

**RELATIONSHIPS AMONG ELECTRONICS TROUBLESHOOTING,
MATHEMATICS, AND ELECTRONICS KNOWLEDGE**

by

Guy L. Loftin

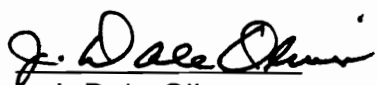
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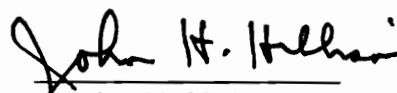
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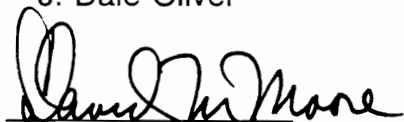
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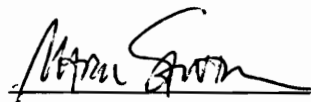
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(ABSTRACT)

One purpose of this study was to determine the relationships among community college students' mathematics, electronics, and electronics troubleshooting knowledge. A second purpose of the study was to determine the extent to which independent variables predicted troubleshooting knowledge. Students involved in the study were enrolled in electronics technician associate degree granting programs. More specifically the study was designed to examine the relationships among electronics troubleshooting knowledge and the following independent variables:

1. Number of mathematics courses taken at the community college level
2. Types of mathematics courses taken at community college level
3. Mathematics knowledge as measured by scores on a standardized mathematics test
4. Number of electronics courses taken at the high school level
5. Number of electronics courses taken at the community college level

6. Prior work experience in the electronics industry

In addition to examining these variables, this study also sought to answer the question: Which combination of variables best tends to predict troubleshooting knowledge?

Usable data were gathered from 100 North Carolina community college students who were enrolled in electronics technician degree granting programs at five randomly selected community colleges. The students participating in this study were administered three data gathering instruments. The instruments included a Student Information and Data Sheet designed to gather demographic information about each student, a standardized mathematics knowledge test designed to cover the mathematical concepts stressed in elementary, intermediate and college algebra, and finally, a paper and pencil electronics and troubleshooting test which consisted of troubleshooting an AM transceiver functional block diagram, a servicing block diagram, a power supply, and a summing circuit.

It was determined that under the conditions imposed by this study only one of the independent variables, score on the Mathematics Knowledge Test, could be used with some accuracy to predict troubleshooting knowledge. The independent variable mathematics knowledge, as represented by scores on the standardized mathematics knowledge test, could only predict troubleshooting knowledge with 6.8% percent accuracy.

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Table of Contents

Abstract ii

Acknowledgements iv

List of Tables viii

CHAPTER 1

INTRODUCTION 1

Statement of the Problem 3

Purpose of the Study 5

Limitations of the Study 7

Definitions 8

Summary 9

CHAPTER 2

REVIEW OF LITERATURE 11

Mathematics and Problem Solving 11

Cognitive Processes of Problem Solving 18

 Memory 19

 Experience 21

Troubleshooting Training and Research 26

Summary 35

CHAPTER 3

METHODOLOGY 39

Research Design 39

Population and Sample 39

Instrumentation 41

 Student Information and Data Sheet 41

 Mathematics Test 42

 Electronics Troubleshooting Test 44

 Content Validity 45

 Concurrent Validity 46

 Reliability 47

Data Collection 49

Data Analysis 50

Summary 51

CHAPTER 4

RESULTS 54

Description of Sample 55

Relationships Among Variables 58

Summary 61

CHAPTER 5

SUMMARY, DISCUSSION, AND RECOMMENDATIONS 63

Summary 63

Discussion 68

Recommendations 72

REFERENCES 74

APPENDICES

A. Student Information and Data Sheet 81

B. Troubleshooting Knowledge Test 83

C. Frequency Distribution of Sample 102

D. Background Characteristics of Sample 104

E. Zero Order Correlations Among Variables 108

F. Request to use Mathematics Placement Test and Reply 110

G. Request to use Examples from Electronic Troubleshooting Text by
Philco and Replies 113

H. Replies to use North Carolina Community Colleges in Study 118

I. Sample Letter Requesting Individual to Serve on Panel of Experts and
Replies 121

Vita 126

LIST OF TABLES

1.	Comparison of Troubleshooting Scores	47
2.	Item Discrimination Index of Troubleshooting Test Questions	48
3.	Means and Standard Deviations of Selected Variables	57
4.	Zero Order Correlations Between Selected Variables and Troubleshooting Knowledge	58
5.	Summary of Stepwise Procedure for Troubleshooting Knowledge	61

CHAPTER 1

INTRODUCTION

The electronics industry has entered a period of unparalleled innovation. In every sector of work and life electronics is playing a significant role in peoples' lives. The Electronics Industries Association (1989) reported that the use of microprocessors and digital electronics has made it possible for high volume manufacturing, faster and more accurate methods of communications, and improved automation systems to become realities.

The Electronics Industry Association (1989) also indicated that the innovations mentioned above and others were preceded by many milestones. Some of the most significant milestones were: (a) Fleming's development of the electron tube in the 1890s, (b) DeForest's invention of the vacuum tube in 1907, (c) the invention of the transistor in 1947 which immediately revolutionized all facets of the electronics industry, and (d) the development of the integrated circuit in 1971 which introduced portable calculators and microprocessors.

Manning (1989) reported that his research anticipating life at the turn of the century led him to the conclusion that technology will cause new types of jobs to be created and traditional jobs to be eliminated. Economic forecasters also reported that most of these new jobs will

emerge as a result of industry's increased reliance on technology and automation to achieve higher productivity (Brown,1989). New workers will be needed to operate, maintain, and repair this new technology, and much of this technology will be associated with the field of electronics.

Hazen (1991) stated the electronics industry will continue to expand as electronic devices and systems become smaller and more sophisticated. New discoveries in electronics will open new frontiers in all human endeavors. Whether these endeavors be in manufacturing, space exploration, robotics, or medicine the use of electronics technology will increase as industries grow, and new innovations are discovered and brought on line.

People employed in electronics who utilize this new and emerging technology will be working with sophisticated systems. And in order to minimize system "down-time," equipment servicing must be performed rapidly and accurately. Technicians assigned to diagnose and repair these systems must be able to think logically and possess a thorough knowledge of the electronic technologies employed.

Statement of the Problem

The greatest concern associated with the maintenance of complex electronic systems is the diagnosis of faulty equipment or

troubleshooting. Baldwin (1978) reported that undesirable amounts of equipment downtime may not be dependent upon electronic system sophistication. "Inaccurate task analysis, lack of ability to use auxiliary test equipment and the inability to use systematic fault isolation (troubleshooting techniques) are major factors contributing to the judgment that technicians are not trained adequately" (p. 26).

Wickens, Geiselman, Samet, and Yelvington (1982) reported that the performance of complex tasks such as maintaining mechanical equipment and troubleshooting electronic devices requires highly skilled personnel. However, the training of such personnel to troubleshoot and maintain this increasingly sophisticated equipment has typically been less than successful (Sanderson, 1988).

As business and industry seek to increase product quality and boost productivity, there will be an increased use of electronic equipment and thus a need for electronics technicians. There is a growing need for electronics technicians who are proficient in the theory and application of the fundamentals associated with electronics (United States Department of Labor, 1992-93). In order to become proficient, student technicians are instructed in electronics technology and the use of mathematics figures highly in that instruction (Guilford Technical Community College, 1991).

Electronics is considered a rather abstract subject because many of its concepts and basic fundamentals cannot readily be observed. Instructors have attempted to illustrate these concepts and basic fundamentals through the use of mathematical equations and calculations. Research by Baker (1979) has revealed that mathematics ability has figured highly in predicting the success of students enrolled in electronics programs. However, his research also revealed that practicing technicians indicated that their use of mathematics was minimal.

Although research has been conducted on the troubleshooting process, few if any, studies have considered the use of mathematics as a mitigating factor when addressing the troubleshooting efficiency of technicians. Many electronics textbook authors (Buscombe, 1984; Grob, 1989; Perozzo, 1985; Sanderson, 1988; Sinnema & McPherson, 1991) strive to minimize the use of mathematics in their texts. However, when reviewing the typical program designed to prepare electronics technicians, mathematics (algebra, trigonometry, and calculus) figures highly in that program and the success of technicians enrolled in that program (Guilford Technical Community College, 1991). The major problem addressed by this study was the lack of knowledge that exists about relationships among troubleshooting, mathematics and electronics

knowledge.

Purpose of the Study

One purpose of this study was to determine relationships among students' troubleshooting, mathematics, and electronics knowledge. A second purpose of the study was to determine the extent to which these variables best predicted students' troubleshooting knowledge. Although investigation of mathematics and electronics troubleshooting relationships was a major thrust of this study, conversations by the author with practicing technicians and personal experiences revealed that mathematics was used infrequently in the performance of troubleshooting tasks. In addition to conversations and personal experiences it was also noted upon examination of numerous electronics textbooks that most authors stated that student use of mathematics in electronics had been kept to a minimum. This, in effect, implied that it is the use of and repeated exposure to fundamental theories and knowledge of the principles of electronics theory that provide persons with necessary knowledge to become effective troubleshooters.

In this study, focusing on potential relationships among mathematics, electronics knowledge, and troubleshooting knowledge necessitated the use of a wide range of employment and experience

related variables. These variables were selected for inclusion in the study based on a review of relevant research studies (see Chapter 2) as well as conversations, personal experiences, and an examination of electronics text books. More specifically, this study sought answers to the following questions:

1. What relationship exists between the number of mathematics courses taken at the community college and troubleshooting knowledge?
2. What relationship exists between the type of mathematics courses taken at the community college and troubleshooting knowledge?
3. What relationship exists between mathematics knowledge and troubleshooting knowledge?
4. What relationship exists between the number of electronics courses taken at the high school level and troubleshooting knowledge?
5. What relationship exists between the number of electronics courses taken at the community college level and troubleshooting knowledge?
6. What relationship exists between the amount of prior work experience in the electronics field and troubleshooting knowledge?
7. Which combination of variables best tends to predict

troubleshooting knowledge?

Limitations of the Study

There were three limitations associated with this study. They are listed below.

1. A paper and pencil troubleshooting test was utilized. Assessment of psychomotor skills or hands-on skill involved in the troubleshooting process was not included.
2. Electronics students participating in the study were limited to day students (8 a.m. -- 3 p.m.) enrolled in electronics technician degree programs offered by the community colleges located within the central region of North Carolina as defined by the North Carolina Board of Community Colleges.
3. Data gathered were limited to the assessment and identification of troubleshooting knowledge needed by electronics technicians in the industrial and home consumer electronics industries.

Definitions

In order to clarify the meaning of terms associated with this study, the following definitions are provided:

Consumer or Home Electronics Technicians (also called electronics

home equipment repairers) are persons who repair radios, television sets, stereo components, video cameras, compact disk players, video games, home security systems, microwave ovens, and electronic organs. Some repairers specialize in one kind of equipment; others repair many types (United States Department of Labor, 1992-93, p. 327).

Electronics Technicians (also called electronics equipment repairers)

are persons who install, maintain, and repair electronics equipment used in offices, factories, homes, hospitals, aircraft, and other places. Equipment includes television sets, radar, industrial equipment controls, computers, telephone systems, and medical diagnosing equipment (United States Department of Labor, 1992-93, p. 323).

Industrial Electronics Technicians are persons who install and repair

electronic equipment used in industrial automated equipment controls missile control systems, radar systems, medical diagnostic equipment, transmitters, and antennas (United States Department of Labor, 1992-93, p. 325).

Troubleshooting is the process of finding the faulty component or components in a malfunctioning unit of equipment (Gibillisco & Scialer, 1990).

Procedural Knowledge consists of the skills an individual knows how to perform (Johnson, 1987).

Problem Solving is the process in which one starts from an initial state and proceeds to search through a problem space in order to identify the sequence of operations or actions that will lead to a desired goal (Johnson, 1987).

Summary

The electronics industry has entered a period of unparalleled innovation. In every sector of work and life electronics is playing a significant role in peoples' lives. Research has indicated that the electronics industry will continue to expand as electronic devices and systems become smaller and more sophisticated. Technicians assigned to diagnose and repair these systems must be able to think logically, and possess a thorough knowledge of the electronic technologies employed.

There is a growing need for electronics technicians who are proficient in the theory and application of the fundamentals associated with electronics. To become proficient, student technicians are instructed in electronics technology, and the use of mathematics figures highly in that instruction.

Electronics is considered abstract because many of its concepts

and basic fundamentals cannot readily be observed. Instructors of electronics have attempted to illustrate these concepts and basic fundamentals through the use of mathematical equations and calculations.

Although research has been conducted on the troubleshooting process, few if any, have considered the use of mathematics as a mitigating factor when addressing the troubleshooting efficiency of electronics technicians. The major problem to be addressed in this study was the lack of knowledge about relationships among troubleshooting, mathematics, and electronics knowledge.

CHAPTER 2

REVIEW OF LITERATURE

A review of related literature was conducted for the purpose of conceptualizing the research problem and providing a frame of reference for answering the research questions. Research studies were grouped into the following three categories: (a) mathematics and problem solving, (b) cognitive processes of problem solving (memory and experience), and (c) troubleshooting training and research.

Mathematics and Problem Solving

The largest and perhaps the most difficult task facing the electronics technician is that of troubleshooting a malfunctioning unit or system. In order to maintain the systems or units under his or her care, the electronics technician must have a thorough knowledge of the equipment in question and employ a logical approach to locate, isolate, and repair any fault in the equipment's operation.

Numerous texts focusing on troubleshooting electronic systems have been published. Included in these texts are troubleshooting requirements and models. According to the Philco Technical Institute (1966), one of the earlier texts dealing with electronic troubleshooting,

"the troubleshooting process can be summarized into four major areas: (a) determine the symptoms, (b) localize the trouble to a functional unit, (c) isolate the trouble to a circuit, and (d) locate the specific trouble" (p. 2).

A more recent text, written by Patrick and Fardo (1989), stated that much of the technician's time is used in locating troubles. More specifically, " the troubleshooting process found to be most useful to the technician is: (a) using a common sense approach, (b) knowing how electronic systems work, (c) knowing how to use schematic diagrams effectively, and (d) being able to find the trouble through a logical sequence" (p. 627).

Since technical troubleshooting is a subset of problem solving (Johnson, 1987), it is important to examine the literature that is related to problem solving in general and across other disciplines or subject areas in order to help clarify the process of electronic troubleshooting. One such discipline, that of mathematics, is considered indispensable in the education of electronics technicians. Askins (1989) stated that the goal of teaching mathematics is to transform unassertive dependent students into independent problem solvers.

Grouws and Good (1988) reported that problem solving has always been a vigorous part of the history of mathematics education. As

an example of problem solving history, related to mathematics, they stated that Dower, a famed mathematician, did not consider the mastery of fundamental facts and processes to be the ultimate end of mathematics instruction. Instead, Dower argued life itself demands that students have the ability to interpret, comprehend, and solve problems that arise in everyday situations. Another example they cite, from more recent history, was provided by Begle who in 1979 stated that "the real justification for teaching mathematics is that it is a very useful subject and, in particular, that it helps in solving many kinds of problems" (p. 4).

A position paper prepared by the National Council of Supervisors of Mathematics (1989) reported that students educated today are expected to change jobs many times and often the jobs they hold will evolve and change. It is very likely that specific skills will be acquired on these jobs and these skills may or may not be transferable to other types of employment. However, to prepare for this mobility students must develop a thorough understanding of the concepts of mathematics, they must reason clearly, and they must recognize the mathematical applications in the world around them. The Council suggested that mathematics will provide these individuals with the fundamental skills needed to apply their knowledge to new situations and develop a proficiency in problem solving and higher order thinking skills. In

addition, the Council stated that in order to function and function competently in the coming years students will need an enriched body of mathematics that includes: (a) problem solving, where problem solving is the ultimate reason for studying mathematics, (b) mathematical reasoning, through mathematics students should be able to identify and extend patterns, use experiences and observations to make tentative conclusions, and be able to distinguish valid and invalid arguments, and (c) be alert to the reasonableness of results and the logic involved in the solution to the problem.

Lester (1980) reported that anyone who has studied mathematics knows problem solving is the focal point of this educational discipline and that problem solving is the most complex of all learning. Lester also stated that his research on problem solving led him to the formation of a problem solving model to describe the problem solving process. The model he presented contained six distinct but interrelated stages: (a) problem awareness, (b) problem comprehension, (c) goal analysis, (d) plan development, (e) plan implementation, and (f) procedures and solution evaluation. However, it must be pointed out that these stages may or may not occur sequentially.

White and Frederiksen (1986) claimed that when problem solvers reason about physical systems they employ a set of mental models.

White and Frederiksen defined mental models as a knowledge structure that incorporates both declarative knowledge (knowledge of devices, etc.) and procedural knowledge (e.g., procedures for determining the distribution of voltages in a circuit), and a control structure that determines how the procedural and declarative knowledge are used in solving problems. They concluded that models can generate causal accounts, concepts, and laws, and can enable problem solving in a wide context (e.g., Ohm's Law can be used to predict circuit operating characteristics, design circuits, or to troubleshoot them).

While addressing the concerns of mathematics teachers in Alberta, Canada, the Alberta Department of Education (1987) reported that mathematics educators agree on the importance of problem solving. It was stated that many problems can often be solved by employing more than one strategy. When the approach to the solution of a problem is not immediately known, problem solvers often find it useful to operate within a framework. One such framework the Alberta Department of Education noted was provided by the renowned mathematician George Polya. This framework (model) consisted of four steps which could be utilized in the solution of problems.

1. Understanding the problem

In this stage of the model, the problem solver begins to think

about the problem and attempts to clarify what is given and what is being asked (p.3).

2. Developing a plan

Once the problem is understood a plan of action should be developed. Since a problem may be solved in a variety of ways the problem solver should weigh the different strategies which may be employed and choose the one or a combination of strategies which seems to be appropriate (p. 4).

3. Carrying out the plan

In this stage it is essential that the problem solver continuously monitor his or her progress in order to determine whether the plan will lead to a solution (p. 4).

4. Looking back

After the plan has been worked through and the solution achieved the problem solver should look back and reflect on the process.

The solution should answer the original problem (p. 4).

The framework provided by Polya was not considered to be fixed.

Problem solvers could approach a problem in the order outlined or they could return to earlier steps because of obstacles encountered or because it became obvious that another approach would work better (Alberta Department of Education, 1987).

Boreham (1986) related that one approach to solving problems is the use of rule based models. This approach requires the problem solver to apply rules to the problem given (e.g., theorems governing a right triangle), thereby enabling certain inferences to be drawn until enough information is accumulated to reveal the solution to the problem. In some versions of this theory, the rules are said to be formal laws of logic (e.g., Kirchoff's Voltage Law). In others they are said to be reasonable heuristics learned by experience. However, a serious deficiency of rule-based theories is their inability to explain the instinctive flashes by which an experienced problem solver may identify or recognize the cause of the symptoms confronting him/her (Boreham, 1986).

An alternative approach to the Rule-Based Model, as related by Boreham, is the Knowledge-Based Theory of problem solving. This theory attributes expertise in reasoning to the possession of detailed knowledge of the problem domain organized in the form of schemata or stereotypes. With this theory, diagnoses are reached by recognizing the patterns of cues in the symptom display and making implicit inferences to the underlying reality.

Cognitive Processes of Problem Solving

Advances in electronics technology and the increased use of electronics in the commercial, industrial, and home consumer products industry have made diagnosis of malfunctioning equipment much more complex. Thus, consumers of electronics products will demand that electronics technicians have good troubleshooting skills.

In order to understand how troubleshooting is accomplished, it is important to focus on the cognitive processes associated with problem solving. Burton and Magliaro (1988) stated that problem solving is a complex mental activity that involves the interaction between the problem as presented to the individual and the problem solver. The description of the problem may include the information, assumptions, and constraints, as well as the context in which the problem is presented. Based on the perception of the problem and the declarative (facts) and procedural (process) knowledge that has been learned and stored from past experience, the problem solver then forms a mental representation or problem space of the problem. In this space the problem solver evaluates the possible choices, hypotheses, and strategies that may be applied to reach a solution. For example, according to Buscombe (1984), the technician first considers the customer's complaint, then observes the trouble symptoms, defines the problem, and makes a

tentative judgment. In other words, the technician processes the information and makes a decision.

Memory

Memory is basic to any theory of information processing (Frederiksen, 1984). Perceived information first enters the sensory store where it is held in its original form for a brief time period--less than a few hundred milliseconds for visual images and less than four seconds for auditory. Thus the perceiver must be able to quickly recognize cues that will activate relevant information from long-term memory. Short-term memory in which memory may be rehearsed, elaborated, and used for decision making is limited by both the amount of information it can store, and the length of time it can retain that information. Long-term memory is organized according to the way it was encoded.

Individuals differ in the approaches they utilize to solve problems for several reasons. First, people differ in the amount of experience they bring with a particular type of problem. Second, individuals employ different strategies in solving a particular type of problem, and third, individuals pay attention to different aspects of the problem structure based on their conceptions or convictions about what is important (Burton & Magliaro, 1988).

Hayes (1981, p. 7) states that " even when two people represent

the same problem, they may not represent it in the same way. A person who is very good at filtering out irrelevant detail may produce a very sparse representation," and "another person who not good at filtering out irrelevant detail may produce a complex problem presentation." He also relates, "that there are more differences between representations," one person may see the problem in terms of visual cues, another in sentences, and a third auditory cues. However, even if two people represent a problem in visual images, they may not employ the same images.

The problem solver's skill also depends on his or her store of schema. Gagne, Briggs, and Wagner (1988) define schema as an organization of memory elements (propositions, images, and attitudes) representing a large set of meaningful information pertaining to a general concept. Regardless of the subject, a schema contains certain features common to the set of objects or events contained in that category. Schema may differ in their comprehensiveness as well as in the details stored.

Research by Frederiksen (1984), Hayes (1981), and others have found that novices are more likely to have schemata that are tied to concrete aspects of the problem situation. For example, in physics novices tended to classify problems according to specific or surface

features such as inclined plane problems, pulleys, and friction problems whereas experts tended to categorize problems according to the fundamental principles of physics that were involved.

Experience

Kolodner and Riesbeck's (1986) observations led them to believe that experience plays two important roles in problem solving. First, experience contributes to the refinement and modification of the reasoning process. Successful experiences reinforce already known rules or previous hypotheses, whereas failures require reanalysis of the reasoning and knowledge that was used, and modification of faulty rules and knowledge. Consequently experience plays a major role in augmenting problem solving knowledge, and thus turning novices into expert reasoners or problem solvers. Secondly, and equally important, experience acts as an example upon which to base later decisions.

In further discussion, Kolodner and Riesbeck (1986) related that there are two points which are key in the interaction of problem solving and experience. First, using experience in problem solving requires a problem solving framework that includes feedback, and any procedure that is going to use experience to solve problems must be able to make decisions and evaluate their outcomes. A problem solving framework or

system that does not know the outcomes of its suggestions has no basis for evaluating its decisions, and cannot be expected to suggest new solutions based on old ones.

Secondly, the interaction of problem solving and experience requires the services of a "dynamic memory," a memory that is changing with each new experience. As memory receives feedback about its decisions and evaluates them it records its experiences and modifies any knowledge that may have been faulty.

Kolder and Riesbeck (1986) also stated that with experience memory changes. The results of asking a particular memory to solve the same problem at two different times will be different, as will the results of asking two different people with different sets of experiences to solve the same problem. The combination of having solved the same problem once before and the set of experiences that came between the two episodes will result in the differences. If the previous experience on the same problem can be recalled, the second instance of solving the same problem will only require recall. If the second set of experiences encountered by memory between the two cases of solving the same problem reveals new light on some aspect of the problem, then the second solution will take advantage of the new knowledge. The second solution will take advantage even if both started with the same facts their

differing experiences mean that each will have different areas of expertise. The memories will have evolved differently and have learned different things.

Benderly (1984) reports that as knowledge of an area grows there is a gradual change in how people think and reason. The information base does become larger, but more importantly it becomes more abstract and more organized for use, indicating the possession of rapid access to, and efficient utilization of an organized body of conceptual and procedural knowledge. In order to illustrate this point the following example was given:

An experienced doctor takes one look at a spotty, feverish child and instantly diagnoses measles. A young intern looks at the same patient but takes longer to arrive at the same diagnosis, methodically eliminating German measles, chickenpox and scarlet fever. The experienced doctor's analysis is fast and accurate. The doctor constructs the investigation around a comprehensive view of possibilities, unlike the junior colleague who must move through a series of small, ad hoc decisions. (Benderly, 1984, p. 3)

For the beginner, each step was a deliberate decision point. The first few times, the skilled but inexperienced doctor encountered blotchy faces. The doctor was able to apply learned knowledge. Similarly, the experienced doctor also applied learned knowledge and attention, but in a different way. Both doctors took temperatures, listened to the chest, and maybe examined photos of common skin rashes. With increased

experience the inexperienced doctor was able to accumulate more facts about skin inflammation and even more important was able to organize them into an increasingly broad but detailed understanding of contagious diseases consistent with the more experienced doctor.

Based on research Magliaro (1988) reported that central to the concept of "skilled memory" is the rapid and efficient utilization of memory in some knowledge domain to perform a task at an expert level. Experts have many of the processes related to their area of expertise developed to an automatic level or where they are able to perform problem solving skills without effort. Thus, they are free to devote their cognitive capacity to more complex or novel aspects of the problem that requires conscious effort. During problem solving, experts have the capacity to take into consideration simultaneously several hypotheses while cues are constantly being selected to support or disprove proposed solutions.

Magliaro (1988) also reported that in terms of problem solving, skilled memory is of particular importance at the initial stage of the process. It is at this stage that the individual is determining what is unknown, what information is available, and what conditions are given. Equipped with prior experience, relevant cues, and a highly organized knowledge structure experts are able to focus quickly on important cues

and can construct accurate images of the problem.

Hestre and Touger (1988) reported that experts appear to differ from novices in the way they solve problems. Cognitive research indicates that experts begin by cuing on a problem's structure (principles and concepts that could be applied to solve the problems) as the cue to determining which concept(s) or principle(s) should be applied in solving the problem. Experts also take the time to develop a strategy for achieving a solution before they execute any procedures arriving at a solution to the problem. In addition, Hestre and Touger stated that there is evidence to support the theory that experts possess a number of tacit skills in problem solving that novice problem solvers do not have such as:

1. Being able to describe a problem in detail before applying a solution;
2. Being able to determine what relevant information should go into the analysis of a problem; and
3. Being able to decide which procedures can be used to generate a problem description and analysis.

Troubleshooting Training and Research

The performance of tasks as complex as troubleshooting requires highly skilled personnel. The technician must have a detailed understanding of the systems that are being maintained and repaired. Although the technician may be trained exclusively on-the-job it is in the interest of efficiency that most technicians are introduced to electronic fundamentals and theory by formal schooling (Baldwin, 1978).

Electronics technicians programs of the 1950s and 1960s were based on programs developed by the military for the electronic maintenance personnel instruction during World War II. Training programs utilized by the military were, in turn, based on an engineering course developed at the Massachusetts Institute of Technology (Baldwin 1978).

These early military training programs, originally designed for radar technicians, have served as a framework for the subsequent training of electronics technicians by providing the necessary knowledge, concepts, and skills required of personnel on the job. The sequence of instruction had the following characteristics:

1. Instruction in basic principles of electricity and electronics preceded instruction on intact equipment. Specifically, the instruction utilized a "part to whole" approach in which the

sequence of topics paralleled the building of a radio beginning with simple circuits which are then combined to form more complex assemblies as the course unfolds.

2. Instruction on maintenance principles and techniques followed instruction on the principles of electronics. The student was expected to know the principles of equipment functioning before he was taught troubleshooting and repair skills (Baldwin, 1978, p. 4).

One of the earliest studies that attempted to explain the troubleshooting process and to provide a framework for the instruction of electronics technicians instruction was performed by the United States Office of Naval Research (Bryan, 1962). The primary concern of this study was the investigation of the many problems and issues involved in the training of electronics technicians to install, maintain, and, most important of all, to repair electronic equipment. As a result of this study, a 10-step model was developed. Although it was widely recognized that this model did not represent the actual troubleshooting process, it however pointed out the cognitive nature of the troubleshooting process and provided a framework for developing troubleshooting routines.

1. **Symptom Recognition.** The first stage in troubleshooting occurs when the technician becomes aware that the system is functioning

improperly.

2. **Symptom Elaboration.** The exploration of the initial stimulus situation to ascertain the complete symptom pattern being generated by the equipment.
3. **Formulation of Hypotheses.** These could account for the pattern of symptoms being observed.
4. **Selection of Hypothesis.** To be selected for testing. The most likely hypothesis would be in line with past experience with that particular piece of equipment.
5. **Formulation of Testing Plan.** At this point the technician should formulate a concrete plan for testing the hypothesis.
6. **Acquisition of Circuit Status Information.** Now the technician is required to implement the troubleshooting plan he/she has made.
7. **Interpretation of Discrete Readings.** As each reading is obtained, it has to be interpreted into broad categories such as high, normal, or low.
8. **Organization of Information.** Malfunctioning components are not located by measurement only, but by patterns of readings. The troubleshooter must construct these patterns or organize the readings for him/herself.

9. Selection of an Alternative Hypothesis. If the initial hypothesis has been rejected on the basis of a pattern of information developing which is at odds with the hypothesis under test an alternative hypothesis is selected.

10. Confirmation of Hypothesis. When the technician makes some crucial adjustment or component replacement, that eliminates the source of the difficulty. (Bryan, 1962, p. 305)

With the continued increase in the sophistication of electronic equipment utilized in military systems, the military has been in the forefront of research and training methods of electronics technicians. The earlier training techniques, which utilized actual equipment for training, proved to be quite expensive and time consuming. In an effort to become more efficient, both in instruction and in the graduation of proficient electronics technicians from their technical programs, the military commissioned several research studies focusing on the relatively new educational technology and techniques made available by computer assisted instruction to develop new and more efficient training techniques. One such study was carried out by Brown, Rubinstein, and Burton (1976).

Brown et al. (1976) believed that many electronics technicians were trained to repair only specific types of equipment. It is not

surprising then that technicians trained in this manner have difficulty repairing familiar equipment with unusual symptom faults or unfamiliar equipment for which they have had no specific training. In other words their skills were not transferable between equipment types.

The thrust of this study was to produce a skilled troubleshooter who would be capable of repairing familiar as well as unfamiliar equipment without significant retraining. In order to train this expert technician, Brown et al. (1976) employed a computer assisted instructional (CAI) system for teaching the knowledge and reasoning strategies of expert electronics technicians. This CAI system, SOPHIE (Sophisticated Instructional Environment), consisted of artificial intelligence programs which used a circuit simulator to answer hypothetical questions, evaluate student hypotheses, provide immediate feedback to a variety of measurement questions, and allow the student to modify a circuit and discover the ramifications of his/her modification. It was believed that with this system the student would be the recipient of expert troubleshooting strategies and other pertinent electronic knowledge in terms of concrete examples.

Another study utilizing computer assisted instruction techniques was carried out by Rigney, Towne, King, and Moran (1978). This study utilized a computerized instructional system called the Generalized

Maintenance Trainer Simulator (GMTS). The purpose of this trainer was to provide intensive troubleshooting experiences for Naval personnel enrolled in electronics schools.

The GMTS was intended to reduce the requirements of using operational equipment in the laboratory phases of electronics training and to increase the effectiveness of the students' limited opportunities to work on the actual equipment employed in the field by familiarizing them with the equipment's functional and structural construction before-hand. The GMTS was designed to provide a combination of low cost simulation techniques and an automatic instructional system. In addition, the GMTS was designed to be easily adaptable to simulate different kinds of equipment by changing data bases that describe the functional and structural architecture (a) to the computer program that controls the simulation and interacts with the student, and (b) to the student who is interacting with the computer program.

The trainer simulator approach employed by Rigney et al. (1978) was designed to develop valid representations of equipment structural and functional construction that could be used for teaching the student how to answer the following six questions in the context of fault localization:

1. What is it?

2. What should be done about it?
3. How is it done?
4. Is it possible to do it?
5. Am I doing it right?
6. Am I through? (p. 3)

The overall objective of the GMTS was to motivate the student's information processing system to develop appropriate schema structures in long-term memory. These generic schemata would then provide the framework for more refined schemata when the technician begins to react with the actual equipment. Students participating in this study became generally much more fluent at troubleshooting, mean times to solve problems were decreased, and the standard deviations of these times were also decreased.

Taking a slightly different approach Baldwin (1978) reported that electronic maintenance repair, which is domain specific, is characterized by job oriented behaviors which can be placed within one of three main categories: (a) mechanical behaviors such as disassembling and or assembling components; (b) operator behaviors, such as energizing the system; and (c) the decision making function upon which each choice of action is based.

Additionally, Baldwin described the decision making process as having both an active and passive state. Information stored and recalled as needed comprises the passive state while sensing, recognizing, and interpreting events comprise the active state. The active component of the decision making process can be best depicted by examining the way in which it is called into play in the troubleshooting process.

The repairman might need to examine the output displayed by an oscilloscope. The decision function starts when he directs his attention toward the oscilloscope display. He then employs filtering when some instruction such as looking at the synchronization pulse instead of the whole waveform is recalled from memory. At this point he extracts comparative information from experience and memory in form of synchronization pulse characteristics. Through the use of this comparative information the technician determines if the synchronization pulse is good, missing or distorted. (Baldwin, 1978, p. 6)

The next step is the interpretation of the event identified by applying a set of rules to the class. On the basis of the information acquired, the technician using his/her experience puts into place the rules for treating the event he has identified.

Johnson (1987) argued that before effective training programs can be developed, a greater understanding is needed of the knowledge, skills, and cognitive processes required to solve technical problems. He said that, currently most training programs have evolved based on incomplete task analysis and that his research derived from cognitive

tasks analysis results in a deeper and much more complete understanding of the cognitive tasks employed by the troubleshooter.

Johnson (1987) based his research on the three theories of Gott for the use of cognitive task analysis. First, cognitive task analysis can capture more of the substructure of complex technical problems. Secondly, the use of cognitive task analysis concerns the adaptiveness of instruction to the needs of the learner, and thirdly, cognitive task analysis provides an ideal model to guide the development of technical instruction.

In a later study, Johnson (1989) reported that the major goal of technical instruction is to provide the learner with the knowledge and skill, and to guide the learner in the development of expertise. Johnson suggested that for technical instruction to be effective, first the content domain must be completely and adequately defined. The learner must be taught the function and operation of the specific system under study (e.g., computer, communication system, or automation system) and must understand the relationships between the individual parts and the total systems. Secondly, the learner should receive instruction on the technical procedures needed for problem identification. They must know what procedures are available, when and how the procedures are to be used, and what the results mean. Additionally, technical instruction must

provide the learner with realistic learning experiences. Learners should be provided with malfunctioning equipment or systems to afford them the opportunity of actually troubleshooting a malfunctioning piece of equipment or system.

Summary

Since troubleshooting is considered a subset of problem solving, literature was examined that related to problem solving in general, and across other disciplines or subject areas to help clarify the process of electronic troubleshooting. The literature review was divided into three sections. Each section was designed to review the literature as it related to the research questions of this study.

More specifically, the section on Mathematics and Problem Solving was related to research questions 1-3. Questions 1-3 focused on the role mathematics plays in problem solving. The purpose of the second section, Cognitive Process of Problem Solving, was to examine the literature as it related to research questions 4-6. Questions 4-6 were concerned with prior electronics experience and the complex mental activities involved in the problem solving process, and finally, the section on Troubleshooting Training and Research examined the literature on electronics troubleshooting training research.

Research on mathematics and problem solving revealed that mathematics has long held an honored position in the school curriculum, and is necessary in teaching the problem solving process. Research supported the notion that the mastery of mathematical facts and processes was not the ultimate aim of mathematics instruction. Mathematics instruction, it was revealed, provided the student with: (a) the ability to interpret, comprehend, and solve everyday problems; (b) the background to reason clearly and apply existing knowledge to new situations; and (c) assistance in developing a proficiency in problem solving and higher order thinking skills.

Research on mathematics also revealed that workers in the 21st century will need an enriched mathematics curriculum that has as its main thrust problem solving. More specifically, this curriculum will be used to: (a) teach reasoning, (b) to identify and recognize patterns, and (c) to use experience and observations to make tentative conclusions.

The second research area focused on the cognitive processes (research questions 4-6) involved with problem solving and the various approaches employed by problem solvers. Problem solving research revealed that arriving at the solutions to problems requires complex mental activities that involve interaction between the problem solver and the problem, and a memory that changes with each new experience.

Experience, whether gained from prior educational or work related activities, plays several important roles in the problem solving process. First, experience contributes to the refinement, and/or modification to the reasoning process. Second, experience becomes the foundation upon which to formulate problem solutions. Third, experience increases the knowledge base that can be accessed by the problem solver. Fourth, experience organizes the information base for more efficient use. And finally, from experience, a problem solving framework can be developed and employed in solving problems.

The third area focused on troubleshooting training, and the various studies associated with the cognitive processes of troubleshooting. Research related to the training of electronic technicians revealed that early training programs have served and in many cases are still serving as the framework for current training programs for electronic technicians.

One of the earliest studies that attempted to explain the cognitive processes of troubleshooting was performed in 1962 by the United States Office of Naval Research. As a result of this study a 10-step model was developed. This model sought to explain the cognitive processes involved in troubleshooting. In addition to being one of the earliest attempts to explain the troubleshooting process, this model became the framework for developing subsequent troubleshooting

models and routines.

With continued increase in the sophistication of electronic equipment, the earlier training methods proved to be inefficient. In an effort to make the technician more competent, other studies were conducted. The thrusts of these studies were (a) to produce a skilled troubleshooter who would be capable of repairing unfamiliar as well as familiar equipment, (b) to provide intensive troubleshooting experiences, and (c) to reduce the stress on functional equipment. As a result, students participating in these studies became generally much more fluent in the troubleshooting process. In addition to providing students with a more enlightened approach to troubleshooting faulty equipment, these programs also provided an automatic instructional system with relatively low equipment cost and an easily modifiable equipment simulation environment that is necessary in technical instruction.

Researchers agree that the goal of technical instruction is to provide the learner with the knowledge and skills needed in the development of expertise. The learner must be provided with realistic learning experiences. These experiences should include the use of equipment or system simulators that afford students the opportunity to troubleshoot malfunctioning equipment or systems.

CHAPTER 3

METHODOLOGY

This chapter describes the research design employed in the study. Also described in this chapter are the study sample, the instrumentation used, and the data collection and analysis techniques employed.

Research Design

The general design for this study was *ex post facto* research methodology. Wiersma (1969) defined this as "research in which the independent variable or variables have already occurred and in which the researcher starts with the observation of a dependent variable or variables. He then studies the independent variables in retrospect for their possible relations to, and effects on, the dependent variable or variables." Multiple regression analysis techniques were utilized to describe the relationships that existed between the independent and dependent variables, and which combination of variables best tends to predict troubleshooting knowledge.

Population and Sample

The target population of this study consisted of students enrolled during the day time (8 a.m.-3 p.m.) hours of instruction in electronics

programs of community colleges located within the central region of North Carolina.

The central region is the most populous of the State's three regions. This region consists of 34 counties and contains 52% of all North Carolinians. Total employment as of 1984 was 1,614,500 which is equal to 57% of total state employment (Clements,1988).

Eighteen of the State's 58 community colleges are located within this region. Fourteen of the community colleges located within this region grant a two-year associate degree in Electronics Engineering Technology. Of the 14 community colleges granting a two-year degree in Electronics Engineering Technology, five colleges were chosen at random to participate in the study. The five colleges were contacted to determine if they would or could participate in the study. Of these five colleges, two declined to participate. Therefore, two additional colleges, chosen at random from the pool of remaining colleges, were asked and agreed to participate in the study.

From these five community colleges a total of 100 students were selected by their electronics instructors to participate in the study. The instructors selected these students based on student willingness to participate in the study and availability to complete the study instruments. Since students were not randomly selected to participate in the study,

they were considered to be the a purposive rather than a representative sample of students enrolled in electronics programs at community colleges located in the central region of North Carolina.

Instrumentation

Three instruments were utilized in this study for the collection of data: (a) a student data and information sheet, (b) a mathematics knowledge/skills test, and (c) a pencil and paper electronics troubleshooting knowledge test.

Student Information and Data Sheet

The purpose of the Student Information and Data Sheet (see Appendix A) was to gather demographic information from each participant. The information derived from this instrument was utilized in helping to determine what relationship, if any, existed between the independent and the dependent variables associated with the study.

More specifically the Student Information and Data Sheet was used to gather the following information:

1. Student number
2. Name of community college
3. Student birth date

4. Sex of student
5. Number of electronics courses completed in high school
6. Number of electronics courses taken while enrolled at the present institution
7. Number and type of mathematics courses taken while at the community college
8. Previous experience in electronics (education and or work experience)
9. Hobbies

The Student Information and Data Sheet requested the school, age, sex, and hobbies of each student participating in the study. For purposes of this study these variables were not utilized, but may be utilized in a later study.

Mathematics Test

In order to ascertain the mathematical knowledge/skill of each study participant a mathematical knowledge/skill test was administered. The test administered, with permission from the Mathematical Association of America (see Appendix D), was a 32-item, 45-minute standardized mathematics test, version A/3B, designed by the Mathematical Association of America and utilized by colleges and

universities to determine the mathematical placement of entering students (Mathematical Association of America, 1978).

The Mathematics Association of America states that the test has been examined for validity by a panel of experts and was determined to be of value in measuring the mathematical concepts it was designed to measure. The Association states that the test mean is approximately 50% with a Coefficient Alpha of .7 or higher. The test items are constructed so that 25% are considered as easy, 50% are of medium difficulty, and 25% are considered to be difficult.

The mathematics knowledge test administered was designed to cover the mathematical concepts stressed in elementary, intermediate, and college algebra. More specifically, the test covered the following topics:

1. Arithmetic of rational numbers
2. Operations with algebraic expressions
3. Linear equations and inequalities
4. Factoring and algebraic fractions
5. Exponents and radicals
6. Graphing and distance
7. Fractional and quadratic equations and inequalities
8. Logarithms

- 9. Functions
- 10. Complex numbers
- 11. Absolute values
- 12. Systems of equations

Electronics Troubleshooting Knowledge Test

The instrument utilized for assessing student troubleshooting knowledge was derived by this researcher, using examples taken from an electronic troubleshooting text developed by the Philco Technical Institute published in 1966. The examples taken from the text were modified to insure clarity, and to provide the participant with four possible responses to each example. This written test consisted of troubleshooting an AM transceiver functional block diagram, a servicing block diagram, a power supply, and a summing circuit. A copy of the test is included as Appendix B.

The troubleshooting technician utilizes the block diagram to help determine which functional group or circuit group to test first. This requires an examination of the block diagram to ascertain whether test results from any one of the selections could also eliminate other functional units listed as the probable cause. The block diagram is an essential reference for localizing the trouble to a functional unit within an

electronic system.

The purpose of the servicing block diagram is to provide the technician with a general representation of the circuit groups and individual circuits as well as their signal-path relationships, waveforms, and test point location. In addition to troubleshooting using a block diagram and the servicing block diagram, the student was also asked to troubleshoot a power supply and a summing circuit to the component level.

Troubleshooting to the component level is the last step in the troubleshooting process. This stage requires the technician to test various branches of a faulty circuit to determine which component is defective. The proper performance of this step will place the technician in a position to determine the cause of the trouble, repair it, and return the equipment to normal operation (Philco Technical Institute, 1966).

Content Validity. Ary, Jacobs, and Razavieh (1985) stated that in assessing the content validity of a measuring instrument one is concerned with the question, How well does the content of the instrument represent the content to be measured? In order to obtain content validity, three experts (consisting of one representative each from industry, engineering, and technology education) were asked to serve on a content review panel. Of those contacted, only two agreed to

participate in the study (industry electronics engineer and technology education professor).

The focus of the experts was to examine the instrument, evaluate its relevancy as a paper and pencil electronics troubleshooting instrument, and determine if the test was free from the influence of factors that are irrelevant to the purpose of the measurement. As a result of their examination, the experts agreed unanimously that the troubleshooting test was free, in their estimation, from factors that they considered irrelevant.

Concurrent Validity. To ensure the concurrent validity of the paper and pencil troubleshooting instrument, the instrument was administered to two groups of students (84 students total) who were not part of the sample. The two groups were composed of (a) students who were enrolled in either their first, third, or fifth prescribed course in the Industrial Technology electronics curriculum at North Carolina Agricultural and Technical State University in Greensboro, North Carolina and (b) students who were enrolled as Mass Communications majors at the same university. The test results of those students enrolled in electronics courses were then combined to represent a cross section of the students enrolled in electronics courses at North Carolina

Agricultural and Technical State University (see Table 1). The mean scores of both groups were compared. This comparison allowed the researcher to determine that the measuring instrument was indeed able to differentiate between the levels of troubleshooting knowledge (where $F = 63.6$, $df = 83$ and $p < .05$) between the two participating groups.

Table 1
Comparison of Troubleshooting Scores

Group	<i>n</i>	Mean	<u>SD</u>
No Training	30	8.1	2.9
Training	54	11.1	3.9

Reliability. The troubleshooting test data generated from the 84 students included in the study of concurrent validity was used to establish reliability. Reliability was defined by Ary, Jacobs, and Razavieh (1985) as the consistency with which a measuring instrument measures a given performance or behavior. In order to ensure reliability of the measuring instrument an item analysis was utilized to identify the best items utilizing the item discrimination index.

The item discrimination index was calculated (Point Biserial

Correlation) by correlating the item scores with the total scores. No items were shown to have a negative or zero correlation with the total score. The correlation of scores ranged from .094 to .792 (see Table 2).

Table 2

Item Discrimination Index of Troubleshooting Test Questions

Item Number	Index	Item Number	Index
1	.321	16	.245
2	.453	17	.472
3	.377	18	.358
4	.415	19	.302
5	.528	20	.226
6	.170	21	.302
7	.792	22	.245
8	.491	23	.189
9	.623	24	.340
10	.283	25	.302
11	.491	26	.094
12	.623	27	.377
13	.643	28	.283
14	.189	29	.377
15	.547		

In addition to utilizing an item analysis, the Kuder-Richardson (KR-20) procedure was also be employed. The purpose of the Kuder-Richardson (KR-20) was to assess item consistency. This

procedure was applicable to tests whose items are scored either right or wrong (Ary, Jacobs, & Razavieh, 1985). As a result of utilizing the Kuder Richardson (KR-20) procedure it was revealed that the paper and pencil electronics troubleshooting test had a reliability coefficient of .60. The reliability of coefficient of .60 was considered by the researcher as being sufficient for research purposes but not for decisions that affect individuals (Nunnally, 1967).

Data Collection

Permission to conduct the study was secured by contacting various departmental chairpersons and classroom instructors at each of the five randomly selected community colleges. A follow-up telephone call was made to each of the consenting departmental chairpersons and/or classroom instructors to determine the testing date and the number of students consenting to participate in the study. Provisions were then made for the researcher to personally administer the instruments, and provide instructions needed for the proper completion of the data gathering instruments. Data collection began, and was completed during the summer of 1991.

Data Analysis

Multiple regression analysis was utilized because of its ability to describe the relationships that exist between the independent variables (number of prescribed electronics courses taken, number and type of prescribed mathematics courses taken, electronics experience, and mathematical knowledge as related from score on standardized mathematics test), and the dependent variable (troubleshooting knowledge). In addition, multiple regression is used widely by researchers to predict the standing of individuals in a sample on a criterion variable from scores earned on a combination of predictor variables.

More specifically, as defined by Kerlinger (1986), multiple regression analysis is a method for studying the effects and the magnitude of the effects of more than one independent variable on one dependent variable using principles of correlation and regression. Kerlinger also stated that multiple regression assists the researcher in studying the variables' precision, and also examines complex interrelations between the dependent variable and independent variables.

Summary

Ex post facto research methodology was selected to examine the relationship between mathematics, electronics troubleshooting knowledge, and other selected variables of community college students enrolled in electronics technician programs. Multiple regression analysis techniques were employed to describe the relationships among the variables associated with this study, and to determine which combination of those variables best tend to predict troubleshooting knowledge.

Permission to conduct the study was secured by contacting the various departmental chairpersons and classroom instructors at each of the five institutions consenting to participate in the study. A follow-up telephone call was employed to each of the consenting institutions to determine the testing date and the number of students consenting to participate in the study. Provisions were then made to personally administer the instruments and provide the proper instructions needed for the completion of the data gathering instruments. The instruments were personally administered by the researcher during the summer of 1991.

To determine the relationships that existed between the variables of this study three instruments were used to collect data. The first to be employed was a Student Information and Data Sheet. The Data Sheet was completed by 100 community college students enrolled in electronics

technicians degree programs who participated in the study. The purpose of the Student Data Sheet was to gather demographic information associated with each participant.

The second instrument employed was a mathematical knowledge skill test. This was a 32-item, 45-minute standardized test designed by the Mathematical Association of America and utilized by colleges and universities to determine the mathematical placement of entering students. The test items of the math test were constructed so that 25% were considered easy, 50% considered of medium difficulty, and 25% were considered to be difficult. The test administered was designed to cover the mathematical concepts stressed in elementary, intermediate, and college algebra.

The third instrument utilized during the study was the Electronics Troubleshooting Knowledge Test. This test was derived by the researcher using examples taken from an electronic troubleshooting text developed by the Philco Technical Institute. The examples taken from the text were modified to insure clarity and to provide the participant with four possible responses to each example.

In order to ensure that the paper and pencil electronics troubleshooting test was valid a panel of two electronics experts was established. Their charge was to determine if the test was relevant and

free from factors that were irrelevant to the purpose of the measurement.

In addition, the test was administered to two groups of students. One group of students had no prior training or education in electronics and the other group consisted of students who were enrolled either in their first, third or, fifth course in electronics. The test results of the electronics students were combined and then compared with those who had no training. As a result of this comparison, it was determined that the troubleshooting test was able to differentiate between levels of troubleshooting knowledge.

Field testing also allowed the researcher to determine if the instrument was reliable. Results of item analysis revealed that no items had a negative or zero correlation with the total score. In addition to conducting an item analysis, the Kuder-Richardson procedure was employed to assess item consistency.

CHAPTER 4

RESULTS

This chapter is devoted to the presentation and analysis of the data gathered during this study. The chapter is divided into several sections. Each section will present data as it relates to answering the overall purpose of the study.

This study had two purposes. The first was to determine relationships among community college students', mathematics, electronics, and electronics troubleshooting knowledge. The second purpose was to determine which combination of these variables best tended to predict troubleshooting knowledge. More specifically this chapter presents an analysis of the following research questions:

1. What relationship exists between the number of math courses taken at the community college and troubleshooting knowledge?
2. What relationship exists between the type of mathematics courses taken at the community college and troubleshooting knowledge?
3. What relationship exists between mathematics knowledge and troubleshooting knowledge?
4. What relationship exists between the number of electronics courses taken at the high school level and troubleshooting knowledge?

5. What relationship exists between the number of electronics courses taken at the community college level and troubleshooting knowledge?
6. What relationship exists between the kind of prior work experience in electronics field and troubleshooting knowledge?
7. Which combination of variables best tends to predict troubleshooting knowledge.

Description of Sample

The subjects for the study consisted of 100 students enrolled in electronics programs at five community colleges located within the central region of North Carolina. The average age of those participating in the study was 27.6 years with a standard deviation of 8.0 years.

Of the 100 study participants, 92 were male and 8 were female. In addition, 29 of the 100 were recorded as having been employed in the electronics industry as either part or full time employees (23 full-time, 6 part-time). Of those 29 reporting having worked in the electronics industry, 21 reported that troubleshooting was part of their responsibility. Appendix C presents demographic information about the sample as reported on the student data sheet. Appendix D presents the background characteristics of the sample as they relate to the study

research questions.

In order to determine each participant's mathematical and troubleshooting knowledge, two paper and pencil tests were administered. The Mathematics Knowledge Test (Version A/3B) designed by the Mathematical Association of America was utilized to determine each participants mathematical knowledge. This was a timed standardized test consisting of 32 items and was utilized by colleges and universities to determine the correct mathematical placement of entering students.

The Electronics Troubleshooting Test was employed to determine each participant's electronic troubleshooting knowledge. This test was derived by using examples taken from an electronic troubleshooting text developed by the Philco Technical Institute. The examples taken from the text were modified to insure clarity and to provide the participant with four possible responses to each example.

The study participants' mean score on the standardized mathematics test was 11.4 with a standard deviation of 4.9. The study participants' mean score on the paper and pencil troubleshooting test was 10.7 with a standard deviation of 3.2. Study participants averaged completion of 2.4 mathematics courses while enrolled at their respective community colleges. In addition, most students reported that the highest

math course they completed was Algebra/ Trigonometry II (whereas Algebra II/Trigonometry II or its equivalent was their second mathematics course).

Table 3 presents means and standard deviations for study participants' responses/scores related to the research questions gathered either by the Student Data and Information Sheet, the Mathematics Knowledge Test, or the Electronics Troubleshooting Test.

Table 3

Means and Standard Deviations of Selected Variables (N = 100)

Variable	Mean	<i>SD</i>
Math score	11.3	4.7
Troubleshooting score	10.5	3.3
Number of math courses	2.4	1.3
Type of math class	2.3	2.6
College electronics courses	5.3	2.7
High school electronics courses	0.2	0.5
Prior work experience (months)	10.8	3.0

Relationships Among Variables

In multiple regression analysis there are two important objectives: to determine the degree of the relationships between the dependent and independent variables, and to predict the scores or actions of one variable from knowledge of another variable. In order to accomplish the first objective, zero order correlational analysis was used to establish the relationships between the selected independent variables and the dependent variable (see Table 4; Appendix E presents zero order correlations among variables).

Table 4

Zero Order Correlations Between Selected Variables and Troubleshooting Knowledge

Variable	<i>r</i>	<i>p</i>
Number of Math Courses at Community College	.03	.77
Type of Math Course Taken	.21	.04*
Mathematics Knowledge	.26	.01*
Number of Electronics Courses Taken In High School	-.16	.12
Number of Electronics Courses Taken At Com. College	.16	.12
Full-time Employment	.02	.82
Part-time Employment	.05	.62

* $p < .05$

The first research question focused on the relationship that existed

between the number of math courses taken at the community college level and troubleshooting knowledge. Statistical analysis revealed that the correlational relationship between number of math courses taken at the community college level, and the dependent variable, troubleshooting knowledge was .03 ($p = .77$). This was not a significant relationship.

The second research question was designed to examine the relationship between the level of mathematics courses taken and troubleshooting knowledge. Data analysis indicated that there was a significant correlational strength of .21 ($p = .04$) between the number of mathematics courses taken at the community college level and troubleshooting knowledge.

The purpose of research question three was to investigate the relationship between mathematics knowledge and troubleshooting knowledge. In order to determine if a relationship did in fact exist, two paper and pencil tests were administered to each study participant.

The first test administered was a standardized mathematics test consisting of 32 items. The second test was an electronics troubleshooting test consisting of 29 questions. Analysis revealed that there was a significant correlation of .26 ($p = .01$) between mathematics knowledge and troubleshooting knowledge.

In order to investigate the strength of the relationship between the

number of electronics courses taken at the high school level and troubleshooting knowledge, correlational analysis was again utilized (research question four). Analysis revealed that no relationship existed between the number of electronics courses taken at the high school level and the paper and pencil troubleshooting knowledge test. Data analysis for research question five also revealed that the correlation between the number of electronics courses taken at the community college level and troubleshooting knowledge was nonsignificant ($r = .16$, $p = .12$).

The purpose of research question number six was to determine the relationship between being employed either part-time or full-time with troubleshooting as a responsibility and troubleshooting knowledge. Data analysis indicated nonsignificant correlations between these data variables: full-time employment and troubleshooting knowledge, $r = .02$, $p = .82$, and part-time employment and troubleshooting knowledge, $r = .05$, $p = .62$. Table 4 summarizes the correlations for the variables associated with research questions one through six. To determine which combinations of variables best tends to predict troubleshooting knowledge, forward step wise regression analysis was utilized. The basic prediction formula was employed, and the required level of significance was set at $p < .05$.

Forward stepwise regression analysis revealed that when the independent variable, Math Score, was entered into the model it could explain 6.8% of the total variance in Troubleshooting Knowledge at a p value of less than .05. No other variable entered the model at this probability level. Table 5 provides a summary of the stepwise procedure.

Table 5

Summary of Stepwise Procedure for Troubleshooting Knowledge

Variable	R square	Prob>F
Math score	.0681	.0091*

* $p < .05$

Summary

Correlational analysis revealed that the independent variables math test score ($r = .26$) and the type of Math courses completed had the highest correlational strength of those variables as outlined in research questions one through six. The number of math classes completed at the community college and full time employment in the electronics industry had the lowest intercorrelational strength when investigating the relationship between the independent and dependent variables.

bles. Generally all intercorrelations showed a low correlational strength between the above independent variables and the dependent variable of Troubleshooting Knowledge (Bartz, 1988).

In order to determine which combination of variables could best predict troubleshooting knowledge forward stepwise regression analysis was utilized. Through statistical analysis it was determined that under the conditions imposed by this study, only one of the independent variables, Math Knowledge as related from the scores on the math test, could be used with some accuracy to predict troubleshooting knowledge. This variable only accounted for 6.8% of the variation in troubleshooting knowledge.

CHAPTER 5

SUMMARY, DISCUSSION, AND RECOMMENDATIONS

Summary

The electronics industry has entered a period of unparalleled innovation. The advances of digital technology have ushered in the appearance of robotics and improved automation systems, and have created products that have provided the means for faster and more accurate methods of communication, education, and entertainment.

With the approach of the 21st century it has been anticipated there will be greater developments within the electronics industry. The people employed in the electronics industry utilizing this new technology will be working with increasingly more sophisticated systems, and in order to minimize "downtime," servicing must be performed rapidly and accurately. Technicians assigned to diagnose and repair these systems must be able to think logically and possess a thorough knowledge of the electronics fundamentals employed.

Electronics is considered a somewhat abstract subject because many of its concepts and basic fundamentals cannot be readily observed, but instruction has attempted to illustrate these concepts and basic fundamentals through the use of mathematical equations and calculations. Although research has been conducted on the

troubleshooting process, few if any studies have considered the use of mathematics as a mitigating factor when addressing the troubleshooting efficiency of technicians.

When reviewing the typical programs designed to train students in the fundamentals and theories involved in electronics, mathematics (algebra, trigonometry, and calculus) figures highly in that training, and the success of the student enrolled in that program. However, technicians have reported that the use of mathematics seems to provide little, if any, help in the troubleshooting process.

One purpose of this study was to determine the relationships among community college students' mathematics, electronics, and electronics troubleshooting knowledge. A second purpose of the study was to determine the extent to which combinations of these variables predicted troubleshooting knowledge. More specifically, this study sought answers to the following questions:

1. What relationship exists between the number of mathematics courses taken at the community college and troubleshooting knowledge?
2. What relationship exists between the type of mathematics courses taken at the community college and troubleshooting knowledge?

3. What relationship exists between mathematics knowledge and troubleshooting knowledge?
4. What relationship exists between the number of electronics courses taken at the high school level and troubleshooting knowledge?
5. What relationship exists between the number of electronics courses taken at the community college level and troubleshooting knowledge?
6. What relationship exists between the amount of prior work experience in the electronics field and troubleshooting knowledge?
7. Which combination of variables best tends to predict troubleshooting knowledge?

Research on mathematics and problem solving revealed that mathematics is necessary in teaching the problem solving process. Mathematics instruction provides the student with (a) the ability to interpret, comprehend, and solve everyday problems; (b) the background to reason clearly and apply existing knowledge to new situations; and (c) the necessary assistance in developing proficiency in problem solving.

Problem solving research has revealed that solutions to problems requires complex mental activities that involve interaction between the

problem solver and the problem and a memory that changes with each new experience. Experience, it was revealed, contributes to the refinement and or modification to the reasoning process. Experience organizes the information base for a more efficient use. Experience increases the knowledge base that can be used for the analyzation process, and experience will provide a framework that can be employed in the problem solving process.

With the continued increase in sophistication of electronic equipment several studies were commissioned. The thrust of these studies was (a) to produce troubleshooters who were capable of repairing unfamiliar as well as familiar equipment, (b) to provide intensive troubleshooting experiences, and (c) to reduce the stress on functional equipment. As a result, students participating in these studies generally became much more fluent in the troubleshooting process.

Three instruments were utilized in this study for the collection of data: a Student Data and Information Sheet, a Mathematics Knowledge Test, and a paper and pencil Electronics Troubleshooting Knowledge Test. The purpose of the Student Data and Information Sheet was to gather the demographic information associated with each participant and to help determine what relationship if any exists between the independent and dependent variables associated with this study.

The Mathematics Knowledge Test was employed to ascertain the study participants knowledge of mathematical concepts. The administered math test was a 32-item standardized test designed to cover concepts stressed in elementary, intermediate, and college algebra.

The paper and pencil Electronics Troubleshooting Test was derived from examples taken from an electronics troubleshooting text. The examples were modified to insure clarity and to provide the study participant with four possible responses to each example. The troubleshooting test was field tested with 84 students. It was revealed that the instrument had a KR-20 reliability coefficient of .60 and could discriminate between persons with varying amounts of electronics education.

Multiple regression analysis techniques were utilized to determine the relationships that existed between the selected independent variables, and the dependent variable troubleshooting knowledge. Data obtained from the math test scores revealed that mathematics knowledge had the highest correlation with troubleshooting knowledge of any of the independent variables. This correlation was recorded as $r = .26$ which is considered low (Bartz, 1988).

The second highest correlation revealed through data analysis

disclosed that the correlational strength between the independent variable type of math completed at the community college level and the dependent variable troubleshooting knowledge was $r = .21$. The correlational strength of .21 was again considered low.

The independent variables of the number of math courses taken at the community college level and full time employment in the electronics industry displayed the lowest of all the correlational relationships examined within this study. Statistical analysis revealed these to be nonsignificant relationships of $r = .03$ and $r = .02$ respectively. Of the independent variables utilized in this study, the score on the standardized mathematics test proved to be the only meaningful predictor of troubleshooting knowledge.

Discussion

The largest and perhaps the most difficult task of electronics technicians is that of troubleshooting malfunctioning units or systems. To maintain the system(s) under their care technicians should have a thorough knowledge of the equipment in question and employ a logical approach to locate, isolate, and repair any fault in the equipment's operation.

Since technical troubleshooting is a subset of problem solving,

literature was examined that was related to problem solving in general and across other disciplines or subject areas to help clarify the process of electronic troubleshooting. One such discipline, that of mathematics, is considered indispensable in the education of electronics technicians.

The literature on mathematics revealed that the ultimate end of mathematics instruction was to provide students with the ability to think logically, and to interpret and comprehend problems. Besides providing students with the ability to think logically and to interpret and comprehend problems, mathematics would also supply these individuals with the fundamental skills needed to apply their knowledge to new situations.

The results of this study revealed that troubleshooting knowledge could be predicted with only 6.8% accuracy when using the selected variables as outlined in the study research questions. Of those variables, mathematical knowledge, as related from the standardized math test, was the only one found to have any predictive power. Data obtained from the math test scores revealed that mathematics had the highest correlational strength, $r = .26$, of all the variables associated with the study and the type of math taken (i.e., college algebra, and trigonometry) had the second highest correlational strength of $r = .21$.

The low correlation between mathematics and troubleshooting

knowledge might be attributed to mathematics instruction. Regardless of the curriculum, in most community colleges as well as four year institutions, mathematics is taught as an independent entity. Low correlation strength between mathematics and troubleshooting knowledge might also be attributed to (a) students opting to take mathematics instruction any time during their pursuit of electronics studies, (b) an appreciable time lapse between students' last formal education in mathematics and participating in the study (math skills may have become rusty), and (c) certain subcurriculums of electronics studies may or may not require the math skills as measured by the Mathematics Knowledge Test.

Although mathematics instruction figures highly in the education of electronics technicians, most authors of electronics text books often state that the use of mathematics has been kept to a minimum. It is their belief that although mathematics is important in explaining and illustrating the concepts involved in electronics it is the knowledge one has gained from extended exposure to the fundamental theories in electronics education that is most important and provides the electronics technician with the knowledge base needed for troubleshooting.

It is possible that, if textbook authors believe math should be kept to a minimum, that classroom instructors may also subscribe to that

same belief and only use mathematics when absolutely necessary.

Thus, instructors foster the belief in their students that it is the understanding of electronics fundamentals and the systems involved and not mathematical knowledge that makes one an efficient and effective troubleshooter.

The electronics technician's ability to troubleshoot depends upon his or her store of schemata or the organization of memory elements representing meaningful information pertaining to a general concept. Instruction in the fundamentals of electronics, to a large degree, depends upon the expertise and experiences of those employed to provide the instruction.

The research reviewed has stated that electronics troubleshooting appears to be domain specific. The educational experiences of students as it relates to their electronics instruction could also have been a contributing factor to the low correlational relationships between mathematics and electronics troubleshooting knowledge. Although the basic fundamentals are the same, electronics education can take any of several specialized branches of repair (i.e., audio systems, video systems, computer repair, telecommunications systems, automated systems), and if the students taking part in the study had no prior training experiences with the systems utilized they probably would not be

effective or efficient troubleshooters with unfamiliar systems. Thus it could be concluded that this would hold true for the paper and pencil test that was administered. It may have included unfamiliar electronic systems.

Recommendations

This study was designed to determine the relationships among troubleshooting, mathematics, and electronics knowledge. Additionally, the study focused on determining which combination of variables best tend to predict the students' troubleshooting knowledge.

The findings revealed that, of the variables associated with this study, troubleshooting knowledge could only be predicted with 6.8% accuracy. Additionally, of the variables associated with the study, only one, mathematics knowledge as related from the scores on the math test, could best tend to predict troubleshooting knowledge. Data obtained from the math test scores revealed that mathematics knowledge had the highest correlational strength, $r = .26$, and the type of math taken at the community college had the second highest correlational strength of $r = .21$ of the variables associated with the study.

Although mathematics figures highly in the education of electronics technicians, researchers agree that the goal of technical instruction is to

provide the learner with the knowledge and skills needed in the development of expertise with realistic learning experiences. These experiences should include the use of equipment or system simulators that afford students the opportunities to troubleshoot malfunctioning equipment or systems. Because of the low correlational relationships between the independent and dependent variables associated with this study, and consequently being able to predict troubleshooting knowledge with only 6.8% accuracy it is recommended that this line of inquiry not be continued.

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APPENDIX A

Student Information and Data Sheet

STUDENT INFORMATION AND DATA SHEET

1. SSN or Student Number ___ ___ ___
2. Name of Community College _____
3. Birth date ___month ___day ___year
4. Gender (circle one) Male Female
5. Number of year long electronics courses completed in high school
(Circle one) 1 2 3 4 5 6
6. Number of electronics courses taken while enrolled at this institution. Include courses taken this term
(circle one) 1 2 3 4 5 6 7 8 9 10
7. Number of mathematics courses completed at this institution. Include courses taken this term.
(circle one) 1 2 3 4 5 6 7 8 9 10
8. Name of mathematics courses taken while at this institution. Include courses taken this term.
___Algebra & Trig I ___Algebra & Trig II ___Pre-Calculus
___Calculus I ___Calculus II ___Calculus III
9. Have you ever been employed in the electronics or a related industry?
(circle one) yes no
10. If yes to question nine (9) how long?
Full-time (at least 35 hours per week) ___ Months
Part-time (less than 35 hours per week) ___ Months
11. Did you personally do any electronics or electrical troubleshooting while employed in this industry? (circle one) yes no
12. Was it your responsibility to troubleshoot faulty equipment while employed in this industry? (circle one) yes no
13. Please list your hobbies _____

APPENDIX B

Troubleshooting Knowledge Test

Electronics Troubleshooting Knowledge Test

On the facing page is a block diagram of an A-M Transceiver. This block diagram is composed of six functional units with the signal paths clearly shown between each functional unit. Use this diagram to answer the following questions.

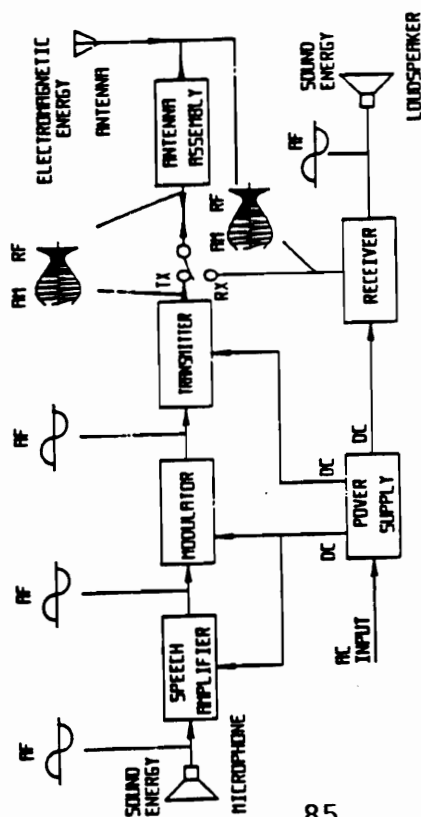
1. From the selections below, which one best describes the information provided by a functional diagram?

- A. This diagram provides a general representation of the major functional units of the equipment as well as their important signal relationships.
- B. This diagram provides test point locations needed for future trouble shooting procedures.
- C. This diagram provides a means for locating the functional units within a piece of electronic equipment.
- D. This diagram provides the means to accomplish all of the above.

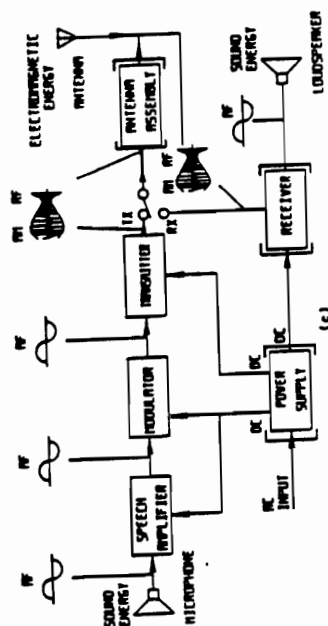
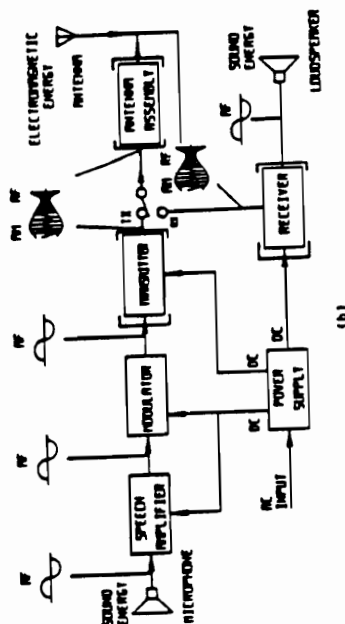
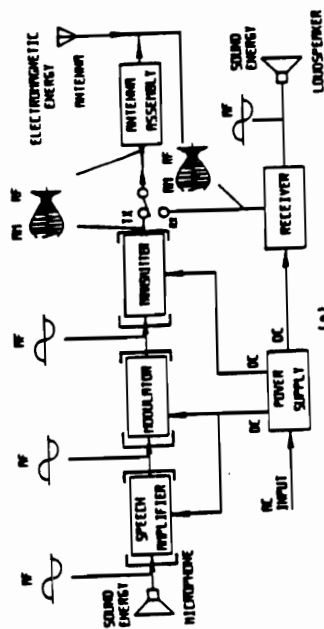
Bracketing provides a means of narrowing the trouble area to a single faulty functional unit to a circuit group and then to a faulty circuit.

2. Which one of the following statements best describes the term bracketing as applied to electronic equipment trouble shooting?

- A. Bracketing is the process of injecting a test signal for evaluating a suspected circuit.
- B. The bracketing process provides a means for testing the input and output of a circuit or a circuit group.
- C. Bracketing is the process by which trouble is pinpointed between a satisfactory input signal and an unsatisfactory output signal.
- D. Bracketing is the process of tracing a signal through a faulty circuit group.



FUNCTIONAL BLOCK DIAGRAM OF AMPLITUDE-MODULATED TRANSCEIVER SET.

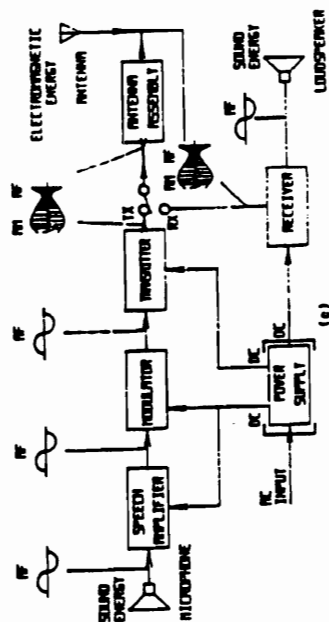
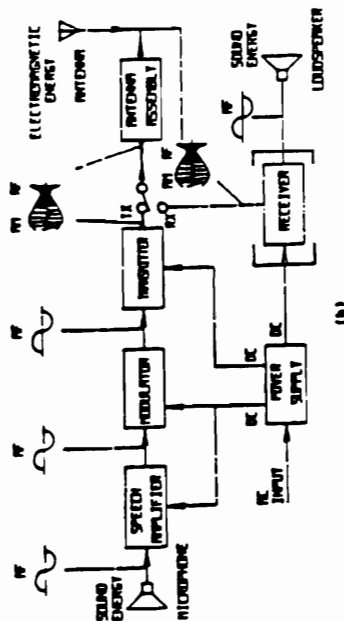
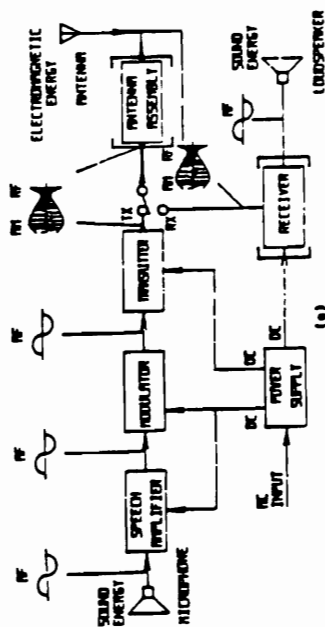


On the facing page is a block diagram of an A-M Transceiver. This block diagram is composed of six functional units with the signal paths clearly shown between each functional unit. Use this diagram to answer the following questions.

Assume that you have found no reception as the trouble symptom for the transceiver. Manipulation of the volume and tuning controls has no effect on the reception condition.

3. Which of the functional units of the transceiver as bracketed could cause the indications? All three units bracketed must cause the indications in order for the selection to be considered correct.

- A. Part A of Figure
- B. Part B of Figure
- C. Part C of Figure
- D. None of the above

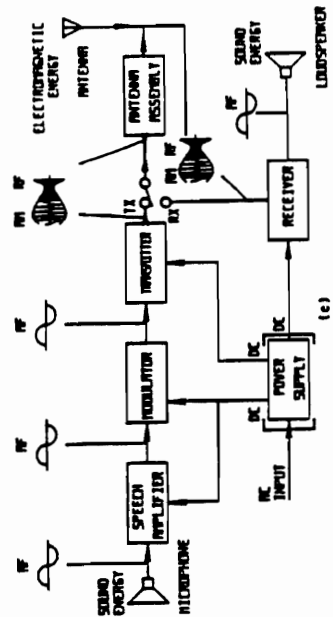
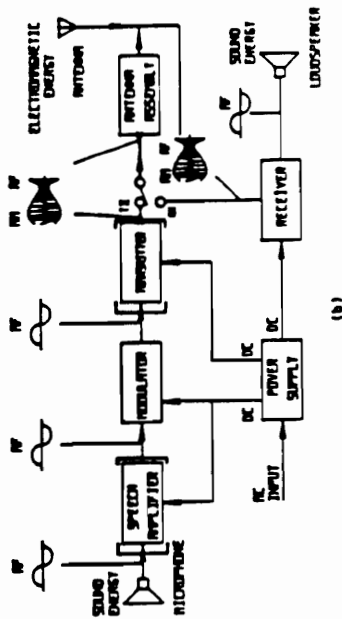
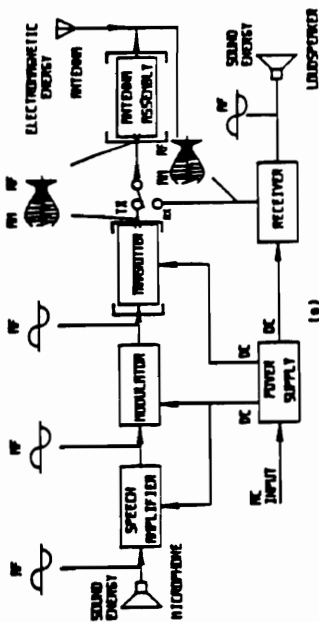


On the facing page is a block diagram of an A-M Transceiver. This block diagram is composed of six functional units with the signal paths clearly shown between each functional unit. Use this diagram to answer the following questions.

4. Assume that the same original symptoms of no signal reception exists. Now, in addition, the receiver tuning control has no effect on the symptom. However, when the receiver volume control is rotated you have a scratching sound in the speaker. You also check the the transmitter and find that all front panel meters provide normal indications.

For the conditions just described, which suspected fault unit or units as bracketed in the figure would you select?

- A. Part A of Figure
- B. Part B of Figure
- C. Part C of Figure
- D. Not enough information provided



On the facing page is a block diagram of an A-M Transceiver. This block diagram is composed of six functional units with the signal paths clearly shown between each functional unit. Use this diagram to answer the following questions.

Again using the transceiver as an example, you are to assume a different trouble exists. The equipment operator reports that, while trying to send a message to another station, he noticed that the indication on the transmitter tuning meter was very low. The operator also kept receiving a message from the other station asking why he was not transmitting. You, as the technician, verify the trouble symptom by operating the equipment yourself. You find that when trying to contact the other station you get no response and the transmitter tuning meter indication is low, just as described by the operator. You try several other frequencies but can contact no one. The monitoring meter on the front panel of the modulator shows the proper modulation on the R-F Carrier Signal. By tuning the receiver over the range, you find you can receive other transmissions perfectly.

5. Which of the selections below brackets the functional unit or units which are probably at fault?

- A. Part A of Figure
- B. Part B of Figure
- C. Part C of Figure
- D. None of the Above

In this section you will be asked to isolate the trouble first to a group of circuits within the functional unit and then to the specific faulty circuit. This process follows the same reasoning you used previously: the continuous narrowing down of the trouble area by making logical decisions and performing logical tests.

6. Which of the selections below best describes the isolation step of the trouble shooting process?
- A. It allows me to isolate the trouble to a group of circuits performing an electronic sub-function.
 - B. It allows me to determine which circuit in the equipment contains the component that must be repaired in order to return the equipment to normal operation.
 - C. It permits me to find the faulty component and perform the repairs which will put the equipment back in operation.
 - D. It allows me to perform all of the tasks listed above.

REPAIRING BLACK CLIPPER FOR RECEIVER UNIT OF
THERM. TRANSMITTER SET.

The diagram illustrates the internal components of a receiver unit, organized into several functional blocks:

- RECEIVER UNIT (Left):** Contains an antenna input, a 1-2 P. AMPLIFIER (B1), a 1-2 P. OSCILLATOR (B1.1), and a 1-2 P. OSCILLATOR (B1.2).
- IF AMPLIFIER (Center):** A dashed box containing a 1-2 P. OSCILLATOR (B1.1), a 1-2 P. OSCILLATOR (B1.2), a 1-2 P. OSCILLATOR (B1.3), and a 1-2 P. OSCILLATOR (B1.4).
- DETECTOR CIRCUIT (Right):** Contains a 1-2 P. OSCILLATOR (B1.1), a 1-2 P. OSCILLATOR (B1.2), a 1-2 P. OSCILLATOR (B1.3), and a 1-2 P. OSCILLATOR (B1.4).
- POWER SUPPLY (Bottom Right):** A dashed box containing a 1-2 P. OSCILLATOR (B1.1), a 1-2 P. OSCILLATOR (B1.2), a 1-2 P. OSCILLATOR (B1.3), and a 1-2 P. OSCILLATOR (B1.4).

Connections are shown between these blocks, with labels such as "1-2 P. OSCILLATOR" and "1-2 P. OSCILLATOR" indicating the type of components used. A "RECEIVER UNIT" label is also present at the bottom left.

In addition, waveforms are given at several test points, numbered star test point symbols represent points which are useful for localizing faulty functional units, and lettered circle test point symbols represent points which are helpful in isolating faulty circuit groups or individual circuits.

7. From the selections below, which one best describes the information provided by the servicing block diagram?

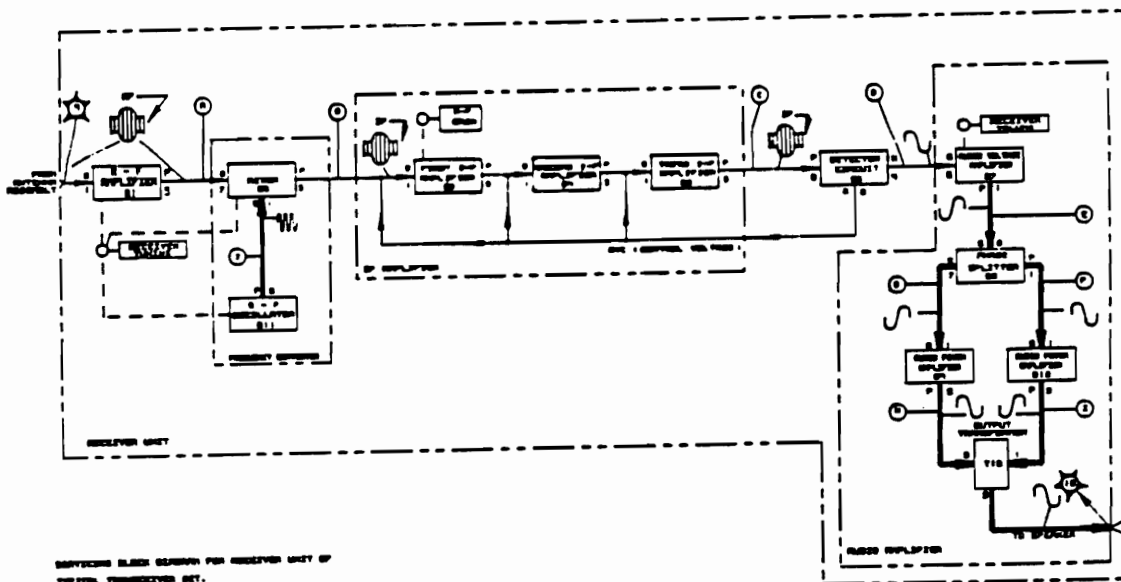
- A. This diagram provides the means for locating the defective circuit group.
- B. This diagram provides a general representation of the circuit groups and individual circuits as well as their signal path relationships, waveforms and test points
- C. This diagram provides the means for locating the defective circuit component.
- D. This diagram provides test point locations needed for future trouble shooting procedures.

8. Which of the following are circuit groups that perform an electronic sub-function? Refer to figure on facing page.

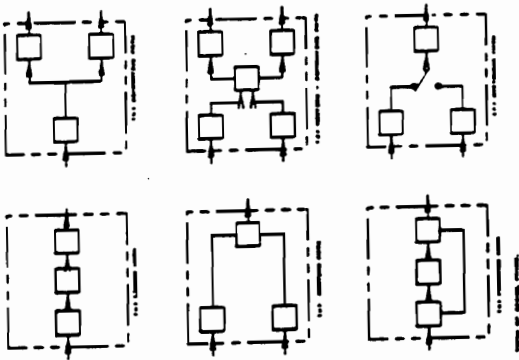
- A. Frequency converter, I-F amplifier, and Audio amplifier.
- B. Frequency converter, Detector, and Audio amplifier.
- C. Receiver tuning, R-F gain, and Receiver volume
- D. Receiver tuning, Detector, and Audio amplifier

9. What are the input and output points for the audio amplifier circuit group on the facing page?

- A. The input is injected at P3 Q6 and the output is obtained at terminal 5 of T10.
- B. The input is injected at G6 of Q7, and the output is obtained at terminal 5 of T10.
- C. The input is injected at G6 of Q7, and the output is obtained at P1 of Q7.
- D. The input is injected at G6 of Q7 and the output is obtained at K7 of Q8



RECEIVER UNIT
SERVICES BLANK SCHEM FOR RECEIVER UNIT OF
TYPE, TRANSMITTER SET.



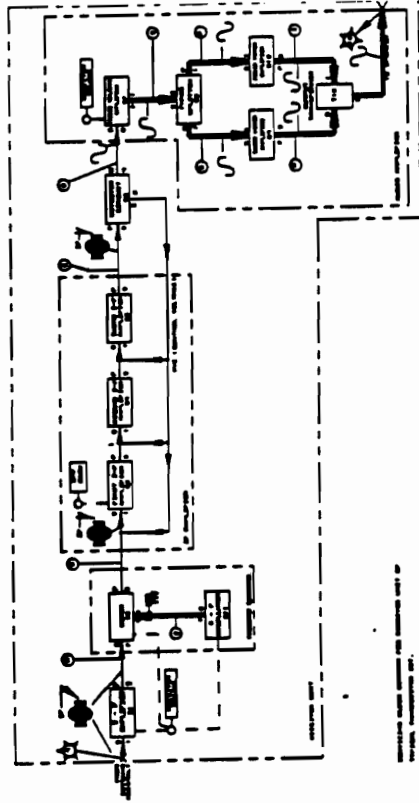
The signals associated with a circuit group normally flows in one or more of four types of signal paths. These circuit paths include the linear, (2) meeting-separating; (3) feedback and (4) switching paths.

The linear path is a series of circuits arranged so that the output of one circuit feeds the input of the following circuit.

The meeting-separating path may be one of three different kinds: meeting, separating, or the combined meeting-separating path. A separating path is one in which two or more signal paths leave a circuit as shown in part B of the figure on the facing page. When two or more signal paths enter a circuit the path is known as a meeting path as shown in part C of the figure on the facing page.

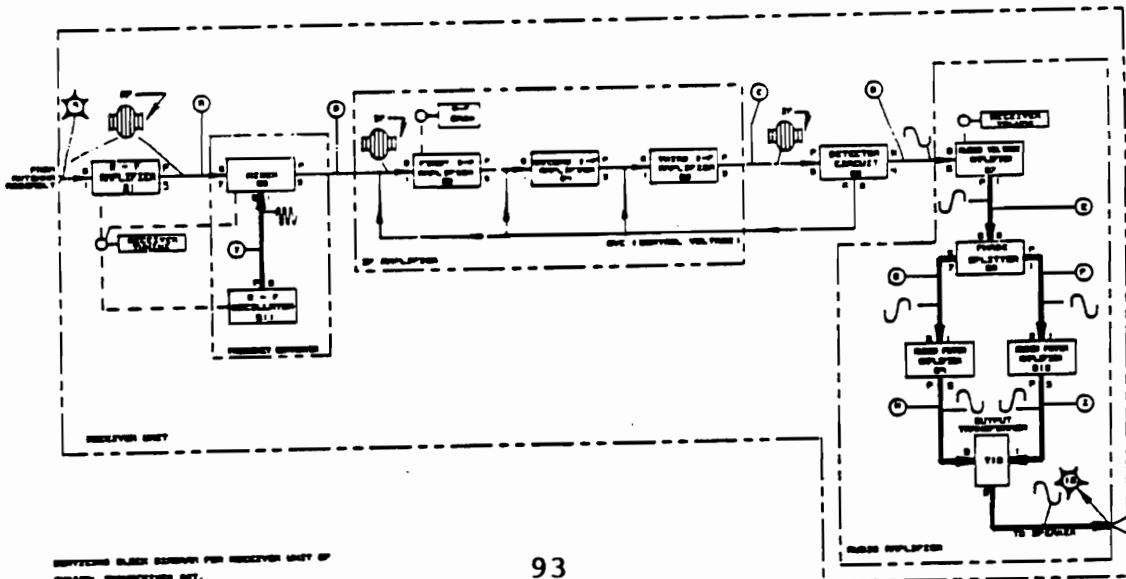
The feedback path is a signal path from one circuit to a point on the circuit preceding it in the signal flow sequence. This is shown in part E of the figure on the facing page.

The switching path contains a selector switch that provides a different path for each switch position. Part F of the figure on the facing page illustrates this type of signal path



10. Now refer to the servicing block diagram on the receiver section of the transceiver on the facing page. What type of signal path is represented in the I-F amplifier circuit group?

- A. Linear path
- B. Feedback path
- C. Meeting path
- D. Meeting-separating



11. Again referring to the servicing block diagram on the facing page and the figures on the types of signal paths which of the following represents meeting paths?

- A. Detector and phase splitter
- B. First, second and third I-F amplifier
- C. Mixer and output transformer
- D. R-F amplifier and mixer

Signal tracing is accomplished by examining the signal at a test point with an oscilloscope, volt-ohm meter, digital volt meter ect.

Signal substitution is accomplished by injecting an artificial signal (from a signal generator, sweep generator ect.) into a circuit to check its performance.

Assume now that the trouble in a transceiver is localized to the receiver unit; that is there is a normal signal from the antenna assembly at star test point 9 (see figure on facing page), but no signal is heard from the speaker. An oscilloscope connected to circle test point C indicates that there is no signal at that point. The oscilloscope connection is then moved to test point B where a normal signal is observed.

12. Which of the following best describes this process?

- A. Signal tracing
- B. Signal substitution
- C. A combination of A and B
- D. Checking oscilloscope operation

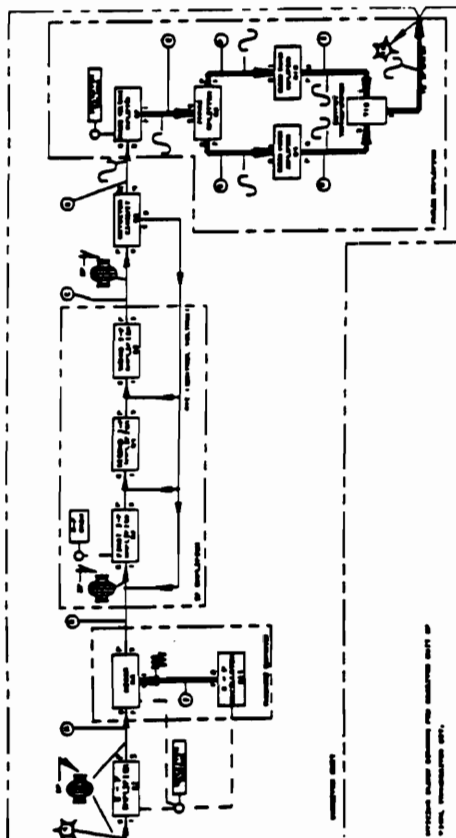


FIGURE 1-10. Receiver circuit diagram.

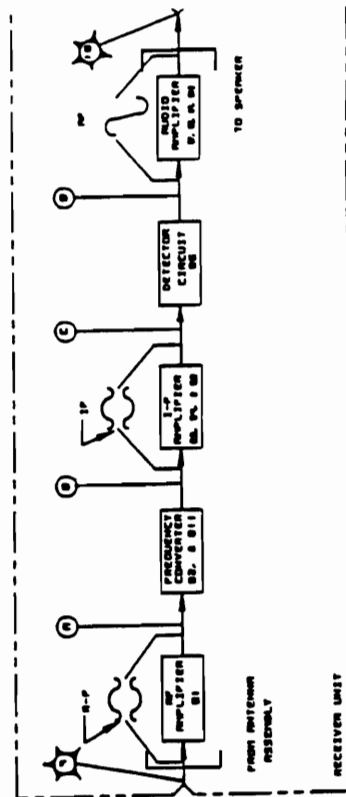


FIGURE 1-11. Simplified servicing block diagram of receiver unit illustrating linear signal path of received signal through circuit groups.

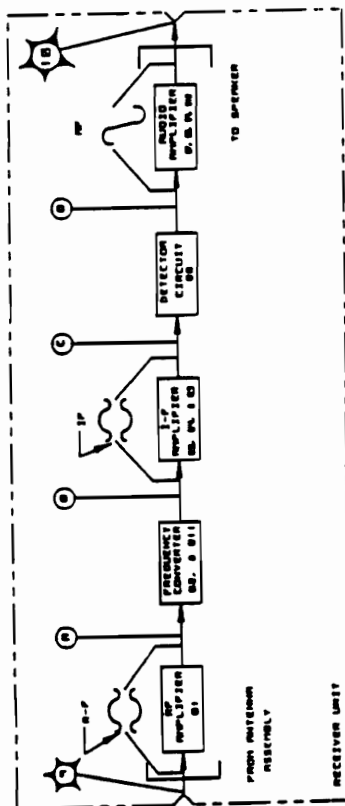
Assuming the same receiver to be the defective unit, a signal generator now used as an artificial signal source is connected to test point C, and no signal is heard from the speaker. The signal generator is then connected to test point D, and a signal is heard from the speaker at this time.

13. Which of the following best describes this process?

- A. Signal Tracing
- B. Signal Substitution
- C. Both A and B
- D. None of the above

The split - half technique is based on the concept of simultaneous elimination of the maximum number of circuit groups or circuits with any test. Stated another way, the half - split technique will isolate the trouble to a single circuit group or circuit in a minimum of test.

The block diagram shown on the facing page is a simplified version of the receiver servicing block diagram used earlier. The simplified servicing block diagram illustrates the linear signal path of the received signal through the receiver unit by showing the circuit groups consolidated into single blocks. The brackets placed at test point 9 (normal signal input) and test point 10 (abnormal signal output) depict the trouble being localized to the receiver unit. The problem is to isolate the trouble to one of the circuit groups in the linear signal path.



SIMPLIFIED SCHEMATIC DIAGRAM OF RECEIVER UNIT ILLUSTRATING LOCATION SIGNAL TEST POINTS OF RECEIVER STAGES, INCLUDING CIRCUIT GROUPS

14. Considering the concept of the half - split technique and the preceding information describing the simplified servicing block diagram. Where in the receiver should the first test be made in order to isolate the trouble?

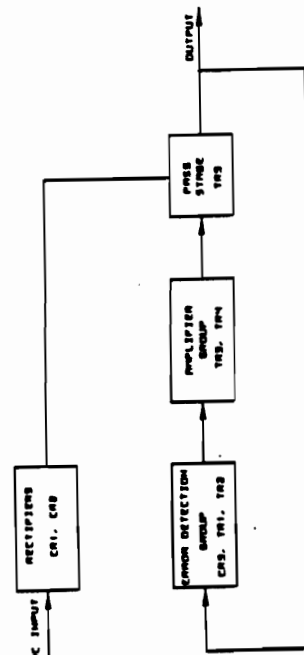
A. Test point A
B. Test point B
C. Test point C
D. Test point D

15. An oscilloscope connected to test point C reveals an abnormal signal. Where in the receiver should the next signal tracing test be made? Refer to the previous diagram.

A. Test point A
B. Test point B
C. Test point C
D. Test point D

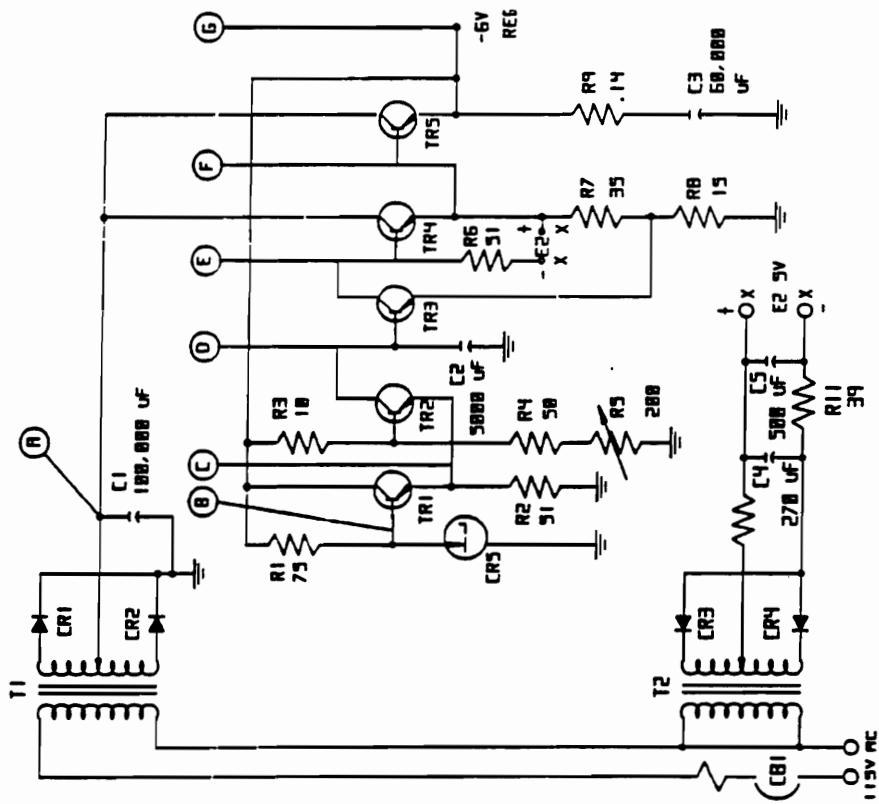
This problem concerns a transistor power supply which functionally looks like the block diagram on the facing page. The rectifiers provide a pulsating d-c voltage to the Pass Stage, which passes the high current output. Part of the output is fed back to the Error Detection Group. The Error Detection Group is a bridge circuit which compares the feedback signal with a constant reference voltage and then supplies a corrected input to the Amplifier Group then drives the Pass Stage amplifying the corrected signal.

The Error Detection Group and the Amplifier Group are part of a feedback loop. A change at any point in the feedback loop is reflected throughout the whole feedback network.



96

- A. Check the voltage at test point D
- B. Check the voltage at test point F
- C. Break the feedback loop
- D. Check the voltage at test point E



SCHEMATIC DIAGRAM OF TRANSISTOR POWER SUPPLY.

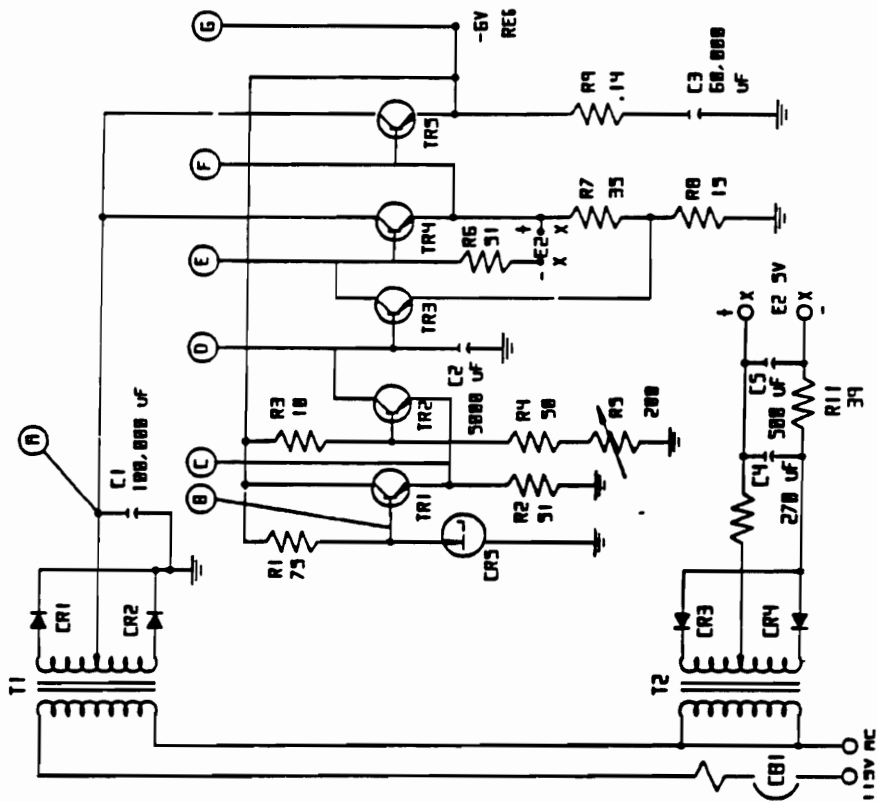
19. If the feedback loop is broken, where should it be done?
 - A. At test point G
 - B. At test point R₃
 - C. At test point R₁
 - D. At test point E

20. After breaking the feedback loop, a negative 6volt d-c signal is connected to the feedback line. What test point should be checked first?
 - A. Test point C
 - B. Test point D
 - C. Test point E
 - D. Test point G

21. Is the trouble located before or after this point?

Chose the most correct answer.

 - A. Before test point D
 - B. After test point D
 - C. Before test point E
 - D. After test point E



SCHEMATIC DIAGRAM OF TRANSISTOR POWER SUPPLY.

Refer back to the schematic diagram of the transistor power supply for the following questions.

22. Where will you make the next test?

- A. At test point E
- B. At test point F
- C. At test point D
- D. At test point C

23. What would be the next test?

- A. Emitter to ground resistance
- B. Resistance check at R₉
- C. Replace TR₅
- D. Replace TR₃

The arithmetic element in a binary computer performs addition or subtraction but not both. There is little difference between an adder and subtractor circuit: the half adder sum and half subtractor difference are one and the same. The figure on the facing page is a logic diagram of a half adder circuit. A 1 input at either A or B will produce a 1 output at S. If a 1 or 0 input is provided at A and B at the same time, a 0 output appears at S. Like inputs produce a 0 output, and unlike inputs produce a 1 output.

A 1 input at A would trigger inhibitor G1 but would block any action in inhibitor G2. A 1 input at B would trigger inhibitor G2. A 0 input at either A or B would be the same as no input.

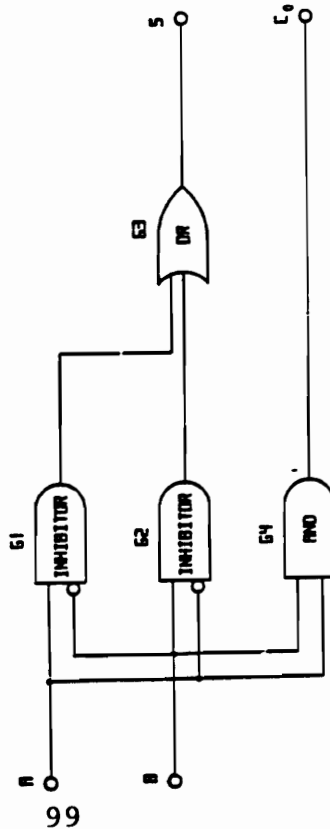
The OR gate G3 will produce an output when any one input is applied. The AND gate G4 requires that all inputs be present simultaneously to provide an output.

Truth tables are used to describe the operation of logic circuits. The following table describes the operation of the half adder circuit.

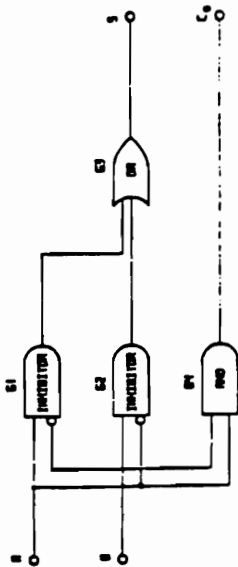
Input A	Input B	S output	C ₀ Output
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

The cost of computer time is expensive. It is important to keep "down time" to a minimum. The troubleshooting procedure is modified. The technician normally locates and replaces the circuit board containing the trouble. Once that has been done the computer can then return to operation. The faulty board can be repaired when time permits.

The tag on a faulty board reads "1,0 = 0". This means that a 1 input at A and a 0 input results in 0 at S. According to the truth table the output should be a 1. The output is normal for all other inputs.



LOGIC DIAGRAM - HALF ADDER.



LOGIC DIAGRAM - WUJ NO. 100.

24. From the preceding information and referring to the figure on the facing page and the truth table. What functional unit contains the trouble?

- A. G1 and G2
- B. G1 and G3
- C. G2 and G3
- D. G4

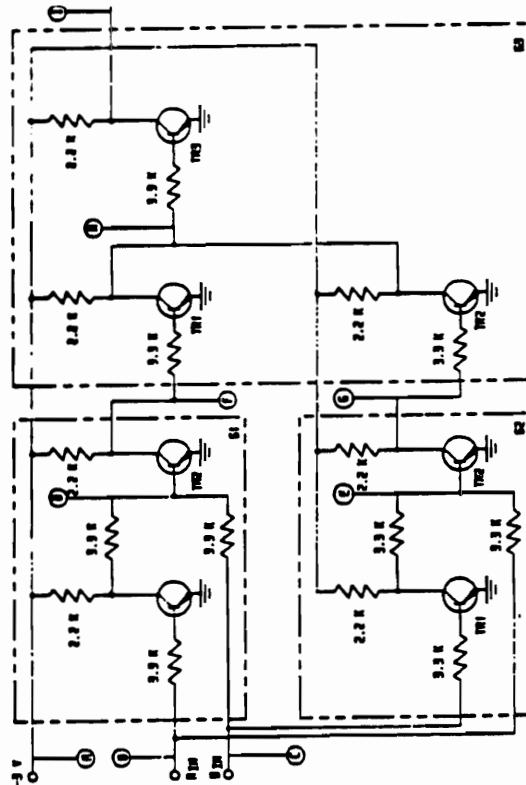
The other figure on the facing page is a schematic diagram of the summing circuits utilized earlier. There are no controls to operate. The next step is a signal check. To make a signal check an input must be injected into the logic circuit.

25. What test point should be checked first?

- A. Test point G
- B. Test point F
- C. Test point D
- D. Test point H

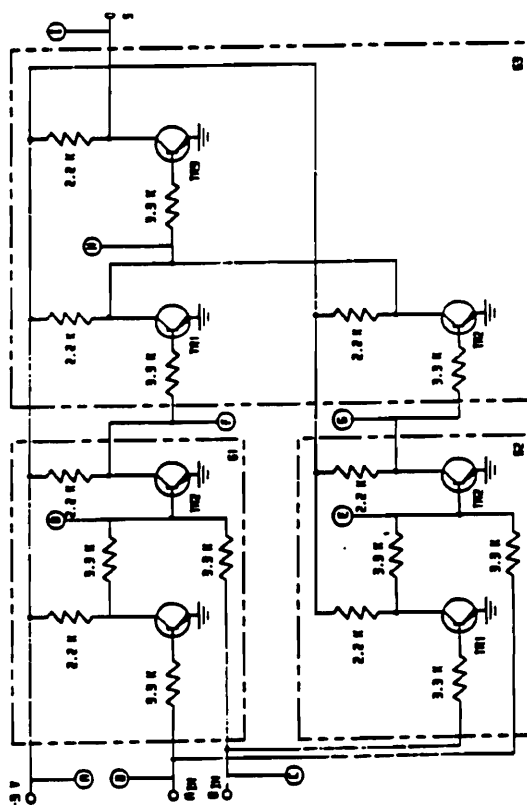
26. Which functional unit contains the trouble?

- A. G1
- B. G3
- C. G2
- D. Not enough information



SCHEMATIC DIAGRAM - SUMMING CIRCUIT.

27. What is the next step to be performed?
- Check signal at test point H
 - Check signal at test point I
 - Check signal at test point G
 - Check signal at test point D
28. What is the next step to be performed?
- Check signals at TR₁
 - Check voltage at TR₁
 - Make resistance checks
 - Make current checks
29. When a signal is applied at A the base voltage changes but the collector voltage remains the same. What conclusion should be reached?
- The collector resistor is bad
 - The base resistor is bad
 - The transistor is bad
 - The components must be checked



SCHEMATIC DIAGRAM - SUPPLY CIRCUIT.

Appendix C

Frequency Distribution of Sample

Frequency Distribution of the Sample (N = 100)

Variable	Frequency
Sex	
Male	92
Female	8
Age	
18 - 24	50
25 - 31	17
32 - 38	22
40 - 52	11

Appendix D

Background Characteristics of Sample

Background Characteristics of Sample

Variable	Frequency	%
Math Courses Taken at Community College		
No Math Courses Taken	17	17.0
Algebra & Trig I	27	27.0
Algebra & Trig II	14	14.0
Pre-Calculus	40	40.0
Calculus I	---	---
Calculus II	2	02.0
Number of High School Electronics Courses Taken		
0	83	83.0
1	14	14.0
2	2	02.0
3	1	01.0
Number of Community College Electronics Courses Taken		
1	6	06.0
2	13	13.0

(table continues)

Variable	Frequency	%
Number of Community College Electronics Courses Taken		
3	6	06.0
4	22	22.0
Number of Community College Electronics Courses Taken		
5	12	12.0
6	6	06.0
7	8	08.0
8	3	03.0
9	24	24.0
Previous Employment in Electronics Industry		
No	73	73.0
Yes	27	27.0
Troubleshooting Experience		
No	78	78.0
Yes	21	21.0

(table continues)

Variable	Frequency	%
Troubleshooting as a Responsibility		
No	81	81.0
Yes	18	18.0

APPENDIX E

Zero Order Correlations Among Variables

Zero Order Correlations Among Variables

	1	2	3	4	5	6	7	8
1. Math Knowledge		.26	-.05	.22	.02	.22	.11	.03
2. Troubleshooting			-.16	.16	.03	.21	.02	.05
3. High School Electronics				-.14	-.15	-.14	.06	.02
4. College Electronics					.29	.26	.03	.21
5. Number of College Math Courses						.67	.30	.03
6. Type of Math							.04	.19
7. Full Time Employment								.01
8. Parttime Employment								

Appendix F

Request to use Mathematics Placement Test and Reply

603 Woodlake Drive
Greensboro, N. C. 27406
February 25, 1991

Dr. John Harvey, Chair
Committee on Test
Department of Mathematics
University of Wisconsin
480 Lincoln Drive
Madison, Wisconsin

Dear Sir:

This letter is to request permission to use the **Mathematics Placement Test A/3B** copyrighted 1978 in a doctoral dissertation at Virginia Polytechnic Institute and State University, located in Blacksburg Virginia as a partial fulfillment of an Ed D degree in Vocational Technical Education.

As you may be aware there is a growing need for electronics technicians who are proficient in the theories and fundamentals associated with electronics. In order to become proficient, student technicians are instructed in electronics technology, and the use of mathematics figures highly in that instruction.

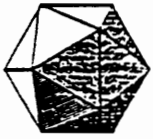
The overall purpose of this study is to determine and examine those relationships that may exist between troubleshooting electronic equipment, which is a major responsibility of the electronics technicians, and mathematical knowledge.

If permission is granted I am willing to abide by all stipulations that may be imposed on my using your placement test as a part of this study.

Thank you for your time and consideration.

Respectfully yours,

Guy Loftin



The MATHEMATICAL ASSOCIATION of AMERICA

COMMITTEE ON TESTING

John G. Harvey, Chair ■ Department of Mathematics ■ University of Wisconsin ■ 480 Lincoln Drive ■ Madison, Wisconsin 53706-1388
(608) 262-3744 & 263-7268 FAX: (608) 238-3811 e-mail: harvey@math.wisc.edu

June 17, 1991

Mr. Guy Loftin
603 Woodlake Drive
Greensboro, NC 27406

Dear Mr. Loftin:

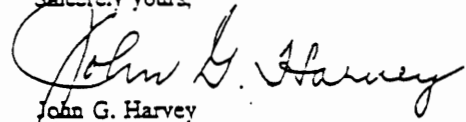
I am responding to your letter of April 25, 1991 in which you request permission to use data generated by administering the MAA Placement Testing Program *Mathematics Test A/3B*. On behalf of the MAA Committee on Testing I grant you to use this test to gather data for your dissertation. However, some conditions must be met; those conditions are:

1. A copy of *Mathematics Test A/3B* may not be included in your dissertation. This condition is imposed in order to maintain security of the test.
2. An original photocopy of your dissertation must be sent to the MAA upon completion of your degree. This dissertation should be sent to: Ms. Linda Heineman, COT Coordinator, Mathematical Association of America, 1529 Eighteenth Street, Washington, DC 20036.

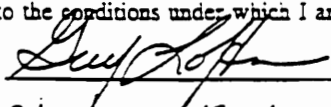
If you agree to these conditions, please sign the copy of the letter I am enclosing and return it to me.

I cannot send you the descriptive data on the test that you requested. Since placement testing programs are programs of individual colleges and universities, we have not generally collected data of the kind you request since national norms are not needed.

Sincerely yours,


John G. Harvey
Chair

I agree to the conditions under which I am permitted to use *Mathematics Test A/3B*.

Signed: 

Date: 21 June 1991

APPENDIX G

Request to use examples from Electronic Troubleshooting Text by Philco
and Replies

603 Woodlake Drive
Greensboro, N. C. 27406
September 20, 1990

Copyrights and Permissions Department
Prentice-Hall, Inc.
Englewood Cliffs, N.J.

Dear Sir or Madam:

This letter is to request Prentice-Hall's permission to use the enclosed document in a doctoral dissertation at Virginia Polytechnic Institute and State University, located in Blacksburg Virginia as a partial fulfillment of an Ed. D degree in Vocational Technical Education.

As you may be aware there is a growing need for electronics technicians who are proficient in the theories and fundamentals associated with electronics. In order to become proficient, student technicians are instructed in electronics technology, and the use of mathematics figures highly in that instruction.

The overall purpose of this study is to determine and examine those relationships that may exist between troubleshooting electronic equipment, which is a major responsibility of the electronics technicians, and mathematical knowledge.

The enclosed document was derived from examples provided in the text **Electronic Troubleshooting** by Philco Technical Institute published in 1966. It is believed by this researcher that the examples provided by this text, with minor modifications, are still applicable to the instruction provided in the electronics programs of today, and will provide the data necessary to discriminate between the various levels of troubleshooting knowledge possessed by the participants in the study.

Thank you for your time and consideration.

Respectively,

Guy Loftin

603 Woodlake Drive
Greensboro, N.C. 27406
January 31, 1991

Mr. Glenn E. Hall, Permissions Editor
College Book Division Prentice Hall Building
Englewood Cliffs, NJ 07632

Dear Sir:

Please find enclosed not only a copy of your reply, dated 10/16/1990, to me concerning my request to use copyrighted material from the text **Electronic Troubleshooting** by the Philco Technical institute but also a copy of the Electronics Troubleshooting test derived from examples taken from said text.

For ease of identification of the quotes and a listing of the pages on which they appear I have taken the liberty to mark each page of the troubleshooting test with the pages on which the quotes and schematics appear from the Philco Electronic Troubleshooting text.

Thanks again for your time and consideration.

Respectfully yours,

Guy Loftin



P R E S E N T S H A L L

COLLEGE BOOK DIVISION

Date: October 16, 1990

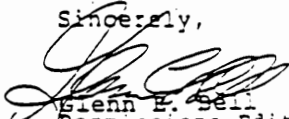
TO: Mr. Guy Lofton

RE: ELECTRONIC TROUBLESHOOTING by Philco Technical Institute
(Your letter of 09/20/90)

We are unable to reply to your request to reprint material from the above title because:

- ☒ The information included in your request is incomplete; Please provide us with:
 - ☐ the page number and/or illustration/figure number from our publication.
 - ☒ a listing of the quotes you wish to use and the pages on which they appear (we cannot grant "blanket" permission).
 - ☐ the date of publication and correct title/edition of the book from which the intended material is taken (please send us photocopies of the title and copyright pages also).
- ☐ Prentice-Hall no longer holds the rights to this title. Your request should be directed to:
- ☐ The material requested is not original with our author(s). For permission to reprint, please write directly to:

Sincerely,


Glenn E. Bell
Permissions Editor

9.5/20918



P R E N T I C E H A L L

Simon & Schuster Education Group
113 Sylvan Avenue, Route 9W
Englewood Cliffs, NJ 07632
201-582-2000

College Division

September 20, 1993

Guy Loftin
603 Woodlake Dr.
Greensboro, NC 27406

Dear Mr. Loftin:

We are glad to give you permission to reprint material from
our text(s),
ELECTRONIC TROUBLESHOOTING by Philco Technical Institute,

in accordance with the conditions outlined in your letter
of 1-31-91. For use in your doctoral dissertation.

Please give credit to our material as follows:
Philco Technical Institute, ELECTRONIC TROUBLESHOOTING,
©1966, pp.--. Reprinted by permission of Prentice-Hall,
Englewood Cliffs, New Jersey.

Sincerely,


Michelle Johnson
Permissions Editor

APPENDIX H

Replies to use North Carolina Community Colleges in Study



DEPARTMENT OF COMMUNITY COLLEGES

NORTH CAROLINA STATE BOARD OF COMMUNITY COLLEGES

200 W. JONES STREET

RALEIGH, NC 27603-1337

ROBERT W. SCOTT
STATE PRESIDENT

919-733-7051

April 17, 1991

Mr. Guy Loftin
603 Woodlake Drive
Greensboro, NC 27406

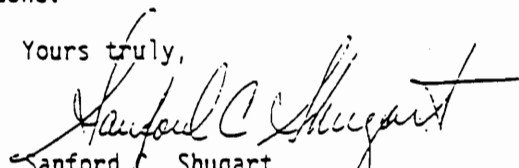
Dear Mr. Loftin:

President Scott has asked me to respond to your letter of April 1. You have requested our consent for you to conduct a study involving students enrolled in electronics technician programs in the N. C. Community College System.

While we have no objections to your study, be advised that we cannot consent to your study on behalf of the colleges in the system. Each college offering the program would have to agree to the terms of your study and provide whatever information you might require. I have attached a copy of our Education Chart which lists the colleges authorized to offer electronics and other curriculums. Mailing addresses for each college can be found in the back of the Chart.

Best wishes for your dissertation research. We will be interested in your findings when the work is done.

Yours truly,


Sanford C. Shugart
Vice President for Programs

SCS/jw

pc: The Honorable Robert W. Scott
Luby Weaver
Mike Pittman



GUILFORD TECHNICAL COMMUNITY COLLEGE

May 7, 1991

Mr. Guy Loftin
603 Woodlake Drive
Greensboro, NC 27406

Dear Mr. Loftin:

You have my support and authorized permission to use selected students enrolled in our Electronics Engineering Technology program in your doctoral study at Virginia Polytechnic State University.

Good luck in your studies.

Sincerely,

A handwritten signature in black ink, appearing to read 'John Meyer', written in a cursive style.

John Meyer
Dean, Technical Education

JM:jc

APPENDIX I

**Sample Letter Requesting Individual to Serve on Panel of Experts and
Replies**

603 Woodlake Drive
Greensboro, N.C. 27406
September 26, 1990

Dr. John Foster, Chairman
Department of Electrical Engineering
North Carolina A&T State University
Greensboro, N.C. 27411

Dear Sir:

This letter is to request that you serve as a member on a panel of experts for the enclosed instrument which was developed for a doctoral dissertation at Virginia Polytechnic and State University. The enclosed document was derived from examples provided in the text **Electronic Troubleshooting** by Philco Technical Institute published in 1966. The overall purpose of this study is to determine and examine those relationships that may exist between troubleshooting electronic equipment, which is a major responsibility of the electronics technicians, and mathematical knowledge.

As you may be aware there is a growing need for electronics technicians who are proficient in the theories and fundamentals associated with electronics. In order to become more proficient, student technicians are instructed in electronics technology, and the use of mathematics figures highly in that instruction.

It is believed by this researcher that the examples provided within this document are still applicable to the instruction received by student technicians in the electronics programs of today and are good measures of that instruction. It is also my thought that through your experience/expertise in electronics and education you may provide additional insights as to how this instrument may be more efficient and measure troubleshooting knowledge.

I would appreciate you returning the enclosed document and your response(s) by the 25th of January, 1991. Thank you in advance for your time and consideration.

Respectfully yours,

Guy Loftin

VIRGINIA TECH

Virginia Polytechnic Institute & State University

Division of Vocational &
Technical Education

Technology Education
144 Smyth Hall
(703)231-6480
FAX (703)231-4188

College of Education
Blacksburg, VA 24061-0432

January 28, 1991

Guy Loftin
603 Woodlake Drive
Greensboro, NC 27406

Dear Guy:

Thank you for your recent letter and proposal for the instrument to possibly be used on your doctoral dissertation. I reviewed the "trouble shooting knowledge test" which you sent me and found it to be still appropriate even though the material was produced in 1966 by Philco Technical Institute. There are some procedural questions that I need to ask you before I can give you a full answer on whether the instrument would be useable for your dissertation. These questions are:

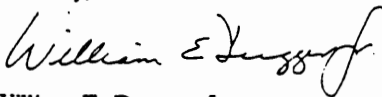
1. Could you give me a brief statement of the problem which you want to pursue?
2. What research questions are relevant to your study?
3. What research design do you plan to utilize in conducting your study? (i.e., number of students, research methodology, type of experimental design or other research technique to be used, validation procedures, etc.)

I believe it would be more helpful if you would go ahead and do a rough draft of chapter one and let me look at that before I get into the details of the test instrument to possibly be used in your dissertation. Maybe you already have this. If so, if you could send it to me it would be very helpful. Also, the last question above deals more specifically with chapter 3 and I think there are a lot of questions that I need answered in this area.

I trust you will understand my hesitation to give you more specific advice on the trouble shooting knowledge test. However, I believe that the above questions need to be answered first.

I look forward to hearing from you soon.

Sincerely,



William E. Dugger, Jr.
Professor & Program Leader
Technology Education

Mr. Loftin,

These are my comments on your study.

- It seemed to be well thought out and planned.
- The examples you selected were good.
- There was good variety and coverage.
- I think it would be better if all the concepts you introduced were included in a paragraph before the questions, and not between questions (ex: questions 1-3).
- In several places references were made to shales or dark lines (dashes) on the diagrams, but I was unable to distinguish them (ex: question = 7).
- In questions 2-5, the use of the symbols [and] should be introduced before use in the diagram.
- Perhaps to better simulate trouble shooting, diagrams and associated information could be placed in a separate booklet (from the questions). This could be a mock manual with an index.
- In some cases you refer to a diagram as "previ" or "facing." I think it would be better to number them and refer to each by its number.
- In general I feel ~~in~~ use this study will be a good gauge of trouble shooting skills.

Good Luck

Joe Ferguson

North Carolina Agricultural
and Technical State University
Greensboro, N.C. 27411

A&T

Electrical Engineering Dept.
551 McNair Hall
919/334-7760

January 18, 1991

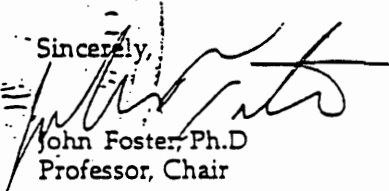
Mr. Guy Loftin
603 Woodlake Drive
Greensboro, NC 27406

Mr. Loftin:

I received your material describing the electronic trouble shooting manual and have had the time to consider the invitation to serve on a panel of experts for your review. After much consideration I must inform you that I cannot serve on the panel. My decision is based upon not having the time to accept additional responsibilities at this point.

Thank you for your consideration. I wish you all the success towards finishing your doctoral degree.

Sincerely,



John Foster, Ph.D
Professor, Chair

VITA

Guy L. Loftin

Home Address

603 Woodlake Drive
Greensboro, NC 27406
Telephone: (910) 273-7178

Educational Background

Virginia Polytechnic Institute and State University
Blacksburg, VA

Doctor of Education (Ed.D) - Vocational and Technical Education
1994

Virginia Polytechnic Institute and State University
Blacksburg, VA

Certificate of Advanced Graduate Study - Vocational and Technical Education
1989

North Carolina Agricultural and Technical State University
Greensboro, NC

Master of Science - Educational Media
1975

North Carolina Agricultural and Technical State University
Greensboro, NC

Master of Science - Industrial Arts Education
1973

North Carolina Agricultural and Technical State University
Greensboro, NC

Bachelor of Science - Vocational Industrial Education [Electronics]

Professional Experience

1992 - Present Dean, Technical Preparation (Tech Prep), Guilford

Technical Community College, Jamestown, NC.
Responsible for initiating and coordinating articulation between similar secondary and post secondary vocational/technical education programs; liaison with public school systems; diagnose present and projected needs of employers, educators, and students to develop relevant articulated curricula.

- 1991 - 1992 Vocational Teacher [Electronics Instructor/Tech Prep and Gender Equity Coordinator], Durham City Schools, Durham, NC. As Tech Prep coordinator responsible for establishing working articulation agreements with the local community colleges; develop and coordinate efforts between administration, classroom teachers, community college teachers, and business representatives in designing curriculum matrix for the Tech Prep initiatives. As Coordinator for Gender Equity Program responsible for the recruitment of students for summer program; provide students with experiences and orientation to non-traditional vocational programs, and an increased awareness of high technology career fields. As Electronics Teacher responsible for the recruitment of students and the establishment of an electronics program within the city school system.
- 1980 - 1991 Instructor of Electronics, North Carolina Agricultural and Technical State University, Greensboro, NC. Responsible for the instruction of students in the basic fundamentals of electronics technology; developed independent study course involving CAD system designed for constructing printed circuit boards; Chair, Curriculum Committee; Chair, Recruitment Committee; Freshman Academic Advisor; Member, Library Building Committee; Member, Faculty Senate, and faculty advisor for the Society of Manufacturing Engineers.
- 1979 - 1980 Interim Director, University Television Studio, North Carolina Agricultural and Technical State University. Administered budget; prepared equipment proposals; supervision of personnel; faculty consultation on the use, types, and effects of media aids on the learner; equipment purchase

consultation; conducted workshops; individual and group instruction; developed scripts for filmstrips and video productions.

- 1972 - 1979 Electronics Technician III, University Television Studio, North Carolina Agricultural and Technical State University, Greensboro, NC. Supervision of personnel; operation, repair, and maintenance of audio and video equipment; equipment purchase consultation; individual and group instruction on the use of video equipment in educational and commercial situations; preparation of graphics utilized during production of instructional programs; conducted workshops on writing scripts for filmstrips and video productions.
- 1970 - 1972 Engineering Associate, Western Electric Inc., Greensboro, NC. Responsible for the construction of manpower and manhour reports; consultation with and some supervision of draftpersons preparing finished engineering drawings; telephone and personal contact/consultation with Army Corps of Engineers concerning job specifications for projects; design and construction of AC power systems; preparation of job and material estimates.

Professional and Community Activities

Member, American Vocational Association

Member, National Tech Prep Network

Member, North Carolina Association of Community College Instructional Administrators

Vice President Church Council, Prince of Peace Lutheran Church, Greensboro, NC

Member, American Legion Post # 107

AWARDS

Certificate of Appreciation (1991-1992)
Student Assistance Program, Durham City Schools

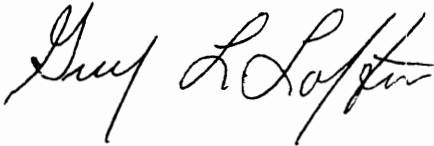
Teacher of the Year (1990-1991)
School of Technology, North Carolina Agricultural and Technical State
University

Inducted in Omicron Tau Theta Honor Fraternity (1989)

Inducted into Epsilon Pi Tau Honor Fraternity (1988)

Freshman Advisor of the year (1987-1988)
School of Technology, North Carolina Agricultural and Technical State
University

Educator of the Year (1986-1987)
School of Technology, North Carolina Agricultural and Technical State
University

A handwritten signature in black ink, reading "Gary L. Laffer". The signature is written in a cursive style with a large, stylized "G" and "L".