PRENTICE-HALL SERIES IN PERSONAL COMPUTING

JOHN E. UFFENBECK

Hardware Interfacing with the Apple II Plus

A step by step introduction to microcomputer interfacing—featuring 13 practical hardware experiments.

HARDWARE INTERFACING WITH THE APPLE II PLUS

JOHN E. UFFENBECK

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HARDWARE INTERFACING WITH THE APPLE II PLUS

For Kathy

PREFACE

This book is written for the computer "*hacker*," the technician, the engineer, and in general anyone with an interest in knowing a bit more about the electronics of the Apple II Plus personal computer system. In particular it deals with interfacing the sometimes "hostile" outside world to the expansion bus of the Apple.

If you have never thought of using the Apple to control your world, consider some of the possibilities. Using simple BASIC software you can monitor the indoor or outdoor temperature, the opening and closing of a door, the level of light in a room, the status of a smoke detector, or the voltage on a charging capacitor. Once input, you can process this information and turn on the light across the room, switch the furnace off or on, generate a piercing alarm signal, or program the "tinkling" of a bell.

All of these interfacing projects and several more are described in the 13 experiments in HARDWARE INTERFACING WITH THE APPLE II PLUS. You will learn interfacing by doing interfacing. The book begins with an explanation of the **PEEK** and **POKE** commands as their use will be critical throughout. From there you will learn *address decoding* and input and output ports. The Intel 8255 programmable peripheral interface is used in Experiment 5 and contrasted with the Motorola MC6820 peripheral interface adapter in Experiment 6. These two ICs greatly simplify the job of interfacing to the outside world.

The last seven experiments deal with special interfacing techniques such as analog-to-digital and digital-to-analog conversion methods. Also covered is serial interfacing and the concept of "handshaking" logic. The book ends with a programmable sound generator project requiring 8 ICs. This circuit is capable of producing a fantastic array of sounds from train whistles to gun shots to an electronic organ.

You will be assumed to be a proficient—but not expert—BASIC programmer. Although machine language could be used for any of the experiments, BASIC is used throughout. You should be familiar with digital breadboarding techniques and the 7400 series of digital logic gates. *Mixed logic* symbology is used for all logic elements, and this technique is reviewed in Appendix D.

The experiments are organized so that you can quickly see what you will be required to do—the OVERVIEW, what you will learn; the OBJECTIVES, what parts you will need; the PARTS LIST; a DISCUSSION on the theory; and the experimental PROCEDURE itself.

One of the most difficult parts of any electronics project today is locating the components and getting started. Part 1 addresses this issue and Appendix B provides a complete parts list for all of the experiments with several sources.

If you have never used your Apple as a hardware controller before, be prepared for a pleasant surprise. You may find hardware interfacing even more challenging and exciting than that last BASIC program you wrote.

JOHN E. UFFENBECK

ACKNOWLEDGMENTS

The following figures and tables from *Hardware Interfacing with the TRS-80* by John Uffenbeck are reproduced with the permission of Prentice-Hall, Inc. Figure numbers refer to *Hardware Interfacing with the Apple II Plus.*

Figure I-4, Tables I-1, I-2, Figures 1-1, 2-4, 3-3, Table 3-1, Figures 4-1, 4-3, 4-4, 5-3, 5-6, 7-1, 7-2, 7-4, 7-5, 7-6, 7-8, 7-9, 8-1, 8-2, 8-4, 8-5, 8-6, 8-7, 9-1, 9-4, 9-5, 10-1, 10-2, 10-3, 10-4, 10-5, 11-1, 11-2, 11-4, 11-5, 11-7, 12-1, 12-2, 12-3, 12-5, 12-9, Table 12-2, Figures 13-1, 13-2, 13-5, 13-7, 13-9, 13-11, Tables 13-1, C-1, Figures D-1, D-2, D-3, D-4, E-1, E-2, F-1.

The data sheets in Appendix G are reproduced courtesy of Intel Corporation, Motorola, Inc., General Instrument Corporation, and National Semiconductor Corporation.

HARDWARE INTERFACING WITH THE APPLE II PLUS

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1 Getting Started

Read this section before attempting any of the experiments in this book. You will need special hardware to do the experiments and this section tells you what to get and where you can find it.

INTRODUCTION

The Apple II plus microcomputer shown in Fig. I-1 is one of the most popular microcomputers on the market today. Because of this there are hundreds of computer programs and operating systems available for the Apple. These range from *Star Invaders* to *Visicalc* to *Pascal*. A nearly equal number of books have been written describing how to use and operate these programs using the Apple's built-in BASIC language, *Applesoft*.

This book, however, deals with that area of microcomputers that is sometimes considered "black magic" or "taboo" by the microcomputer owner: namely, microcomputer hardware and interfacing. It is my hope to clear the air by leading you through 13 progressively more complex hardware experiments on your Apple personal computer. By the time you have completed all 13 experiments, you may not be an expert, but you will certainly understand microcomputer input and output. And you will also appreciate the potential that your computer has as a hardware controller in the home or industry.

Before beginning these experiments you should acquaint yourself with the basic hardware and software necessary to perform the experiments. These are explained in the following sections.

HARDWARE REQUIREMENTS

All of the experiments in this book are written with the Apple II computer in mind and all hardware details are specific to this computer. The Apple is most commonly available in the Apple II Plus version, with 48K bytes of RAM (random access read-write memory) and one disk drive. While this system is more than sufficient, the minimum configuration is assumed to be:

1. Any Apple II computer with Applesoft.
2. At least 8K of RAM.
3. A video monitor or suitable television receiver.

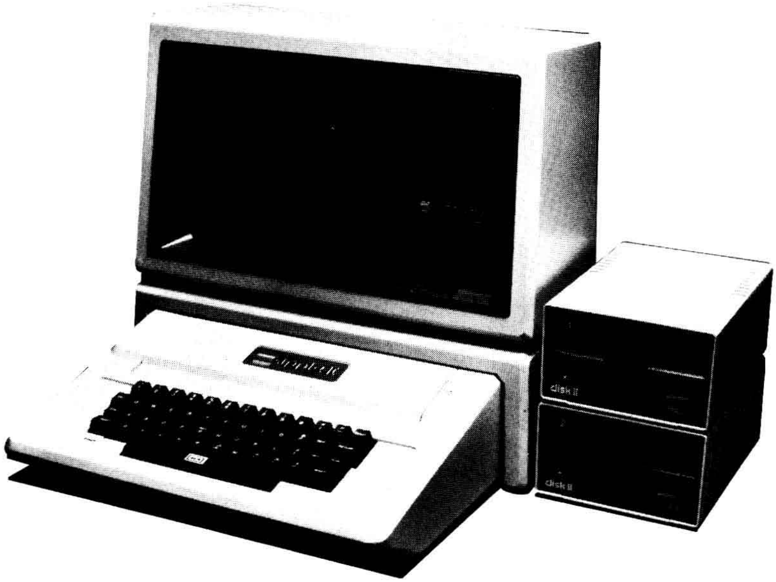

Figure I-1 Apple II Plus microcomputer system. All of the experiments in this book are intended for this computer. Reprinted from the Apple II Reference Manual with the permission of Apple Computer, Inc.

Notice that no disk drive, printer, language card, I/O card, or other peripheral is required. If you have these things, fine, but if not, you won't need them.

What you will need is some means of connecting to one of the peripheral connector slots (preferably slot 7) and a *solderless breadboard* for building the interface circuits. The next few subsections detail these hardware requirements.

THE RIBBON CABLE ASSEMBLY AND INTERFACE CARD

Figure I-2a illustrates the basic interfacing concept to be used throughout this book. A Vector Electronics 4609 *plugboard* is inserted into slot 7 of the Apple's motherboard. The 40-pin connector on the rear of this card is then wired to access the important interfacing signals provided by the Apple at the slot 7 connector. This is shown in Fig. I-2b. A length of 40-conductor ribbon cable with a card edge connector at one end (the computer end) and a socket connector on the other is used to bring these signals out to the motherboard. The socket connector conveniently allows No. 22 or 24 gauge wire connections between it and the breadboard.

The Vector card is available from Jameco Electronics (1355 Shoreway Road, Belmont, CA 94002), Priority One Electronics (9161 Deering Avenue, Chatsworth, CA 91311), and several other suppliers for about $25. The 40-

Figure I-2 (a) Apple computer with its cover removed, revealing the Vector Electronics plugboard in slot 7. The ribbon cable connected to the rear of this card provides access to the interfacing signals required to do the experiments. A solderless breadboard is used to build up the various interfacing circuits.

conductor ribbon cable is available from Digi-Key Corp. (P.O. Box 677, Thief River Falls, MN 56701). The part number is 924150-24 and the approximate cost is $15.

Before proceeding to Experiment 1 you should wire the Vector card following the instructions given in Appendix A. This appendix also gives a complete description of the electrical signals available at each peripheral slot connector and at the breadboard.

One particularly nice feature of the Apple computer is that ±5 V and ±12 V are available at each peripheral connector. This means that it will not

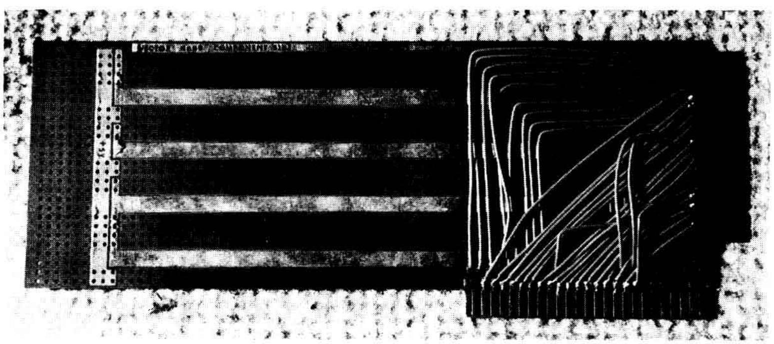

Figure I-2 (b) Jumper wires are used to bring the interfacing signals from the Apple's peripheral connector to the edge connector on the Vector card.

be necessary for you to use an external power supply to perform any of the experiments. The current capacities of these voltages are limited, however, and it may be wise to remove any extra cards you have in your computer when using the Vector card. But you should be able to operate with three or four other cards in the computer besides the interface board (see Appendix F, "If the Experiment Doesn't Work").

SOLDERLESS BREADBOARD

The purpose of the breadboard is to allow easy (solderless) connections between the various integrated circuits (ICs) used in the experiments and the Apple. Referring to Fig. I-3, the ICs are placed so as to straddle the center divider of the socket. There are then four remaining connections to each IC lead in each row. Connections on one side of the center notch are electrically isolated from the other side.

Table I-1 compares several types of solderless breadboards. The more rows per side, the more ICs you will be able to interconnect and the more expensive the breadboard. The first two entries in the table provide sockets only, whereas the last three have the sockets mounted on a small base (see Fig. I-3). If the cost of some of the Proto-Boards seems high, you may want to consider fabricating your own base. In this way you can expand your breadboard with additional sockets as needed while holding down the initial cost.

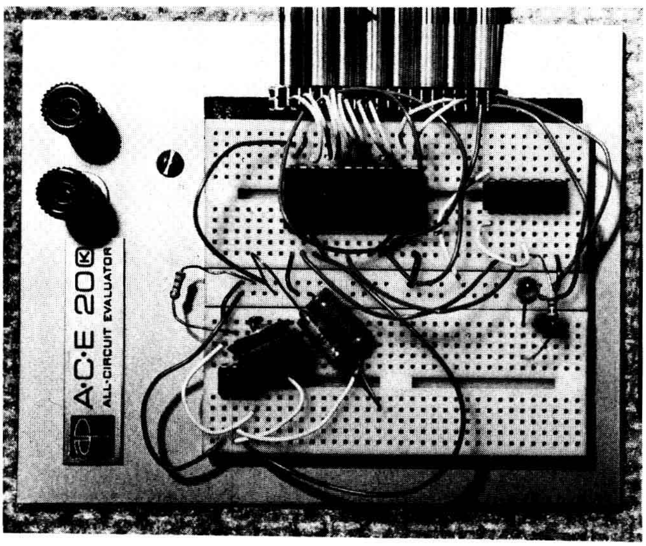

Figure I-3 Breadboard end of the ribbon cable assembly. The two sockets shown provide 68 rows of connections with a power bus (+5 V and ground) running between the two. The ribbon cable socket connector is held in place by the "stickum" on the base plate. The cable itself is a 40-conductor ribbon with a card edge connector on the computer end. Refer to the text for sources for these components.

TABLE I-1 SOLDERLESS BREADBOARDS ARE AVAILABLE IN A VARIETY OF CONFIGURATIONS AND PRICES

Type	Number of rows per side	Part number	Manufacturer
Modular breadboard socket (may be expanded)	47	276-174	Radio Shack about $10
Quick Test Socket and bus strip (may be expanded)	59	QT-59S, QT-59B	Jameco Electronics 1355 Shoreway Road Belmont, CA 94002 about $15
Proto-Board with Quick Test Sockets	68	ACE-200K, 923333	Digi-Key Corp. P.O. Box 677 Thief River Falls, MN 56701 about $20
Proto-Board with Quick Test Sockets	96	ACE-201K, 923334	Digi-Key about $30
Proto-Board with Quick Test Sockets	94	PB-102	Jameco about $35

COMPONENTS

In general, each experiment will require you to wire one or more integrated circuits on your breadboard. These circuits are then connected to the ribbon cable's socket connector with No. 22 or 24 gauge solid insulated wire. Figure I-3 illustrates the method. Note that in addition to the ICs, several other components may be required, depending on the experiment. Appendix B lists the components needed to do all the experiments in this book. Each project also begins with a complete list of parts needed for that experiment.

NICE-TO-HAVE COMPONENTS

There are additional supplies that can make your journey through this book more meaningful and be an aid to you in troubleshooting your circuits.

LOGIC PROBE

A digital circuit may have only two operating states: ON or OFF. The output of a logic gate is either high (1) or low (0). Although we could monitor this condition with a voltmeter, another tool is often used—a *logic probe*. Figure I-4 pictures a typical probe. The light-emitting diodes (LEDs) serve as the logic-level indicators. These correspond to the logic 1 and 0 states and