5.22 and 5.48 for group B. An analysis of covariance computation produced a calculated "f" value of 0.74. The critical value of "f" at the .05 level was 4.15. Thus no significant difference existed between the posttest scores of the two groups. Hypothesis three was retained.

Hypothesis Four

Hypothesis 4. There is no significant difference between the two laboratory training systems in terms of the students' overall retention of information taught during the integrated circuit instructional series.

Hypothesis four was also tested in the null form using the analysis of covariance procedure. Table VI presents the performance of the experimental groups on the retention test. The highest possible score obtainable on the retention test was a score of 50. A review of the test scores revealed that neither a "floor" or a "ceiling" effect occurred as the scores were not grouped at the low or high end of the scale. The mean scores for experimental group A and experimental group B were 35.36 and 33.37 respectively. These scores were adjusted for differences which may have existed between the performance of the groups on the pretest. Adjusted mean scores on the retention test for experimental group A and experimental group B were 35.46 and 33.29 respectively. Experimental group A produced a standard deviation on the retention test of 5.21 while experimental group B produced a standard deviation of 6.42. A reliability coefficient of 0.82 was calculated for the

TABLE VI

Comparison of Experimental Groups A and B
Retention Test Performance

Participant	Group A Retention Test	Group B Retention Test
1	43	18
2	--	47
3	37	29
4	34	31
5	49	36
6	30	27
7	--	33
8	31	34
9	39	32
10	36	43
11	30	40
12	41	26
13	37	31
14	40	32
15	34	39
16	24	31
17		35
18		34
19		36
$\overline{X}$	35.36	33.37
$\overline{X}$ - Adjusted	35.46	33.29
S	5.21	6.42
Test Reliability	0.82	
F = 1.18		

retention test. The analysis of covariance computation for this test produced a calculated "f" value of 1.18. When the calculated "f" value was compared with the critical value of 4.15, no significant difference at the .05 level was found to exist between the two groups in terms of their retention test scores. Thus, hypothesis four was retained.

Hypothesis Five

Hypothesis 5. There is no significant difference between the two laboratory training systems in terms of student achievement on individual units when selected student differences are controlled. More specifically, there is no significant difference in student achievement on (a) introductory concepts of integrated circuits, (b) digital integrated circuitry including gates and flip-flops, (c) linear integrated circuitry including operational amplifiers and timers, and (d) digital and linear integrated circuit applications.

Hypothesis five was tested in the null form using the analysis of covariance procedure. Table VII presents the performance of the experimental groups on the Unit I test. A score of 25 represented a perfect response on all unit tests. A "floor" or "ceiling" effect did not occur on any of the unit tests for either experimental group. The mean for experimental group A was 19.87 while the mean for group B was 18.94 on the Unit I test. These mean scores were adjusted for differences which may have existed between the performance levels of the groups on the pretest. Adjusted mean scores on the Unit I for experimental group A and experimental group B were 19.91 and 18.91 respectively. A median score of 20.2 was obtained by group A while group B

TABLE VII

Comparison of Experimental Groups A and B
Unit I Test

Participant	Group A Unit I Test	Group B Unit I Test
1	18	17
2	21	21
3	21	16
4	22	14
5	22	20
6	20	19
7	20	22
8	20	21
9	20	20
10	20	21
11	20	22
12	17	16
13	23	18
14	16	17
15	21	20
16	17	20
17		21
18		16
19		19
$\bar{X}$	19.87	18.94
$\bar{X}$ - Adjusted	19.91	18.91
S	1.89	2.28
Median	20.2	19.5
Test Reliability	0.71	
F = 1.98		

obtained a median score of 19.5. The standard deviations for these groups were 1.98 for group A and 2.28 for group B. A test reliability coefficient of .71 was calculated for the Unit I test. When the analysis of covariance procedure was completed for this test, a calculated "f" value of 1.98 was obtained. The critical value of "f" at the .05 level is 4.13. Thus, no significant difference was found to exist between the two groups at the .05 level.

Table VIII presents the performance of the experimental groups on the Unit II test. The mean score for group A was 17.73 while the mean score for group B was 16.79. Standard deviations for the two groups on the test were 3.42 and 3.81 for experimental group A and experimental group B respectively. A test reliability coefficient of .72 was associated with the Unit II test instrument. The adjusted mean for group A was 18.7466 while the adjusted mean for group B was 17.4106. Adjusted mean scores were obtained with the analysis of covariance procedure in which the true mean scores were statistically adjusted for differences which may have existed in the performance of the experimental groups on the pretest. Group A obtained a median score on the Unit II test of 18.2 and group B obtained a median score of 16.4. When the calculated "f" value of 1.41 was compared with the critical "f" value of 4.15, no significant difference was found to exist, at the .05 level, between the two groups on the Unit II test.

Table IX presents the performance of the experimental groups on the Unit III test. The mean score for group A was 17.57 and the median was 17.3, while the mean score for group B was 18.12 and the

TABLE VIII

Comparison of Experimental Groups A and B
Unit II Test

Participant	Group A Unit II Test	Group B Unit II Test
1	22	10
2	19	22
3	23	16
4	20	15
5	25	21
6	16	17
7	--	14
8	15	23
9	21	18
10	21	24
11	11	22
12	20	13
13	19	15
14	15	12
15	17	22
16	15	16
17		17
18		18
19		18
$\overline{X}$	17.73	16.79
$\overline{X}$ - Adjusted	18.75	17.41
S	3.42	3.81
Median	18.2	16.4
Test Reliability	0.72	
F = 1.41		

TABLE IX

Comparison of Experimental Groups A and B
Unit III Test

Participant	Group A Unit III Test	Group B Unit III Test
1	23	12
2	--	24
3	22	14
4	17	24
5	25	19
6	20	18
7	--	17
8	11	21
9	18	19
10	22	22
11	11	20
12	16	12
13	17	17
14	15	14
15	17	20
16	17	18
17		13
18		21
19		19
$\bar{X}$	17.57	18.12
$\bar{X}$ - Adjusted	18.02	18.04
S	3.92	3.71
Median	17.3	18.5
Test Reliability	0.76	
F = 0.00		

median was 18.5. A score of 25 represented a perfect response to all questions on the unit test. Standard deviations for this test were 3.92 for experimental group A and 3.71 for experimental group B. The reliability coefficient for this instrument was calculated to be 0.76. Mean scores for these groups were adjusted using analysis of covariance for the difference which may have existed in group performance on the pretest. Experimental group A had an adjusted mean of 18.02 while experimental group B had an adjusted mean of 18.04. The analysis of covariance calculations revealed an "f" value of 0.00, which was not surprising in that the difference between the adjusted mean scores was only two one-hundredths of a point. When the calculated "f" value of 0.00 was compared with the critical "f" value of 4.15, no significant difference was found to exist between the two groups on the Unit III test.

Table X presents the performance of the experimental groups on the Unit IV test. The mean score for group A was 19.57 and the median was 20.0, while the mean score for group B was 19.53 and the median was 19.3. Standard deviations for the two groups were calculated to be 2.69 and 1.53 for experimental group A and experimental group B respectively. The Unit IV test was found to have a reliability coefficient of .73. The adjusted mean for group A was 19.6188 while the adjusted mean for group B was 19.4914. When the calculated "f" value of 0.03 was compared with the critical "f" value of 4.15, no significant difference was found to exist between the two groups on the Unit IV test.

The analysis of the data from all four unit tests revealed that

TABLE X

Comparison of Experimental Groups A and B
Unit IV Test

Participant	Group A Unit IV Test	Group A Unit IV Test
1	20	19
2	--	23
3	21	19
4	20	20
5	23	18
6	19	19
7	--	19
8	19	18
9	20	20
10	21	24
11	12	21
12	21	19
13	23	15
14	20	19
15	16	20
16	19	18
17		18
18		20
19		22
$\bar{X}$	19.57	19.53
$\bar{X}$ - Adjusted	19.62	19.49
S	2.69	1.53
Median	20.0	19.3
Test Reliability	0.73	
F = 0.03		

there was no significant difference in group performance. Thus, hypothesis five was retained. Table XI presents the performance of experimental group A and experimental group B on each instrument for the four instructional units used in the study. The means and adjusted means for each experimental group are presented along with the calculated "f" value from the analysis of covariance computations. Thus, this table presents the data in a summary form so that a quick comparison can be made of the performance of the groups on each instrument.

TABLE XI

Summary of Group Performance

	$\bar{X}$	$\bar{X}$ - Adjusted	F
Pre-Test			
Group A	18.43	(Served as the Covariant)	
Group B	18.84		
Unit I Test			
Group A	19.87	19.91	1.98
Group B	18.95	18.91	
Unit II Test			
Group A	17.73	18.75	1.41
Group B	16.79	17.41	
Unit III Test			
Group A	17.57	18.02	0.00
Group B	18.11	18.04	
Unit IV Test			
Group A	19.57	19.62	0.03
Group B	19.53	19.49	
Post Test			
Group A	38.85	38.97	0.74
Group B	37.53	37.43	
Retention Test			
Group A	35.36	35.46	1.18
Group B	33.37	33.29	

SUMMARY

Five hypotheses were tested in this study. Hypothesis one was tested with the t-test for correlated samples. A median confidence interval was calculated and compared with an industry cut off score to test hypothesis two. Hypotheses three, four, and five were tested using the statistical procedure, analysis of covariance. An analysis of the data indicated that there was a significant difference between the pretest and posttest scores for both experimental groups. This was an important significant difference in that the calculated "t" value for each experimental group was much larger than the critical value of "t". Although the "n" for both experimental groups was small, the significant difference was very large, indicating that the difference was produced by more than chance, exposure, and time involved in the experiment.

In addition, the analysis of the data indicated that: training system A produced student performance equal to or greater than that considered to be acceptable by industry; training system B produced student performance equal to or greater than that considered to be acceptable by industry only when used to teach introductory concepts of integrated circuits and digital and linear integrated circuit applications; there was no significant difference between group achievement over the total instructional series; there was no significant difference between the achievement levels of both experimental groups in terms of overall retention of integrated circuit information; and there was

no significant difference between the achievement levels of experimental group A and experimental group B on any of the four instructional units covered in the series.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY OF THE STUDY

Purpose

This study was designed with a dual purpose. Two laboratory training systems for teaching integrated circuit concepts were (1) evaluated and (2) compared. The study sought to determine if either system could be effectively used to teach certain concepts which industry recommended. Student achievement was used as the criterion measure to evaluate and compare the two training systems. An acceptable industry performance level was used as the standard for evaluation.

Statement of the Problem

Past research has indicated that needs exist for: (1) ways in which electronics educators may stay abreast of advances in technology; (2) the identification of fundamental factors for improvements in effectiveness of current instruction, the most effective method of instruction, and effective teaching aids and materials; and (3) instructional materials for industrial and vocational education electronics programs which cover the area of integrated circuits. Industry has recommended and placed a high priority on selected integrated circuit concepts for inclusion in electronics problems. However, no research could be found which evaluated or compared systems for teaching these concepts. Five hypotheses were used in this study to investigate this problem:

Hypothesis 1. There is no significant difference between pretest and posttest scores when selected integrated circuit concepts are taught using the lecture method supplemented by either System A or System B.

Hypothesis 2. The participants' median posttest score in either experimental group A or experimental group B will be less than the cut off score of 75.

Hypothesis 3. There is no significant difference between the two laboratory training systems in terms of the students' overall retention of information taught during the integrated circuit instructional series.

Hypothesis 4. There is no significant difference between the two laboratory training systems in terms of the students' overall retention of information taught during the integrated circuit instructional series.

Hypothesis 5. There is no significant difference between the two laboratory training systems in terms of student achievement on individual units when selected student differences are controlled. More specifically, there is no significant difference in student achievement on (1) introductory concepts of integrated circuits, (b) digital integrated circuitry including gates and flip-flops, (c) linear integrated circuitry including operational amplifiers and timers, and (d) digital and linear integrated circuit applications.

Methodology

The sample selected for the study was an intact class of 35

male students enrolled in the industrial education electronics course in the Department of Industrial and Occupational Education at Mississippi State University. Subjects were randomly assigned to treatments A and B. Each experimental group received the same instruction in integrated circuit theory through the conventional lecture technique. Laboratory activities supplemented the lectures. Experimental group A utilized existing laboratory equipment while experimental group B utilized a teacher designed and constructed laboratory training system to conduct the assigned laboratory activities.

Six criterion measures were used to measure student achievement and retention on integrated circuit subject matter material. These included four unit tests, a posttest, and a retention test. A pretest was administered at the beginning of the experiment to measure the participant's knowledge of integrated circuitry. These scores were used to statistically control for student differences which may have existed in the intact class selected as the sample. Pretest scores were also compared with the posttest results in evaluating each group's performance over the instructional series. A unit test was administered upon the completion of each instructional unit and assigned laboratory activity. Upon the completion of the total instructional series and the associated laboratory activities, a posttest was administered to measure overall student performance. A retention test was administered two weeks after the experiment was completed without being announced in advance.

Statistical procedures chosen for the analysis of the data

included: the t-test for correlated samples, the median confidence interval, and the analysis of covariance. These procedures were chosen on the basis of the experimental design selected for the study, the research hypothesis under investigation, and the conditions which existed at the research site.

Findings of the Study

When the t-test for correlated samples was used to test hypothesis one, a significant difference was found to exist between the pretest and posttest scores for experimental group A and experimental group B. This difference was significant at the .05 level and was considered to be important in that the calculated "t" value was much larger than the critical value.

A confidence interval was calculated for the median posttest score for each of the experimental groups and compared with the industry cut off score of 75 to test hypothesis number two. It was found that experimental group A reached an achievement level which was equal to or above the industry accepted level of performance. Thus, the existing laboratory equipment utilized by experimental group A could be considered as being effective for teaching the integrated circuit concepts which industry recommended.

When the confidence interval was calculated for the group B median score, the lower confidence interval limit fell slightly below the established cut off point. Therefore, the teacher designed and constructed laboratory training system used by experimental group B could not be considered as being effective for teaching the

integrated circuit concepts recommended by industry. However, when the researcher took a closer look at the groups' performance on the individual units, it was found that training system B was effective in teaching instructional Unit I (Introductory Concepts of Integrated Circuits) and Unit IV (Applications of Digital and Linear Integrated Circuits).

Analysis of covariance was used to determine if there were any significant differences in the performance levels of the experimental groups over the total instructional series. Pretest scores were used in this analysis, as was done in all other analysis of covaraince calculations, to adjust the group mean scores for any differences which may have existed prior to beginning the experiment. The analysis of covariance procedure revealed that no difference existed in performance levels between experimental group A and B over the total instructional series.

Group performance was compared on the retention test results by using the statistical procedure of analysis of covariance. This procedure was used to determine if any significant difference existed between experimental group A and experimental group B in terms of retention of integrated circuit information taught during the instructional series. No significant difference was revealed by the analysis of covariance procedure between the retention levels of the two experimental groups.

Analysis of covariance was also used to determine if there were any significant differences in the performance of the two experimental groups on each of the instructional units. When this statistical procedure was used to check for significant differences between the

experimental groups on Unit I (Introduction to Integrated Circuits), no significant difference was found.

The analysis of covariance was used to determine if significant differences existed between experimental group A and experimental group B in terms of performance on Unit II (Digital Integrated Circuits), Unit III (Linear Integrated Circuits), and Unit IV (Applications of Digital and Linear Integrated Circuits). An analysis of the data from each of these three remaining instructional units revealed that no significant differences existed between the performance levels of experimental group A and experimental group B.

CONCLUSIONS

Data published in the 1975 edition of the Electronic Market Data Book established the fact that the electronics industry is rapidly moving toward integrated circuitry. In an attempt to update electronics programs, industry has been surveyed to make recommendations to include certain integrated circuit concepts in industrial education electronics courses. In addition, industry has recommended that industrial education curriculums include "laboratory activities using linear, digital, and memory integrated circuits" (Rigby, 1972:53). Manufacturers of integrated circuits considered breadboarding and the complete project approach to be the two best instructional techniques for teaching integrated circuits. Thus, industry has made numerous recommendations concerning the teaching of integrated circuit theory. However, no research could be found in the literature review which supported or refuted these

recommendations. At the same time, educational research has indicated that a need exists for education to stay abreast of advancing technology as well as identifying factors for improvement in instruction and the most effective teaching methods, aids, materials, etc.

This study evaluated and compared two laboratory instructional systems for teaching the integrated circuit concepts which industry recommended. Each laboratory instructional system was used by industrial education students to conduct assigned laboratory activities which included both linear and digital integrated circuitry. In addition, each system utilized a different type of breadboarding method which students used to set up the complete circuits included in the assigned laboratory activities. The findings of this study appear to indicate that laboratory training systems are effective in teaching the integrated circuit concepts recommended by industry. This may provide one possible solution for solving part of the problems facing the electronics educator in the area of integrated circuit instruction. Thus, this study appears to be the first of its kind to bridge the gap between the recommendations made by industry for teaching integrated circuits and the industrial education electronics classroom and laboratory. In addition, it has increased the quantity of information available to industrial and vocational education teachers concerned with teaching integrated circuit concepts and provided a basis for future studies of instructional materials, methods, and laboratory equipment for teaching advanced integrated circuitry.

Based upon the findings of this study the following conclusions were drawn:

1. Existing laboratory equipment, not including commercial laboratory training systems, can be effectively used to teach the integrated circuit concepts which industry has recommended at an industry accepted level of performance.

2. Teacher designed and constructed laboratory training systems, of the type evaluated in this study, can be effectively used to teach introductory concepts of integrated circuits and digital and linear integrated circuit applications which industry has recommended at an industry accepted level of performance.

3. Existing laboratory equipment and teacher designed and constructed laboratory training systems of the type evaluated in this study produce equal levels of retention of selected integrated circuit concepts.

4. Teacher designed and constructed laboratory training systems and existing laboratory equipment of the type evaluated in this study produce approximately equal student performance levels when used to teach: (1) introductory concepts of integrated circuits, (2) digital integrated circuitry including gates and flip-flops, (3) linear integrated circuitry including operational amplifiers and timers, and (4) digital and linear integrated circuit applications.

RECOMMENDATIONS

Based on the findings of this study, the review of literature, and the experience of the researcher, the following recommendations were made:

1. Research should be conducted to compare teacher designed and constructed laboratory training systems with similar commercial laboratory training systems presently on the market for teaching integrated circuitry.

2. Additional research should be conducted to compare existing laboratory equipment, not including commercial training systems, with commercial laboratory training systems presently on the market for teaching integrated circuit concepts.

3. Studies should be designed to evaluate and compare a lecture approach with a laboratory approach for teaching integrated circuitry.

4. Additional research should be conducted to identify the most effective method for teaching integrated circuit concepts in industrial and vocational education electronics courses.

5. Electronics courses presently being taught in industrial and vocational education programs should be modified and up-dated to include the instructional area of integrated circuits.

6. New electronics courses should be developed and introduced into the industrial and vocational education programs which concentrate heavily on integrated circuit technology.

7. Laboratory activities should be structured more toward circuitry which illustrates realistic applications of electronics principles in industry.

8. Additional research should be conducted to further evaluate low cost instructor designed and constructed laboratory equipment of the type used in this study in teaching integrated circuit concepts.

9. Low cost instructor designed and constructed laboratory training equipment, of the type evaluated in this study, should be fabricated and used to reduce operating costs of electronics training programs.

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APPENDIX A

Descriptions of Instructional Systems

GROUP A - INSTRUCTIONAL SYSTEM

EQUIPMENT *	COST
1. Breadboard - Energy Concepts	$ 42.00
2. I.C. Conversion sockets - Radio Shack	1.10
3. Mounted components (switches, variable resistors, etc.) - Energy Concepts	16.00
4. 0-30 volt variable power supply - Heath model IP-28 (2)	100.00
5. Oscilloscope - Tektronix model S54A	495.00
6. Low frequency function generator - Hewlett Packard model 202A	300.00
7. Universal counter - Computer Measurements Co. model 2268	500.00
8. Associated resistors, capacitors, integrated circuits, etc. for laboratory activities	5.00
9. Laboratory activities for Unit I,II,III,IV	nc
Total	$1459.10

* Complete descriptions are available from the manufacturer.

GROUP B - INSTRUCTIONAL SYSTEM

EQUIPMENT	COST
1. Teacher designed and constructed integrated circuit laboratory training system containing:	$ 450.00
A. Main frame with built-in +5v., ± 15v., & 0-20v. power supplies	
B. Module R.O.-1 containing a universal counter, six readout LED indicators, & logic probe.	
C. Module B.B. - 1 & 2 containing E & L Instruments IC breadboard, 4 channel oscilloscope multiplexer, & power connections	
D. Module L.G.-1 containing (2) debounced push buttons, (2) debounced toggle switches, (4) +5v & ground - Hi - Lo swithches, (2) 10k linear pots, (1) BNC signal input connector, & (1) BNC signal output connector.	

	E. Module F.G. - 1 containing a low frequency function generator with sine, square, and triangle wave outputs.	
2.	Oscilloscope - Tektronix model S54A	495.00
3.	Assorted resistors, capacitors, integrated circuits, etc. for laboratory activities	5.00
4.	Laboratory activities for Unit I,II,III,IV	nc
	Total	$ 950.00

APPENDIX B

Biographical Information on Participants

EXPERIMENTAL GROUP - A

PARTICIPANTS	AGE	CLASSIFICATION	MAJOR	ACT	GRADE PT. AVE.
1.	20	Jr.	IA	22	2.90
2.	23	Sr.	IT	22	2.30
3.	22	Sr.	IT	24	2.45
4.	21	Sr.	TE	18	3.40
5.	23	Sr.	IA	20	3.23
6.	26	Sr.	IA	18	3.01
7.	20	Jr.	IA	20	3.68
8.	21	Jr.	TE	15	2.40
9.	24	Jr.	TE	18	2.69
10.	21	Sr.	IA	18	3.25
11.	21	Sr.	IA	13	2.50
12.	22	Jr.	IT	20	2.10
13.	22	Jr.	IA	18	2.65
14.	20	Jr.	IA	15	2.30
15.	21	Sr.	IT	15	2.50
16.	21	Sr.	IA	13	2.50

EXPERIMENTAL GROUP - B

1.	27	Sr.	IT	21	3.00
2.	22	Sr.	IA	23	3.21
3.	20	Jr.	IA	15	2.60
4.	19	Fr.	IA	16	2.80
5.	28	Sr.	IT	18	2.85
6.	47	Sr.	IA	15	2.50
7.	21	Jr.	IT	21	3.00
8.	21	Jr.	IA	16	2.00
9.	35	Sr.	TE	19	3.50
10.	21	Jr.	TE	22	3.00
11.	22	Sr.	IA	16	2.80
12.	20	Sr.	IA	15	2.25
13.	21	Jr.	IA	17	2.30
14.	22	Sr.	IA	15	2.40
15.	28	Fr.	IA	16	3.00
16.	21	So.	IA	10	2.11
17.	21	Jr.	IA	15	2.80
18.	21	So.	IA	12	2.65
19.	20	Jr.	IA	18	2.45

IA - Industrial Arts
IT - Industrial Technology
TE - Technical Education

Four Point Grading System
All Male Sample
Integrated Class

APPENDIX C

Instructional Materials - Examples

UNIT # 1 - INTRODUCTION TO INTEGRATED CIRCUITS

I. The Integrated Circuit Concept
   A. Basic Construction
      1. Definition
      2. Internal Construction
      3. Discrete vs. Integrated Circuits
   B. Advantages
      1. Size
      2. Cost
      3. Reliability
      4. Low Power Consumption
   C. Limitations
      1. Low Power
      2. Low Voltage
      3. Limited Selection of Components
      4. Temperature
   D. Manufacturing Processes
      1. Planar Diffusion Process
      2. Photomasking
   E. Packaging
      1. Plastic Dual-In-Line
      2. Ceramic Dual-In-Line
      3. Metal Flat Packs
      4. Ceramic Flat Packs
      5. Round Cans
      6. SSI, MSI, LSI
   F. Testing Integrated Circuits
      1. Industrial & Commercial Specifications
      2. Military & Space Specifications
   G. Basic Integrated Circuit Types
      1. Digital
      2. Linear

II. Practical Considerations
   A. Selection of The Integrated Circuit Package
      1. Heat
      2. Cost
      3. Reliability
   B. Mounting & Connecting
      1. Breadboard Mounting and Connecting
      2. Ceramic Flat Pack
      3. TO-5 Case
      4. Dual-In-Line
   C. Handling of Integrated Circuits
      1. Lead Bending
      2. Printed Circuit Boards
      3. Soldering & Soldering Techniques
      4. Handling of MOSFET Integrated Circuits
   D. Layout of Integrated Circuits
      1. Digital Integrated Circuits
      2. Linear Integrated Circuits

E. Power Dissipation & Temperature Effects
   1. Power ICs
   2. Maximum Power Dissipation
   3. Thermal Resistance
   4. Thermal Runaway
   5. Operating With Heatsinks
   6. Operating Without Heatsinks
   7. Calculating Power Dissipation
   8. Effects of Temperature Extremes

F. Power Supplies for ICs
   1. Digital
   2. Linear
   3. Labeling of IC Power Supplies
   4. Typical Connections
   5. Tolerances
   6. Precautionary Procedures

UNIT # II - DIGITAL INTEGRATED CIRCUITS

I. Digital Integrated Circuits
   A. Definition
   B. Uses of Digital ICs
      1. Process Information
      2. Store Information
   C. The Binary System
      1. "1" & "0"
      2. Number System
      3. Arithmetic Operations
   D. Truth Tables
      1. Basic Design
      2. Applications
   E. Logic Signals
      1. Positive
      2. Negative
   F. Binary Logic
      1. AND Function
      2. OR Function
      3. AND-OR Function
      4. NOT Function
   G. Combined Logic Circuits
      1. NAND Function
      2. NOR Function
      3. Exclusive OR Function
      4. Exclusive NOR Function
   H. Basic Logic Elements & Symbols
      1. Gates
      2. Switching Elements
      3. Delay Elements
      4. Timing Elements

I. Terminology
   1. Fan-In
   2. Fan-Out
   3. Load
   4. Propagation Delay

J. Basic Designs
   1. Gates
   2. Timers
   3. Flip-Flops
   4. Decoders
   5. Counters
   6. Readouts
   7. Shift Registers
   8. Memories

K. Logic Families or Forms
   1. RTL
   2. DTL
   3. TTL
   4. CMOS

UNIT # III - LINEAR INTEGRATED CIRCUITS

I. Linear ICs
   A. Basic Types
      1. Audio Amplifiers
      2. Wideband & Video Amplifiers
      3. High Frequency Linear ICs
      4. Operational Amplifiers
      5. Voltage Regulators
      6. Arrays
      7. Timers (555)
      8. Phase Locked Loops PLL (567)
   B. Audio Amplifiers
      1. Types
      2. Functions
      3. Circuitry
   C. Operational Amplifiers
      1. Definition
      2. Basic Types
      3. Terminology
      4. Elementary Operational Amplifier Circuits
      5. Ideal Operational Amplifiers
      6. Common Mode
      7. Differential Mode
      8. Operational Amplifier Problems
   D. Voltage Regulators
      1. Types
      2. Functions
      3. Circuitry

E. Timers
   1. Basic Concept
   2. Functions
   3. Operation
   4. Circuitry

UNIT # IV - APPLICATIONS OF INTEGRATED CIRCUITS

I. Introduction to IC Applications
   A. Printed Circuit Board Assembly
   B. Equipment Design
   C. Fields of Application
      1. Computers
      2. Desk Calculators
      3. Industrial Controls
      4. Aircraft Electronics Equipment
      5. Space Vehicles & Missiles
      6. Automobile Electronic Equipment
      7. Electronic Instruments
      8. Communications & Telephones
      9. Consumer Appliances
      10. Consumer Entertainment
      11. Medical Electronics

II. Typical Digital IC Applications
   A. Flip-Flops
      1. RS
      2. JK
      3. D
   B. Signal Sources
      1. Multi-vibrators
      2. Oscillators
   C. Timers
      1. Mono-stable Multi-vibrator
      2. The 555
   D. Counters, Decoders, & Readouts
      1. Decade Counters
      2. Binary Counters
      3. Decoders
      4. Readouts
   E. Counter Applications
      1. Multi-meters
      2. Frequency Counters
      3. Event Counters
      4. Elapsed Time Counter
      5. Capacitance Meters
      6. Electronic Thermometer
      7. Time Clocks

IV. Typical Linear IC Applications
- A. Tone Controls
- B. Active Filters
  1. Band Pass
  2. High Pass
  3. Low Pass
  4. Band Reject
- C. Current to Voltage Converters
- D. Clipper Circuits
- E. Computing Applications
  1. Addition
  2. Subtraction
  3. Multiplication
  4. Division
  5. Integration
  6. Differentiation
- F. Signal Averaging
- G. Oscillators
- H. Power Supply Regulators
- I. Communications

LABORATORY ACTIVITY # II - DIGITAL INTEGRATED CIRCUITS

Purpose - The purpose of this laboratory activity is to demonstrate the operation of the 7400 IC (Quad 2 input positive NAND gate) and the 7402 IC (Quad 2 input positive NOR gate).

Schematic - Part A

Fig. 2-1

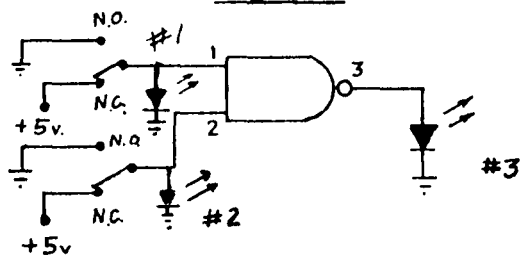
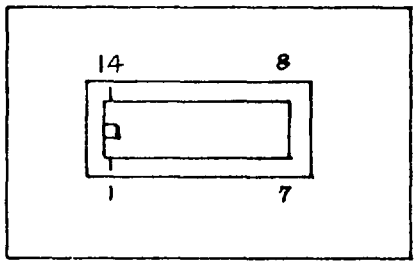


Fig. 2-2



Reference Sheet - Refer to the reference sheet prior to starting this laboratory activity.

Steps of Procedure

1. Carefully examine the schematic for laboratory activity Figure 2-1. Note that only one NAND gate is utilized out of the four that are actually contained in the IC package.

2. Plug the 7400 IC into the breadboard socket. Be sure that the key slot is positioned properly so that pin # 1 and pin # 14 are in the location as shown in Fig. 2-2.

3. With the 5 volt power supply in the OFF position, connect the positive power supply lead (+) to pin # 14 of the 7400 IC. Now connect the negative power supply lead (-) to pin # 7 (GND). DO NOT TURN ON THE POWER SUPPLY UNTIL YOUR ARE SPECIFICALLY TOLD TO DO SO IN THE FOLLOWING STEPS OF PROCEDURE!!!!!

4. Connect the push-button to the (+) power supply connection point on the breadboard and to the GND connection point as shown in Fig. 2-1. Note the N.C. (normally closed) and the N.O. (normally open) connections.

5. Connect the switching arms of the switches to the inputs of the NAND gate as shown in Fig. 2-1.

6. Connect the output of the NAND gate to the LED indicator as shown in Fig. 2-1.

7. Connect each input of the NAND gate to the LED indicator as shown in Fig. 2-1.

8. Connect the GND point on each LED indicator to the GND or negative power supply point on the breadboard.

9. Now turn on the 5 volt power supply and press push button # 1. Observe the LED indicator at input A and at the output. Is LED # 3 on or off? _____. Record this information in Table 2 - A.

10. Press push button # 2 and observe the LED indicator at input B and at the output. Is LED # 3 on or off?_____Record this information in Table 2 - A.

11. Press both push buttons at the same time and observe the LED indicator at the output of the NAND gate. Is LED # 3 on or off? _____. Record this information in Table 2 - A.

TABLE 2-A

Step #	Inputs A	Inputs B	Output Q1 1/0	LED on/off
9	0	1		
10	1	0		
11	0	0		
12	1	1		

NOTE: "0" represents a "low" logic level and the push button in the down or pushed condition (GND). "1" represents a "Hi" logic level and the push button in the up position (+5v.). "1" = true and "0" = false.

12. Now observe all LED indicators when both push buttons are in the up or un-pushed position. Is LED # 3 on or off? _____. Record this information in Table 2 - A.

13. Does the information that you have recorded in TABLE 2-A agree with the operation of a NAND gate as was discussed in lecture? _____.

14. Fill in TABLE 2-B with the results that you would expect from the experiment if you substituted an AND gate in the circuit in place of the NAND gate.

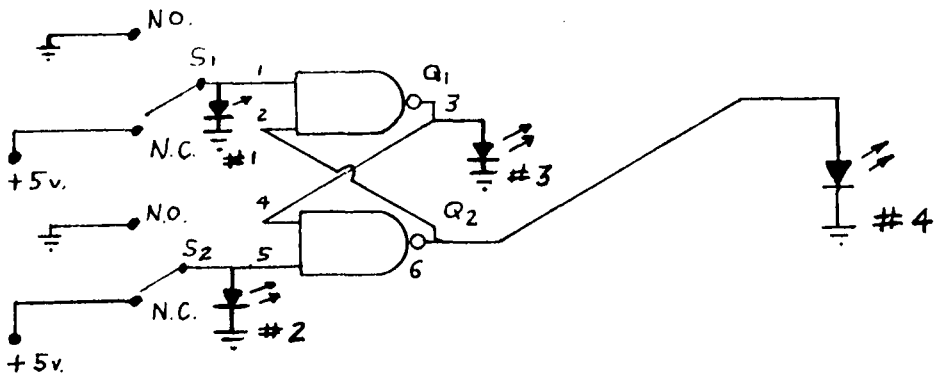
TABLE 2-B

Step #	Inputs A	Inputs B	Output Q1 1/0	LED on/off
9	0	1		
10	1	0		
11	0	0		
12	1	1		

15. Check the results that you recorded in TABLE 2 A & B with your lecture notes on the operation of both AND and NAND gates. Do the recorded results agree with the information presented in the lecture? TABLE 2-A _____. TABLE 2-B _____.

16. Turn off the 5 volt power supply and modify the circuit as shown in Fig. 2-3 to form a RS FLIP-FLOP. Do not change the power connections to pins # 7 and # 14 on the 7400 integrated circuit.

Fig. 2-3



17. Now turn on the 5 volt power supply and press push button # 1. Observe all LED indicators. Is LED # 3 on or off? _____ Is LED # 4 on or off? _____ Record this information in TABLE 2 - C.

18. Press push button # 2 and observe all LED indicators. Is LED # 3 on or off? _____ Is LED # 4 on or off? _____. Record this information in TABLE 2 - C.

19. Now press both push buttons and observe all LED indicators. Is LED # 3 on or off? _____ Is LED # 4 on or off? _____. Record this information in TABLE 2-C.

20. Now observe all LED indicators when both push buttons are in the up or un-pushed position. Is LED # 3 on or off? _____ Is LED # 4 on or off? _____ The results in this step will depend upon which push button has been pushed prior to making this observation. Press push button # 1 and observe all LED indicators. Note the opposite results!

TABLE 2-C

Step #	Input A	Input B	Output Q1	Output LED	Output Q2	Output LED
17	0	1				
18	1	0				
19	0	0				
20*	1	1				
20*	1	1				

* NOTE: The results in these steps will depend upon the prior condition of the circuit or which push button was pushed last.

21. Turn off the 5 volt power supply and dismantle the circuit. Now remove the 7400 IC and proceed to PART B.

PART B **********

Purpose - The purpose of this laboratory activity is to demonstrate the operation of the 7402 Quad 2 input positive NOR gate.

Schematic

Fig. 2-4

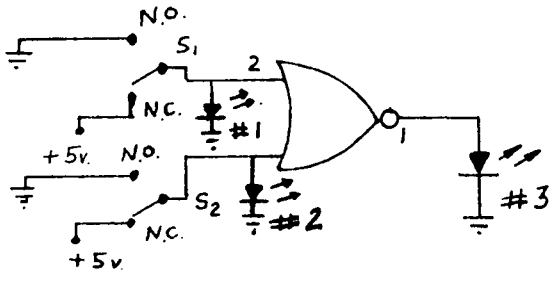
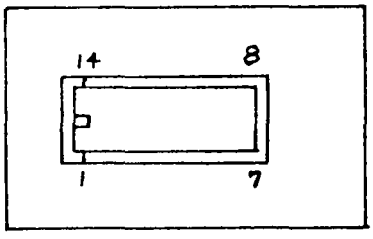


Fig. 2-5



Reference sheet - Refer to the reference sheet prior to starting this laboratory activity.

Steps of Procedure

1. Carefully examine the schematic for the activity in Fig. 2-4. Note that one NOR gate is utilized out of the four that are actually contained in the 7402 IC.

2. Plug the 7402 into the breadboard socket. Be sure to properly position it as shown in Figure 2-5.

3. With the power supply in the OFF position, connect the positive (+) power supply lead to pin # 14 on the IC. Now connect the negative (-) power supply lead to pin # 7 (GND). Do not turn on the power supply until you are specifically told to do so!!

4. Connect the NOR gate into the circuit as shown in Fig. 2-4. Note that the push button switches are wired exactly as they were in PART A.

5. Now turn on the 5 volt power supply and press push button # 1. Observe all LED indicators. Is LED # 3 on or off? _____ Record this information in TABLE 2-D.

6. Press push button # 2 and observe all LED indicators. Is LED # 3 on or off? _____ Record this information in TABLE 2-D.

7. Press both push buttons at the same time and observe all LED indicators. Is LED # 3 on or off?_____. Is LED # 3 on or off when both buttons are un-pushed? Record this in TABEL 2-D.

8. Compare your recorded results in TABLE 2-D with your lecture notes on the operation of the NOR gate. Do your results agree with the information presented in lecture? _____

9. Fill in TABLE 2-E with the results that you would expect from the experiment if you substituted an OR gate for the NOR gate in the circuit.

TABLE 2-D

	Inputs		Output Q 1	LED
Step #	A	B	1/0	on/off
5	0	1		
6	1	0		
7	0	0		
7	1	1		

TABLE 2-E

	Inputs		Output Q1	LED
Step #	A	B	1/0	on/off
5	0	1		
6	1	0		
7	0	0		
7	1	1		

10. Check your recorded results in TABLE 2-E with your lecture notes on the operation of an OR gate. Do they agree with the information presented in lecture? _____

11. Turn off the power supply and dismantle the circuit. Return all parts to the stroage container and check with your laboratory instructor for additional information prior to leaving the lab.

UNIT II - TEST

Directions - Read the question and all answers carefully before choosing your answer. Answer each question on the standardized answer with a No. 2 pencil!!

1. _____ integrated circuits are ICs whose basic function is to handle information by means of switching circuits.

   A. Digital
   B. Linear
   C. Five volt
   D. all of the above

2. A "1" represents _____ condition in a digital circuit.

   A. false
   B. ground
   C. true
   D. inoperative

3. _____ tables are used to indicate the overall operation of a digital logic circuit.

   A. Digital
   B. Analog
   C. Condition
   D. Truth

4. A _____ pulse goes from a lower level to a higher level and back to lower level.

   A. negative
   B. positive
   C. both A & D
   D. low level

5. An AND gate gives a logical "1" output

   A. When all inputs are "1"
   B. When all but one input is 1.
   C. When all inputs are "0"
   D. None of the above

6. An OR gate gives a logical "1" output

   A. When any one input is logical "1"
   B. When all inputs are logical "0"
   C. Only when all inputs are logical "1"
   D. Only when any two inputs are logical "1"

7. The NOT circuit or gate

   A. has several inputs and a single output
   B. is the same as a NOR gate
   C. has identical inputs and outputs
   D. is alternately called an inverter circuit.

8. The NAND gate gives a logical "1" output

A. when all inputs are "1"
B. when any input is "0"
C. when any one input is "1"
D. both B & C

9. The NOR gate will have a logical "1" at its output

A. when all inputs are "1"
B. when one input is "1"
C. when one input is "0"
D. when all inputs are "0"

10. The following symbol represents a _____gate.

A. OR
B. AND
C. NAND
D. NOR

11. The following symbol represents a _____gate.

A. AND
B. OR
C. NOR
D. NAND

12. The following symbol represents a _____gate.

A. AND
B. NAND
C. NOT or INVERTER
D. OR

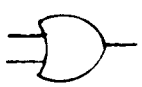
13. The following symbol represents a _____gate.

A. AND
B. NAND
C. NOR
D. OR

14. The following symbol represents a _____ gate.

A. NAND
B. NOR
C. OR
D. AND

15. In the symbol below, the lead on the right represents the _____.



A. output
B. input
C. power lead (+)
D. none of the above

16. The flip-flop circuit (RS)

A. has unstable output states
B. has two stable states of operation
C. cannot be made with integrated circuits
D. cannot be reset

17. _____are used to display information (numbers, letters, etc.)

A. Decoders
B. Counters
C. Multi-vibrators
D. Readouts

18. A_____ is a special IC in which bits of binary information can be written into (stored) it, read out of it, or changed at any desired time.

A. ROM
B. PROM
C. PLL
D. RAM

19. _____is probably the most common logic family or configuration of all integrated circuits used today.

A. TTL
B. DTL
C. RTL
D. ECL

20. With _____logic, the upper level of the pulse represents the "true" condition and the lower level of the pulse represents the "false" condition.

A. positive
B. negative
C. 5 volt
D. none of the above

21. A "0" in digital logic circuits represents _____.

A. an "on" condition
B. a false condition
C. a ground or zero voltage
D. both B & C

22. When a RS flip-flop is operating properly _____

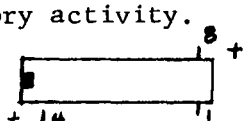
A. one input and one putput will be "on", "1", or true.
B. both outputs will be OFF, "0", or false.
C. both outputs will be "on", "1", or true
D. none of the above

23. A LED indicator will _____ if a "1" appears at the output of the digital IC or gate to which it is connected.

A. be on
B. be off
C. burn out
D. blink continually

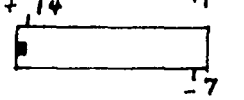
25. Which of the following illustrates the proper pin layout for connecting a 7400 digital IC into a circuit as you did in your laboratory activity.

A.



B.

C.



D. none of the above

COMPREHENSIVE TEST

Directions - Read the question and all answers carefully before choosing. Answer each question on the standardized answer sheet with a No. 2 pencil

1. An _____ is a complete electronic circuit, containing transistors and perhaps diodes, resistors, and capacitors, along with their interconnecting electrical conductors, processed on and contained entirely within a single chip of silicon.

   A. integrated circuit
   B. amplifier
   C. operational amplifier
   D. none of the above

2. An IC is a complete, predesigned functioning circuit that cannot be altered in regard to _____.

   A. power dissipation
   B. operating voltage
   C. shape
   D. size

3. The main problem (s) in working with integrated circuits is (are) _____.

   A. size
   B. heat
   C. shape
   D. none of the above

4. Which of the following is not a limitation of the integrated circuit?

   A. available selection of components
   B. reliability
   C. low power capability
   D. low voltage capability

5. Which of the following IC packaging method was used in the laboratory activities?

   A. plastic dual in-line
   B. flat packs
   C. round cans
   D. none of the above

6. _____type (s) of integrated circuits can be mounted in sockets for breadboarding and permanent installation?

   A. all
   B. one
   C. no
   D. six

7. Which of the following tools are required to properly bend IC leads?

   A. long nose pliers
   B. diagonal cutters
   C. screw driver
   D. all of the above

8. Which of the following is not a precaution for handling MOSFET integrated circuits?

A. prevent static build up and discharge
B. leads should not be shorted
C. soldering irons must be kept at ground potential
D. all of the above

9. Linear integrated ciruits generally require _____power supplies.

A. + 5 volt
B. + 15 volt, - 15 volt
C. + 3 volt, - 3 volt
D. none of the above

10. Digital integrated circuits require _____power supplies.

A. + 5 volt
B. + 18 volt, - 18 volt
C. 0-20 volt variable
D. none of the above

11. Protective _____ are recommended for any power supply circuit in which the leads could be reversed.

A. transistors
B. switches
C. diodes
D. resistors

12. The time delay produced by the 555 IC is controlled by _____.

A. applied power supply voltage
B. its internal resistance
C. the value of a outside resistor
D. the combination of an external resistor and capacitor.

13. _____integrated ciruits are ICs whose basic function is to handle information by means of switching circuits.

A. Digital
B. Linear
C. both A & B
D. Operational amplifier

14. _____tables are used to indicate the overall operation of a digital logic circuit.

A. Digital
B. Analog
C. Decision
D. Truth

15. A _____pulse goes from a lower level to a higher level and back to a lower level.

A. negative
B. positive
C. low level
D. none of the above

16. An AND gate gives a logical "1" or positive voltage at its output

A. when all inputs are "1"
B. when all but one input is 1.
C. when all inputs are "0"
D. none of the above

17. An OR gate gives a logical "1" or positive voltage at its output

A. when any one input is "1"
B. when all inputs are "0"
C. when all inputs are "1"
D. none of the above

18. The NAND gate gives a logical "1" output

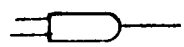
A. when all inputs are "1"
B. when any input is "0"
C. when any one input is "1"
D. both B & C

19. The NOR gate will produce a logical "1" at its output

A. when all inputs are "1"
B. when one input is "1"
C. when one input is "0"
D. when all inputs are "0"

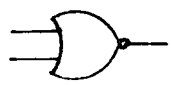
20. The symbol shown below represents a _____gate.

A. OR
B. AND
C. NAND
D. NOR



21. The following symbol represents a _____gate.

A. AND
B. NAND
C. NOR
D. OR



22. In the symbol shown below, the lead on the right represents the _____.

A. output
B. input
C. (+) power lead
D. none of the above

23. The flip-flop circuit (RS)

A. has unstable output states
B. Has two stable states of operation
C. cannot be made with integrated circuits
D. cannot be reset

24. _____ is used to display digital information.

A. Decoders
B. Digital
C. Flip-flops
D. Readouts

25. LED indicators are used to display output signals from _____.

A. linear ICs
B. digital ICs
C. op amps
D. none of the above

26. With _____logic, the upper level of a pulse represents the "true" or "1" condition, and the lower level represents the "false" or "0" condition.

A. positive
B. negative
C. 5 volt
D. none of the above

27. Which of the following is not a linear IC?

A. audio amplifier
B. op amp
C. logic gate
D. voltage regulator

28. The most common form of linear IC is known as a (an)

A. operational amplifier
B. regulator
C. NAND gate
D. PLL

29. Which of the following is not a linear IC?

A. operational amplifier
B. 567 PLL
C. voltage regulator
D. NAND gate

30. _____ is an unspecialized amplifier very commonly used in IC form, characterized by extremely high voltage gain and differential inputs.

A. An op am
B. Digital amplifier
C. Discriminator
D. none of the above

31. A 555 IC serves which of the following functions?

A. operational amplifier
B. decoders
C. timer
D. phase lock loop

32. The following symbol represents a _____.

A. inverter
B. NAND gate
C. timer
D. none of the above

33. The input lead (not the power lead) which is marked with a negative sign (-) on the OP AMP symbol will produce _____at the output when a signal is applied to it.

A. a non inverted signal
B. modulated
C. an inverted signal
D. no signal

34. The input lead (not the power lead) which is marked with a positive sign (+) on the OP AMP symbol will produce _____at the output when a signal is applied to it.

A. a non inverted signal
B. modulated signals
C. an inverted signal
D. no signal

35. The ratio of output voltage to input voltage, Vin/Vout for an OP AMP is known as _____.

A. closed loop output
B. feedback gain
C. open loop gain
D. none of the above

36. Which of the following characteristics of an OP AMP did you identify in the laboratory activity?

A. a gain of one
B. a gain greater than one
C. a gain of zero
D. none of the above

37. An OP AMP will give an output of _____when two signals of the same polarity and amplitude are applied to both inputs.

A. twice the input
B. two times the gain
C. 10 volts positive
D. zero

38. A 555 IC uses the _____time constant to determine the duration of its output function.

A. diode/transistor
B. resistor/capacitor
C. resistor/inductor
D. none of the above

39. OP AMPS are easily combined with _____ to provide for a more accurate measurement of temperature.

A. diodes
B. transistors
C. thermisters
D. SCRs

40. IC Op amps can be combined with _____to provide greater current handling capabilities.

A. transistors
B. TRIACS
C. SCRs
D. all of the above

41. A flip-flop circuit of the _____type can be used as part of a digital stop watch.

A. RS
B. OR
C. PLL
D. none of the above

42. Digital ICs can be used as _____.

A. control gates
B. flip-flops
C. op amps
D. both A & B

43. A 555 IC can be used for _____.

A. tone decoding
B. long time delays
C. counting
D. none of the above

44. Counters, decoders, and readouts are used in _____.

A. universal counter
B. time clocks (electronic)
C. both A & B
D. none of the above

45. Decade counters will count up to ____ before they reset to zero.

A. 1
B. 2
C. 100
D. none of the above

46. ICs are being used in _____ circuits (digital).

A. reaction time counters
B. temperature measurement
C. both A & B
D. none of the above

47. The output of a binary counter can be converted to a decimal number with a _____.

A. decoder
B. OR gate
C. multiplexer
D. none of the above

48. If the output voltage of an OP AMP is zero, this would indicate that _____.

A. both inputs are grounded
B. one input is grounded
C. both inputs have equal or like voltages applied to them
D. both A & C

49. OP AMPS can be used to control _____.

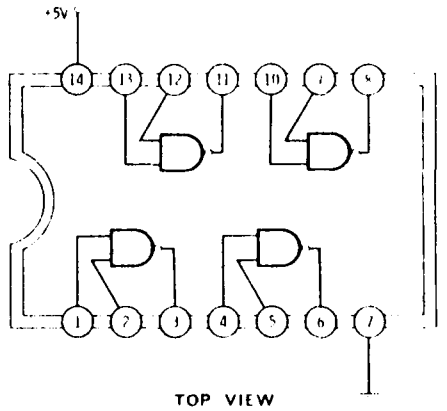
A. heating and cooling systems
B. alarms
C. other solid state devices
D. all of the above

50. OP AMPS can be used to amplify _____ signals.

A. AC
B. DC
C. audio
D. all of the above

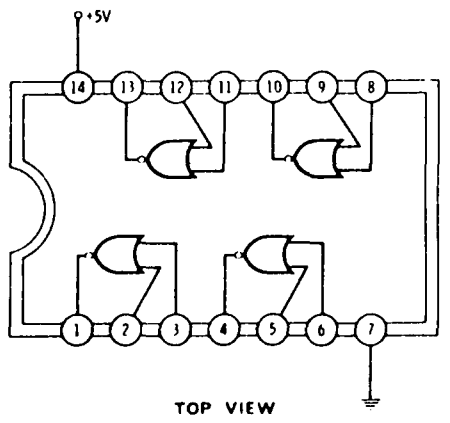
REFERENCE SHEET

7400 - Quad 2 Input Positive NAND Gate



TOP VIEW

7402 - Quad 2 Input Positive NOR Gate



TOP VIEW

APPENDIX D

Participants' Reactions

SELECTED--REACTIONS AND COMMENTS FROM PARTICIPANTS

POSITIVE

1. The instructional materials were very interesting.
2. More courses of this type should be offered.
3. It was an enjoyable experiance.
4. The course on ICs was interesting.
5. I enjoyed the course.
6. The laboratory activitites were rewarding.
7. I hope that I can take a full course in integrated cricuits.
8. The course was very interesting.
9. I thought it was a great learning experience.
10. It has greatly increased my interest in electronics
11. The laboratory activities were the best part of the course.
12. I really enjoyed taking the class.
13. This has been a good course and I wish I could take a whole course on integrated circuits.
14. I wish that there was more time to really go into depth on ICs.
15. It would make a great course.
16. Your teaching methods are clear and well prepared.
17. Labs were interesting.
18. I learned more by applying what I learned in the class the very next day.
19. I learned a lot and hope to advance my knowledge even further.
20. An IC course should be offered here at MSU.
21. I have enjoyed the class lectures and laboratory activities.
22. I fully enjoyed the class.
23. This course has offered much insight and understanding.
24. I feel that further development and introduction of this course will be a vast improvement over the present electronics course in the IED curriculum.
25. I have already found an application for what I learned in this course.
26. A very good course. It was outlined and taught well.

NEGATIVE

1. The mini course was not long enough.
2. Too much material was covered in the second unit lecture.
3. I did not understand all of the laboratory work.
4. The mini course was too short.
5. Laboratory activities were too advanced.
6. The material was covered too fast.
7. There was too much material covered in a short period of time.
8. The lectures were too long.

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A QUASI-EXPERIMENTAL EVALUATION AND COMPARSION OF TWO LABORATORY INSTRUCTIONAL SYSTEMS FOR TEACHING SELECTED INTEGRATED CIRCUIT CONCEPTS

by

Robert Dansby Brook

(ABSTRACT)

The purpose of this study was to evaluate and compare two laboratory training systems for teaching integrated circuit concepts which surveys of industry have indicated as having a high priority in industrial education electronics programs. More specifically, the study sought to determine if either system could be effectively used to teach those concepts which industry recommended.

The population from which the sample was obtained consisted primarily of industrial arts and industrial technology majors in the Industrial and Occupational Education Department at Mississippi State University. An intact class enrolled in an industrial electronics course was selected as the sample for the experiment. It consisted of thirty-five students who had similar educational backgrounds and abilities. The sample was randomly divided into two experimental groups. Each experimental group received the same instruction in integrated circuit theory through the conventional lecture technique. Experimental Group A utilized existing laboratory equipment while experimental group B utilized a teacher designed and constructed laboratory training system to conduct assigned laboratory activites. The instructional series which was used in the experiment included four instructional units which were: (1) introduction

to integrated circuits, (2) digital integrated circuits, (3) linear integrated circuits, and (4) digital and linear integrated circuit applications.

The following hypotheses were investigated in this study:

1. There is no significant difference between the pretest and posttest scores when selected integrated circuit concepts are taught using the lecture method supplemented by either System A or System B.

2. The participants' median posttest score in either experimental group A or experimental group B will be less than the cut off score of 75.

3. There is no significant difference between the two laboratory training systems in terms of overall student achievement on the complete instructional series when selected differences are controlled.

4. There is no significant difference between the two laboratory training systems in terms of the students' overall retention of information taught during the integrated circuit instructional series.

5. There is no significant difference between the two laboratory training systems in terms of student achievement on individual units when selected student differences are controlled.

Six criterion measures were used to measure student achievement and retention on integrated circuit subject matter material. These included four unit tests, a posttest, and a retention test. Statistical procedures chosen for the analysis of the data included: the t-test for correlated samples, the median confidence interval, and the analysis of covariance. On the basis of the data analysis, the following conclusions were drawn:

1. Existing laboratory equipment, not including commercial laboratory training systems, can be effectively used to teach integrated circuit concepts which industry has recommended and at an industry accepted level of performance.

2. Teacher designed and constructed laboratory training systems, of the type evaluated in this study, can be effectively used to teach introductory concepts of integrated circuits and digital and linear integrated circuit applications which industry has recommended and at an industry accepted level of performance.

3. Existing laboratory equipment and teacher designed and constructed laboratory training systems of the type evaluated in this study produce equal levels of retention of selected integrated circuit concepts.

4. Teacher designed and constructed laboratory training systems and existing laboratory equipment of the type evaluated in this study produce approximately equal student performance levels when used to teach: (1) introductory concepts of integrated circuits, (2) digital integrated circuitry including gates and flip-flops, (3) linear integrated circuitry including operational amplifiers and timers, and (4) digital and linear integrated circuit applications.