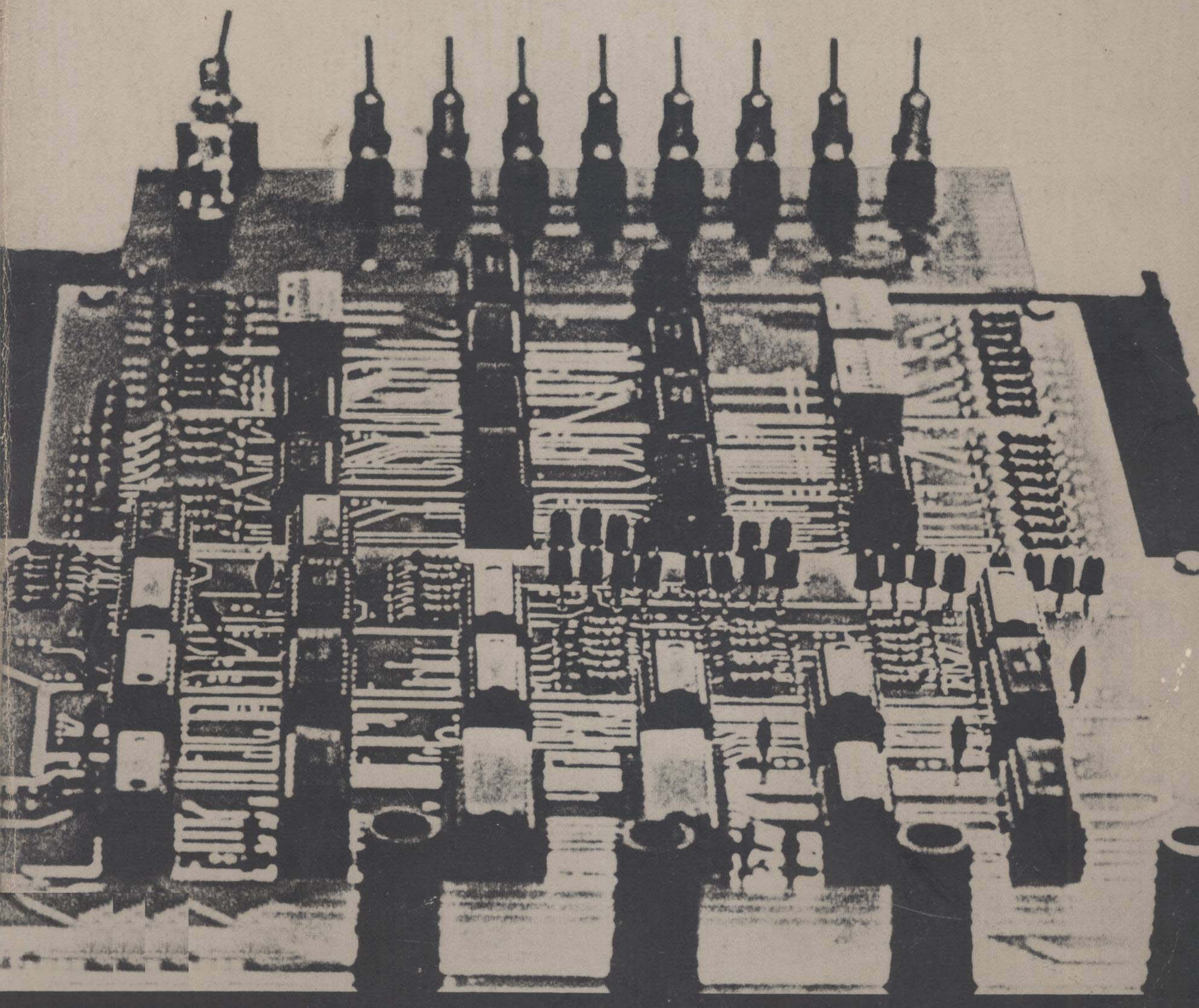
LABORATORY EXPERIMENTS FOR MICROPROCESSOR SYSTEMS



JOHN CRANE

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John Crane

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PREFACE

This laboratory manual is written to provide an introduction to microprocessors. It covers hardware details and relationships of the basic elements that make up a typical microprocessor system. Because of its popularity, the 8080 was chosen as the microprocessor to guide the writing details of each experiment. Designed to follow and implement James W. Coffron's UNDERSTANDING AND TROUBLESHOOTING THE MICROPROCESSOR, the experiments in this manual are written around topics and functions that are typical of all microprocessor systems. This approach makes the experiments suitable for use in any hardware-oriented laboratory on microprocessor systems, regardless of the textbook that may be used to provide essential lecture and theory material.

The recent spectacular growth in numbers and applications of microprocessor-based digital systems has brought a new urgency to understanding exactly how such systems work. For those who will deal with these systems on a hardware level the foremost question is, "How do I learn what I need to know about microprocessor systems in order to work with them?"

This question must be answered on two levels: First, the theory level and, second, the practical hardware level. Usually, a textbook is selected to cover the theory of organization of microprocessor systems, elements that make up the system, how they relate to each other functionally, and how to program the system in order to use it. Such a procedure is useful as far as it goes, but it cannot and does not satisfy the needs of the troubleshooter, the technician, or anyone who must deal with microprocessor systems on a practical hardware level. Here, hands-on experience with hardware itself is an absolute essential: there simply is no satisfactory substitute. This laboratory manual has been carefully designed and written to meet this need.

ORGANIZATION OF THIS LABORATORY MANUAL

The basic organization of this laboratory manual has been carefully planned to conform to sound rules to learning. That is, wherever possible throughout the manual each step and each explanation is chosen to take advantage of, and build on, the reader's previously acquired knowledge and understanding.

Every effort is made to ensure that the reader will be able to understand and execute the operations that form the topic of focus and nucleus of each experiment. To that end, each experiment is page-referenced to the textbook UNDERSTANDING AND TROUBLESHOOTING THE MICROPROCESSOR, each experiment begins with a capsule summary and explanation of important information, each experiment presents a clear set of objectives to be achieved, each experiment employs both figures and text to enhance and maximize understanding, and each experiment represents a steady progression from what is known to what is new. In short, the objectives of each experiment are achievable. This serves as a great confidence builder as the mystery of microprocessors is steadily disspelled.

The study of microprocessors is much easier when we recognize and take advantage of one basic fact: a microprocessor system is a collection of hardware that is stable in one or the other of two basic states, logical 1 or logical 0; when operating, the system switches from one static state to the other in rapid succession. In the actual circuitry of a microprocessor system these two basic states are represented by two different voltage levels.

Now, if we can develop a way to apply and hold a logical 1 (or a logical 0) voltage for as long as we choose or need at the point of signal origin, then we can check for proper voltages at all points along the signal path from the point of origin to its destination point. Moreover, the voltage can be checked with inexpensive instruments such as a logic probe or a DC voltmeter. This is the basic premise of static stimulus testing. The value to the beginning troubleshooter of being able to have time to trace signal paths and verify and learn "what should be there" at each point in a system is incalculable.

The experiments in this manual assume that the user will acquire or construct a Static Stimulus Tester.* This instrument is inexpensive to build, and serves as both a valuable learning tool and as an effective troubleshooting aid later. By the use of this instrument one is able to realize the very real advantages that static techniques have to offer. Because it permits a beginning microprocessor troubleshooter to set a logic level and hold it for as long as needed, it is unparalleled in aiding the understanding of microprocessor system organization, logic paths, as well as the details of hardware operation. This approach provides a unique means of learning "what should be

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*Available from Creative Microprocessor Systems, Post Office Box 1538, Los Gatos, California 95030 there" from the very beginning, while building a solid base of information plus techniques for effective troubleshooting that can be called upon often in the years ahead.

The fact is that every single memory cell, every operation, and every signal path of a microprocessor system must be checked before it can be said with confidence that a system will work properly. Even if sophisticated automatic test equipment is used to go through the steps of the checking process, the operator or <u>someone</u> must know that system organization and those signal paths well enough to pinpoint the trouble points when they occur and repair or correct them. Even if a troubleshooter comes to microprocessors with a software rather than a hardware background, one's introduction to microprocessor system hardware will be easier and the progress in understanding more rapid when using static techniques rather than dynamic techniques, in which the system is switching logic levels at kilohertz to megahertz speeds.

In this easy to follow manual, experiments 1 through 10 are devoted to the various aspects of hardware organization and the details of circuit operation using the static stimulus testing technique. At the conclusion of Experiment 10 the reader should be able to perform basic system operations, check to verify their proper execution, and locate the trouble site if the system fails to execute a command properly.

Experiments 11 through 18 are designed to develop an ability to write elementary programs and to expand on one's understanding and appreciation of the 1-to-1 relationship between hardware operation and program steps.

Experiments 19 and 20 focus on the troubleshooting of memories and I/O ports. Experiment 21 specializes in the effective use of the oscilloscope to examine and analyze the dynamic address, data, and control signals when a microprocessor system is in operation. Specific data sheets, schematics and other helpful information are included in the appendices which provide important information for the professional microprocessor technician.

The writing and preparation of this manual has involved the efforts of a group of people. In particular, I would like to thank Bill Long for his patient guidance, Kathy Wissig for all the keystrokes, Jim Coffron for his technical and moral support, and especially my wife, Alison, for going an extra mile. Beyond this there is my daughter, Charlotte, who at 8 months taste-tested every page of the manuscript.

John Crane

Palo Alto, California

INSTRUMENTS AND MATERIALS

Description of Item	Quantity
8080 microprocessor training system	12
Static Stimulus Tester (Creative Microprocessor Systems)	12
DC Volt-Ohmmeter	12
Logic probe	12
Current probe	12
TTL Data Book (Texas Instruments, Inc.)	12
MCS-80 User's Manual (Intel Corp., 1977), or MCS-80/85 Family User's Manual (Intel Corp., 1979)	12
DC power supply, 5 volt	12
Oscilloscope, dual-trace	6-12

This list of instruments and materials is based on a class size of 24 students. While a ratio of 1 student to 1 equipment set-up is ideal, costs may be a deterring factor. Experience in classes and seminars has shown the 2 student team to be workable, even exhibiting some positive elements. For one, the opportunity to cooperate and consult together when questions arise often produces answers from the students themselves, without requiring aid from the instructor. This is desirable, for it leads to an atmosphere of independence and self teaching, of self reliance and looking inward for solutions first. Also, the

2 student unit permits a trade-off which frees one member to concentrate on literature, specifications and documentation while his partner operates the hardware, makes measurements, and accumulates data.

CONTENTS

EXPERIMENT 1

SYSTEM FAMILIARIZATION

DISCUSSION

In Experiment 1, we examine the make up of a typical microprocessor system: that is, we look at the functional block diagram, the integrated circuits (ICs) used, the function of each IC, the locations of the various ICs in the system and the source where data and specifications about each IC can be found. This is general "must have" information for anyone who works with microprocessors. Some of this information, such as the device's physical location on a printed circuit (PC) board, varies from system to system; however, these actual locations must be found before meaningful measurements can be taken and before work on the hardware can be done.

In the experiments that follow we shall look closely at which ICs are involved in each particular subsystem and operation that takes place in a microprocessor system.

In order to have a common starting point, let us look at the functional blocks that make up a typical microprocessor system. The microprocessor, or Central Processing Unit (CPU), is generally regarded as the center of the system, while the other functional units are usually referred to as peripherals, or subsystems. This simple system is shown in Figure 1-1.

As we examine each functional subsystem or peripheral one at a time in later experiments, we will become familiar with "what should be there" in terms of the devices, the circuit organization, the logic levels, and the signal or data paths. Our goal in Lab 1 is to do some preliminary work that will provide the basic information needed for the 20 experiments that follow.

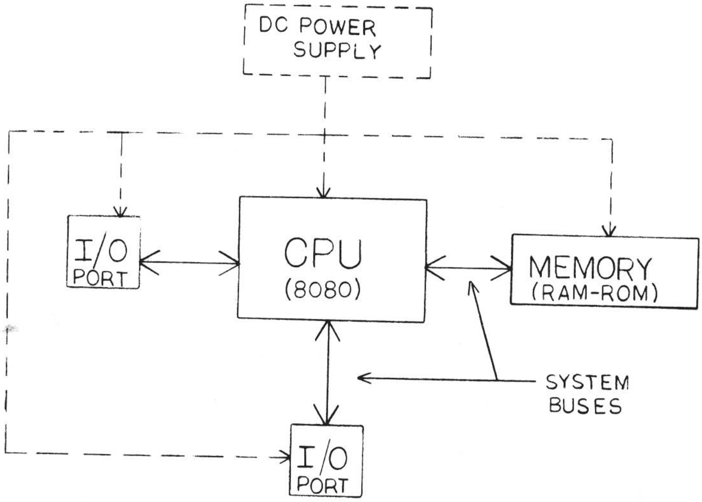

FIGURE 1-1 Functional block diagram of a microprocessor system

OBJECTIVES

1. To identify the major elements that make up a typical microprocessor system

2. To identify and find, using hardware and paper documentation, the physical location of all ICs used in the microprocessor system

3. To identify and make note of the sources of information about each IC for easy reference later

4. To identify the different classes of IC logic blocks that make up a total system and understand where each block is located, and

5. To practice locating relevant data and specifications, using the manufacturers' data sheets.

INSTRUMENTS AND MATERIALS

1 8080 microprocessor training system

1 TTL data book

1 MCS-80 User's Manual (Intel Corp. 1977)

Note: If the MCS-80 User's Manual is not available, use the MCS-80/85 Family User's Manual (Intel Corp., 1979) or an equivalent. Referenced page and chapter numbers will need to be corrected.

Recommended Reading: UNDERSTANDING AND TROUBLESHOOTING THE MICROPROCESSOR (referred to hereafter as "Reference 1") by James W. Coffron, Prentice Hall 1980, Pages 1-33

PROCEDURE

Step 1

1.1 If these are not already provided or available, make a complete sketch of your system following the pattern of Figure 1-2. List the manufacturers part number for each IC, the function of the part (from manufacturers data sheets), and the page number in the data reference book so that the part information can be looked up easily later.

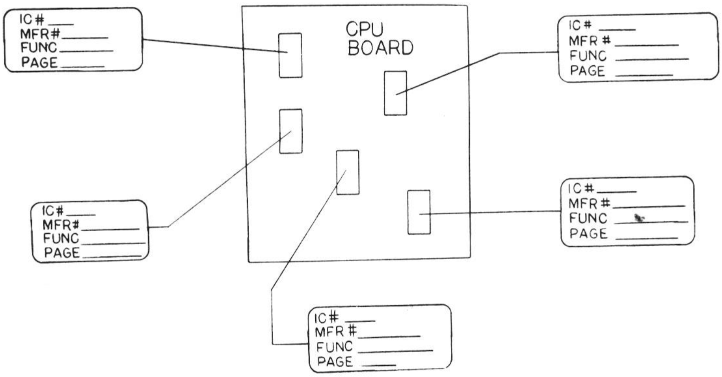

FIGURE 1-2 Partial block diagram of a microprocessor system showing physical locations of ICs on the PC board

Step 2

2.1 Classify all of the ICs according to the functional group to which they belong. This gives one a review of the digital elements (with which you are already familiar) that make up a microprocessor system. A suggested format for this step is given in Table 1-1.

TABLE 1-1 Summary of system Integrated Circuits

Part Number	Page Reference	Supply Voltages Required	Notes and Comments
NAND gates 1. 2.			
Hex Inverters 1. 2.			
AND gates 1. 2.			
Bit Comparators 1. 2.			
Multivibrators 1. 2.			
Line Buffers 1. 2.			
Flip Flops 1. 2.			
Counters 1. 2.			
Memories 1.			

NOTE: Any additional functional devices in your system should be added to this table.

QUESTIONS

1. What voltage (or voltages) does your DC power supply provide?

2. Referring to the data collected in Step 2, how does the voltage required by the various ICs conform to the voltage available from the power supply? Are there any important differences?

3. Other than the Central Processing Unit, did you find any digital functions with which you are not familiar?

4. What logic families (TTL, CMOS, NMOS, etc.) are used in the ICs of your system?

5. How well did this experiment fulfill its five objectives? Were there any shortcomings?

EXPERIMENT 2

INTRODUCTION TO THE STATIC STIMULUS TESTER (SST)

DISCUSSION

The Static Stimulus Tester (SST) represents a unique tool for the investigation of microprocessor systems. The fundamental advantage of the SST is that it simplifies the complex, dynamic analysis of a microprocessor system into a straightforward static investigation. The demonstration and understanding of this instrument is the goal of this experiment.

When a microprocessor is commanding a system, it provides the proper logic levels and timing automatically; in this mode, the required combinations of logical voltage levels to read or write are held at logical 1 or logical 0 very briefly, usually just long enough to permit the read or write function to take place. The fleeting nature of such short duration logic pulses when the microprocessor is in command presents a number of difficulties and uncertainties in circuit testing and troubleshooting.

In static stimulus testing the SST takes the place of the microprocessor that is used in the system. Now you, the operator, become the microprocessor and you send out the correctly timed, proper logic levels on the right bus lines to the proper memory or other device pins to accomplish a memory read or write. To do this, the microprocessor is first removed from its socket. This permits outside access to all of the address, data, and control bus lines that are normally controlled by the microprocessor. To realize this access in the easiest and most effective way, the Static Stimulus Tester, a simple switch-