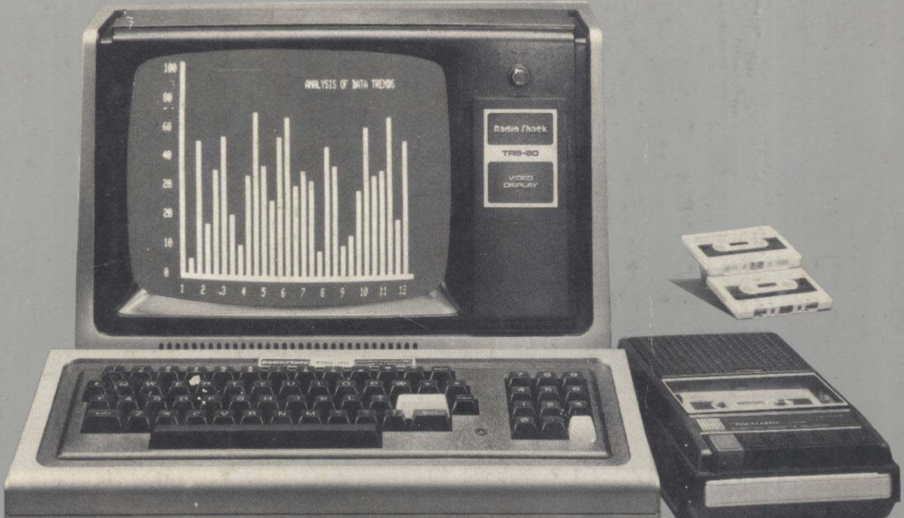
PRENTICE-HALL SERIES IN PERSONAL COMPUTING

JOHN E. UFFENBECK

Hardware Interfacing with the TRS-80



A step by step introduction to microcomputer interfacing—featuring 14 practical hardware experiments.

HARDWARE INTERFACING WITH THE TRS-80

JOHN E. UFFENBECK

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PREFACE

This is a *doing* book. It features *14* experiments on interfacing the outside world to the Radio Shack Model I and Model III TRS-80 computers. You will learn interfacing by *doing* interfacing. Each experiment is intended to be built on a breadboard and not constructed as a permanent circuit. The emphasis is on understanding input/output (I/O) concepts, not on wiring skills.

All the interface circuits will be controlled from **BASIC** and numerous annotated programs are included. As such, you should have had two- to three months of experience working with TRS-80 BASIC and writing your own programs. You will also need an understanding of the binary number system and be able to convert back and forth easily between binary and decimal. Most of the circuits will use 7400 family ICs, and a basic knowledge of flip-flops and logic gates is presumed. Appendices C, D, and E provide a review of these areas.

This book is organized into three parts. *Part 1* tells you what you need to get started. This is critical, as you must have certain hardware available to do the experiments. Fortunately, most of these components should be available to you locally at minimal cost. Appendix B gives a complete parts list and a key to several suppliers.

Part 2 details the basic concepts of I/O that you must understand. The three-bus system architecture is introduced and simple input and output ports tested. Finally, the *8255* programmable peripheral interface chip is described and used for most of the remaining experiments.

Much of the outside world presents a "hostile" environment to the TRS-80 and *Part 3* describes interfacing to this non-TTL world. Included are special interfacing problems such as controlling 110-V AC devices, analog inputs and outputs, serial interfacing, and devices requiring "handshaking" techniques. The last experiment includes an interface to the General Instruments *AY-3-8910* programmable sound generator. This circuit allows a fantastic range of sounds to be produced by your TRS-80.

Each experiment is organized into five parts. In the *OVERVIEW* a quick description of what you will be doing in that experiment is given. Next, the experiment learning *OBJECTIVES* are listed. If you already feel comfortable about these objectives, you can then go on to another experiment. The *PARTS LIST* indicates all components needed to perform that experiment. A brief *DISCUSSION* follows, explaining the theory about to be tested on the breadboard. Examples help to illustrate the concepts being discussed. The *PROCEDURE* section details a step-by-step procedure for performing the experiment. Appendix E is provided to give troubleshooting hints "*if the experiment doesn't work.*"

So, if you are like many users and owners of microcomputers today and have never connected a piece of hardware to your computer system, be prepared for a pleasant surprise. You may find hardware interfacing every bit as fascinating and challenging as that last BASIC program you wrote.

I would like to thank Mark for helping to test these experiments, Karen for the photography, and my wife Kathy for understanding why I spent every night at the office for the last year. I dedicate this book to Benji and Michael.

JOHN E. UFFENBECK

CONTENTS

PREFACE
vii

PART 1
GETTING STARTED
1

Introduction *3*
Essential Components *5*
Nice-to-Have Components *9*
Conclusion *11*

PART 2
BASIC CONCEPTS OF MICROCOMPUTER INPUT/OUTPUT
13

Experiment 1 The Four I/O Commands in BASIC *15*
Experiment 2 Address Decoding *25*
Experiment 3 I/O-Mapped Output Port Concepts *35*
Experiment 4 I/O-Mapped Input Port Concepts *46*
Experiment 5 I/O-Mapped I/O Using the 8255 *56*
Experiment 6 Memory-Mapped I/O Using the 8255 *69*
Experiment 7 1K Static Memory Interface *81*

PART 3
SPECIAL INTERFACING PROBLEMS
91

Experiment 8 Hardware Interfacing Techniques, Part 1: Inputs *93*
Experiment 9 Hardware Interfacing Techniques, Part 2: Outputs *106*
Experiment 10 Interfacing a Digital-to-Analog Converter *119*
Experiment 11 Interfacing an Analog-to-Digital Converter *131*
Experiment 12 Handshaking I/O *147*
Experiment 13 Serial Interfacing *163*
Experiment 14 Interfacing a Programmable Sound Generator *185*

APPENDICES
205

A Description of the Model I and Model III Expansion Connectors *207*
B Parts List *213*
C Binary and Decimal Numbers *217*
D Basic Logic Gates *220*
E JK Flip-Flop *223*
F If the Experiment Doesn't Work *225*

INDEX
229

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

To take full advantage of the various experiments in this book, there are certain hardware and software requirements for your computer system.

MODEL I VERSUS MODEL III

Radio Shack no longer produces the Model I TRS-80, having replaced it with the newer Model III (see Fig. I-1). The main difference between these two computers, as far as this book is concerned, is that *memory-mapped I/O* cannot be done on the Model III. This is because the *high-order* address lines have not been brought out to the expansion connector on the underside of the Model III computer. Two of the experiments in this book require these high-order address lines and therefore *cannot* be done with the Model III. However, you may still wish to read through the discussion of these experiments to familiarize yourself with the concepts.

With the exception of these two experiments, all experiments in this book will work on *both* the Model I and Model III computers. Any special considerations that must be made to make an experiment work on one model or the other will be noted.

Regardless of your computer model, you should have a version of BASIC that includes the **INP**, **OUT**, **PEEK**, and **POKE** commands. This version of BASIC is called *Level II* on the Model I and *Model III* BASIC on the Model III. As long as your version of BASIC has these four commands, you should have no problems with software.

HARDWARE

This book deals with computer *hardware* (integrated circuits, light-emitting diodes, switches, wire, etc.). Your TRS-80 computer will talk to this hardware via a multiconductor *umbilical cord* or ribbon cable. This cable is discussed in detail in the next section, "Essential Components."

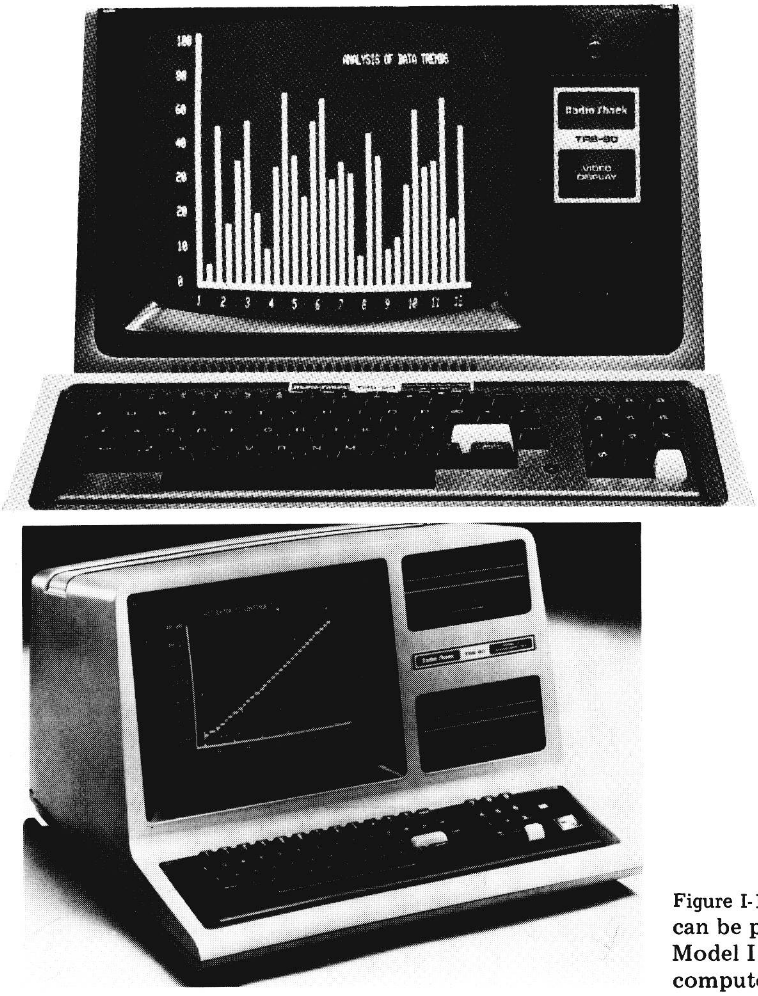


Figure I-1 Experiments in this book can be performed using (a) the Model I or (b) the Model III TRS-80 computer. (Courtesy of Radio Shack.)

In addition to this ribbon cable, you will need a *solderless breadboard* to construct the various hardware interfaces, a +5-V DC *power supply* to power these circuits (the TRS-80 does not have enough extra power to accomplish this), a supply of components, and various lengths of No. 22 or 24 gauge wire to perform each experiment.

Although you may be dismayed to learn that you must purchase these items, consider them to be the "tools of your trade" if you plan to be seriously involved in hardware interfacing. The next section will give you some hints on where to find these items and what possible substitutions can be made.

All the items mentioned so far must be considered essential hardware.

If you do not have these items, you will be *unable* to perform the majority of the experiments, if any. Of course, you may use this book as a guide to hardware interfacing and simply read through those experiments of interest to you, but maximum benefit is obtained by actually "getting your hands on the hardware."

There are also a couple of *nice-to-have* hardware items, such as a logic probe and a simple DC voltmeter. More about these in a later section.

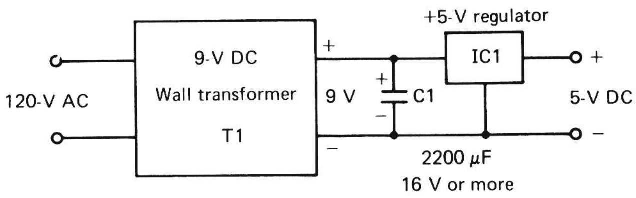
ESSENTIAL COMPONENTS

In this section we discuss components that you must have available if you are to seriously attempt the experiments in the following two parts of this book.

5-V DC POWER SUPPLY

Nearly all the integrated circuits used in this book require +5 V DC for their function. When choosing a power supply, be sure it has at least a +5-V output rated at *0.2 A* of current or more. Although this will be sufficient for a majority of the experiments, it would also be desirable to have a *negative* output voltage (−5 V) for a couple of the experiments.

Fully assembled power supplies are readily available, but it may be cheaper to assemble your own. Figure I-2 illustrates a simple power supply

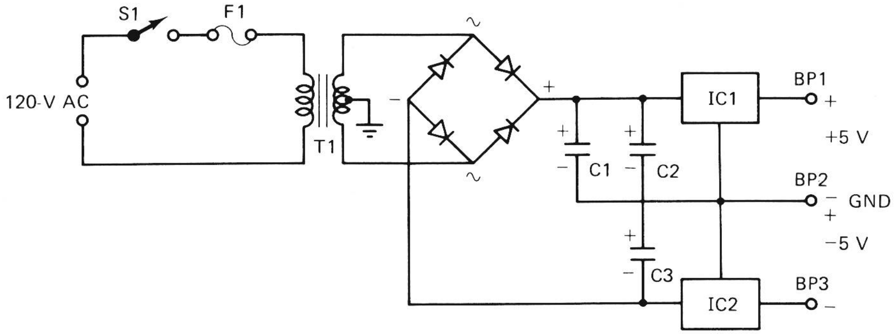


Component	Radio Shack	Jameco
T1	9-V battery eliminator 270-1552	DC 900
C1	272-1020 2200 μF at 35 V	2200 μF at 16 V
IC1	7805 276-1770	LM340T-5

Figure I-2 Most experiments in this book require a +5-V power supply. This simple circuit uses a 9-V DC wall transformer, a 2200-μF filter capacitor, and a 7805 +5-V voltage regulator. Parts may be obtained at your local Radio Shack store or other parts house, such as Jameco Electronics (1355 Shoreway Road, Belmont, CA 94002). The connector on the wall transformer should be cut off and the wires connected to the capacitor and voltage regulator, which may be mounted on your breadboard. Be sure to observe the transformer output voltage polarity.

requiring only *three* components. The wall transformer (together with internal rectifier) converts the 120 V AC to approximately 9 V DC. The capacitor helps smooth out any voltage fluctuations, and the regulator integrated circuit maintains the output voltage constant at +5 V.

Figure I-3 illustrates another possible power supply circuit. This circuit



Component	Radio Shack	Jameco
S1 on/off switch	SPST 275-612	FTD01/JMT-123
F1 fuse $\frac{1}{4}$ A	270-1270	AGC $\frac{1}{4}$ A
Fuseholder (panel mount)	270-364	HKP
T1 12.6-V CT transformer	273-1505 1.2 A	–
Bridge rectifier 1A 50 PIV	276-1161	MDA 980-1
C1, C2 2200 μF 35 V	272-1020	2200 μF 35 V
C3 1000 μF 16 V	272-1019	1000 μF 16 V
IC2 −5 V-regulator	–	LM320T-5
BP1-3 binding posts	274-662	–
IC1 +5 V-regulator	276-1770 7805	LM340T-5

Figure I-3 This circuit provides both +5 V at 1 A and −5 V at 0.2 A output (the negative output is useful for the digital-to-analog and analog-to-digital experiments). It can be built on a small piece of perforated board and mounted in a suitable cabinet. Again, components are available from Radio Shack, Jameco Electronics, and most other electronic parts houses.

has the advantage of providing a −5-V output as well as +5 V. The negative output voltage is needed in the digital-to-analog and analog-to-digital experiments in Part 3.

RIBBON CABLE ASSEMBLY

As mentioned earlier, a multiconductor ribbon cable will allow you to connect wires to the TRS-80 expansion port connector. This cable is a very critical part of the interface, and not just any cable can be used. If you have a Model I computer, the cable must have a *40*-pin *card edge connector* at one end (this end connects to the TRS-80) and a *socket connector* at the other. If you have a Model III computer, the cable must have a *50*-pin card edge connector at one end and a socket connector at the other. *Appendix A* lists the signals that are on the various pins of these connectors and discusses how to connect the cable properly to your computer.

Figure I-4 illustrates the 50-conductor cable and the solderless breadboard assembly. Note that the socket connector will allow No. 22 or 24 gauge wire connections between it and the breadboard. The breadboard

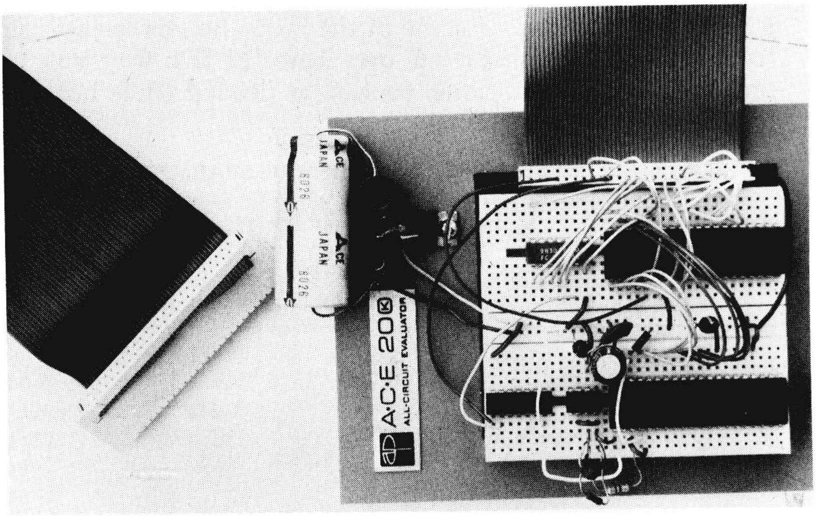


Figure I-4 This photograph illustrates the entire breadboard interface. The power supply (Fig. I-2) is mounted on the breadboard, with the base plate serving as a *heat sink* for the +5-V regulator. Banana plugs on the wall transformer cable facilitate connection to the breadboard. The two solderless breadboard sockets 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 50-conductor ribbon with a card edge connector on the computer end (a 40-conductor cable should be used with the Model I TRS-80). Refer to the text for sources of these components.

sockets have been offset slightly to the left to allow the socket connector to be held down by the *stickum* on the base plate.

Although it is possible to fabricate your own ribbon cable, a preassembled 40-conductor cable is available from Digi-Key Corp., P.O. Box 677, Thief River Falls, MN 56701. The part number is 924150-24. A 50-conductor cable is available from Priority One Electronics, 9161 Deering Avenue, Chatsworth, CA 91311. It is part number PRI50CESK.

SOLDERLESS BREADBOARD

The purpose of the breadboard is to allow *easy* (solderless) connection between the various integrated circuits (ICs) used in the experiments and the TRS-80 computer. Referring to Fig. I-4, 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 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-4). 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 the initial cost down.

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	84	ACE-201K, 923334	Digi-Key about $30
Proto-Board with Quick Test Sockets	94	PB-102	Jameco about $35

INTEGRATED CIRCUITS (ICS)

Each experiment will require that a number of ICs be inserted into the solderless breadboard. Number 22 or 24 gauge wire will then be used to connect the IC pins together and to the ribbon cable socket connector. At the beginning of each experiment all necessary parts to do that experiment will be specified. In addition, *Appendix B* lists all components needed to do the experiments in this book. You may want to order all of these parts or only those for the experiments you choose to do.

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-5 pictures a typical probe. It is powered by +5 V and is then touched to the various points in the circuit to be tested. Three light-emitting diodes (LEDs) generally serve as the logic-level indicators. These correspond to the

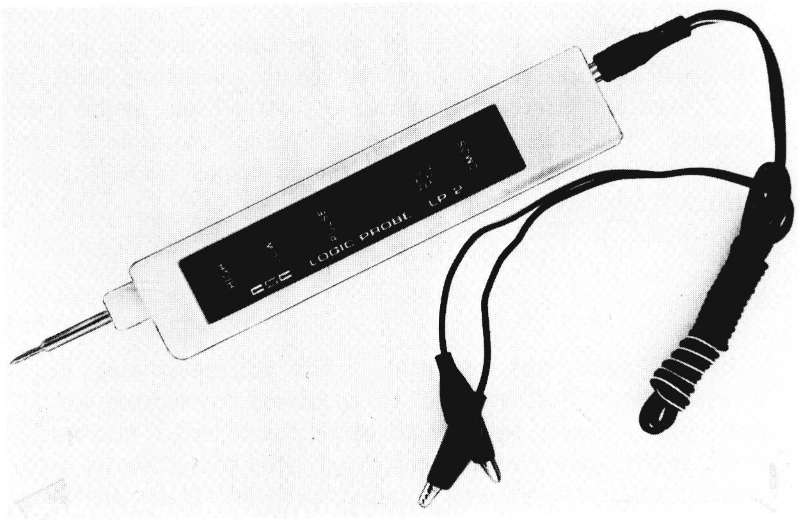


Figure I-5 A logic probe will be handy for monitoring logic levels. Its three LEDs brightly indicate a logic 1, a logic 0, or a pulse condition.

logic 1 and 0 states and to a pulse condition (a logic-level switching rapidly between the 1 and 0 states).

A logic probe will be very handy for monitoring circuit conditions in the various experiments in this book. Often we will be programming the TRS-80 to output a certain binary pattern of 1's and 0's which can easily be monitored with the logic probe. Table I-2 lists several common logic probes, their distinguishing features, and suppliers.

TABLE I-2 VARIOUS COMMONLY AVAILABLE LOGIC PROBES[a]

Source	Part number	Description
Radio Shack about $25	22-300	Fully assembled, detects pulses to 300 ns
Jameco Electronics 1355 Shoreway Road Belmont, CA 94002 about $23	LPK-1	Logic probe kit, detects pulses to 300 ns; f_{max} = 1.5 MHz
Jameco about $50	LP-1	Fully assembled, detects pulses to 50 ns; f_{max} = 10 MHz

[a]A logic probe, although not essential, will be handy for monitoring logic levels in the interface circuits.

Again you can save money by building your own. There have been numerous articles on logic probe construction over the last few years—for example, Steve Dominguez, "Probos V," *Kilobaud Microcomputing*, October 1979, p. 78. In this article Dominguez describes a logic probe with capabilities equal to those in Table I-2 but costing less than $5 for parts!

Another interesting example is the logic probe described by Robert Kreiger, "Build an Audible Logic Probe," *Popular Electronics*, July 1980, p. 73. This circuit produces different audio tones for the three logic conditions (high, low, and pulse).

DC VOLTMETER

Although again not essential, a DC voltmeter may be handy to measure power supply voltages and to troubleshoot simple electrical circuits. It is particularly handy to have an ohms function for continuity testing in cables (testing for *open* circuits and *short* circuits). A meter with volts, ohms, and current ranges is generally called a *VOM*. There are numerous sources for such meters, with prices ranging from $5 to several hundred dollars.