14.95

Beyond Games: Systems Software for Your 6502 Personal Computer

Ken Skier

Beyond Games: Systems Software for Your 6502 Personal Computer

Ken Skier

BYTE/McGraw-Hill, Book Division, 70 Main St, Peterborough NH 03458

Beyond Games: Systems Software for Your 6502 Personal Computer

Library of Congress Cataloging in Publication Data

Skier, Ken.
Beyond games.

Includes index.
1. 6502 (Computer)—Programming. I. Title.
QA76.8.S63S59 001.64'2 80-28512
ISBN 0-07-057860-5

Cover photo by Bob Hamor

Text set in Paladium
by BYTE Publications

Edited by Blaise Liffick

Design and Production Supervision
by Ellen Klempner

Copy Edited by Rich Friedman

Printed and bound using 50#MH Matte

Table of Contents

Introduction

Objectives

Sometimes I hear people talk about how smart computers have become. But computers aren't smart: programmers are. Programmers make microprocessors act like calculators, moon landers, or income tax preparers. Programmers must be smart, because by themselves microprocessors can't do much of anything.

Sound programming, then, is fundamental to successful computer use. With this principle in mind, this book has two objectives: first, to introduce newcomers to some of the techniques, terminology, and power of assembly-language programming in general, and of the 6502 in particular; and second, to present a set of software tools to use in developing assembly-language programs for the 6502.

Chapter 1 takes you on a quick tour of your computer's hardware and software; Chapters 2 thru 4 comprise a short course in assembly-language programming for those readers new to the subject. The rest of the book presents source listings, object code, and assembler listings for programs that you may enter into your computer and run.

Programmers have long sought to develop small and fast programs with the unfortunate result that occasionally code has been written that is unreadable (and even unworkable) simply because a programmer wanted to save a few bytes or a few cycles. In certain instances when memory space is particularly tight or execution time is critical, readability is sacrificed for performance. But today the average programmer is not forced to make this choice. Of course, all other things being equal, I, too, value programs that are quick and compact.

But how often are all other things equal?

While developing the programs that appear in this book, I had a number of objectives, most of them more important than the speed or size of a block of code. I designed these programs to be:

Useful: No program is presented simply to demonstrate a particular programming technique. All of the programs in this book were written because I needed certain things done — usually something I didn't want to be bothered with doing myself. The monitor monitors, the disassembler disassembles, and the text editor lets me enter and edit text strings. These programs earn their keep.

Easy to Use: Simply by glancing at the screen you can tell which program is running and what mode it is in. When a program needs information, it asks you for it and allows you to correct mistakes you might make while answering. This software doesn't require you to remember the addresses of programs or of variables. Functions are mapped to individual keys, and you can assign functions to keys in any way that makes sense to you.

Readable: A beginning 6502 programmer should be able to understand the workings of every program in this book. The labels and comments in the listings were carefully chosen to reveal the purpose of each variable, subroutine, and line of code. I am writing first and foremost for you, the reader, not for the 6502.

Portable: The book's software runs on an Apple II, an Atari 400 or 800, an Ohio Scientific (OSI) Challenger I-P, or a PET 2001. With proper initialization of the System Data Block, it should run on *any* 6502-based computer equipped with a keyboard and a memory-mapped, character-graphics video display.

Compatible: These routines are very good neighbors. As long as the other software in your system does not use the second 4 K bytes of memory (hexadecimal memory locations 1000 thru 1FFF), there should be no conflict between your software and the software in this book. In particular, most of the software in this book preserves the zero page, so your software may use the zero page as much as you like, and you won't be bothered with having to save and restore it before and after calls to the software presented herein.

Expandable: The programs in this book are highly modular, and you may extend or restructure them to meet your individual needs. System-specific subroutines are called indirectly, so that other subroutines may be substituted for them, and most values are treated as variables, rather than as constants hard-wired into the code. There are no monolithic programs in this book; they're all subroutines and may be combined in many ways to build powerful new structures.

Compact: I know that every personal computer has exactly the same available memory: too little. I also know ways to write a program in ten or twenty percent less space. But if doing so required sacrificing readability, portability, or expandability, I did not do so. In many cases I feared that to save a byte, I might lose a reader's clear understanding of how a program works. I considered that too great a price to pay for a somewhat smaller program.

Fast: Assuming that the above objectives have been met, the software in this book has been developed to operate as quickly as possible. But in any trade-off between speed and the other objectives, speed loses. A fast program that you can't understand holds little value. None of the programs in this book are likely to make you complain about how long you have to wait. I can't tell if I'm waiting an extra millisecond. Can you?

So go ahead. Read. Program. Enjoy!

Chapter 1:

Your Computer

The software in this book can run on a number of computers because it assumes very little about the host machine. Let's examine these assumptions and in so doing take a quick tour of your computer.

The 6502 Microprocessor

We'll start with the 6502 microprocessor, the component in your system that actually computes. By itself, the 6502 can't do much. It has three *registers* (special memory areas for storing the data upon which the program is operating), called A, X, and Y, which can each hold a number in the range of 0 to 255. Different registers have different capabilities. For example, if a number is in A (the accumulator), the 6502 can add to it, or subtract from it, any value up to 255. But if a number is in the X register or the Y register, the 6502 can only increment or decrement that number (ie: add or subtract one from it).

The 6502 can also set one register equal to the value of another register, and it can store the contents of any register anywhere in memory, or load any register from any location in memory. Thus, although the 6502 can only operate on one number at a time, it can operate on many numbers, just by loading registers from various locations in memory, operating on the registers, and then storing the results of those operations back into memory.

Types of Memory

You may have heard that a computer stores information as a series of ones and zeros. This is because the computer's memory is simply an elaborate array of switches, and an individual switch can have only two states: closed or open. These two states may also be expressed as on and off, or as one and zero.

Not all memory switches are the same. Some, in what is called ROM (read-only memory), are hard-wired into your computer's circuitry and cannot be changed except by physically replacing the ROM circuits containing those switches. Others, in what is called RAM (random-access memory) or programmable memory, can be changed by the processor. The 6502 can open or close any of the switches, called bits (binary digits), in its programmable memory, and later on read what it "wrote" into that memory. Figure 1.1 shows how the processor has access to read-only memory and programmable memory.

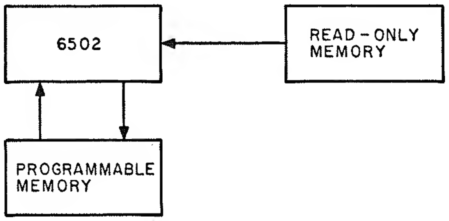


Figure 1.1: *How the 6502 interacts with memory. The arrows indicate the flow of data.*

A third kind of memory is set by some external device, not by the 6502. Such memory switches are called *input ports,* and may be connected to keyboards, terminals, burglar alarms — virtually anything that can generate an electrical signal. The 6502 perceives these externally generated signals by reading the appropriate input ports.

Yet another kind of memory switch, called an *output port,* generates a high or a low voltage on some particular wire depending on whether the 6502 sets a given memory switch to a one or a zero. One or more of these output ports can enable the 6502 to "talk" to the outside world.

Now don't jump up and think I'm going to show you how to synthesize speech in this book. "Talk" is just my way of anthropomorphizing the 6502. It will happen elsewhere in this book, when the 6502 "sees," "remembers," and "knows" what to do. Of course the 6502 doesn't see, remember, or know anything, but I often find it helpful to put myself in its place. That way I can better understand how a program will run, or why a program doesn't run, and I *do* see, remember, and know things.

But don't take such verbs too literally. The 6502 doesn't talk. It causes signals to be generated that may be sensed by other devices, such as cassette recorders, printers, disk drives — and yes, even speech synthesizers. But not in this book.

Some peripheral devices are actually connected to both an input and an output port. Examples of these devices are cassette tape machines and floppy-disk drives, which are mass-storage or secondary-storage devices. Figure 1.2 summarizes the processor's access to memory and to peripheral devices.

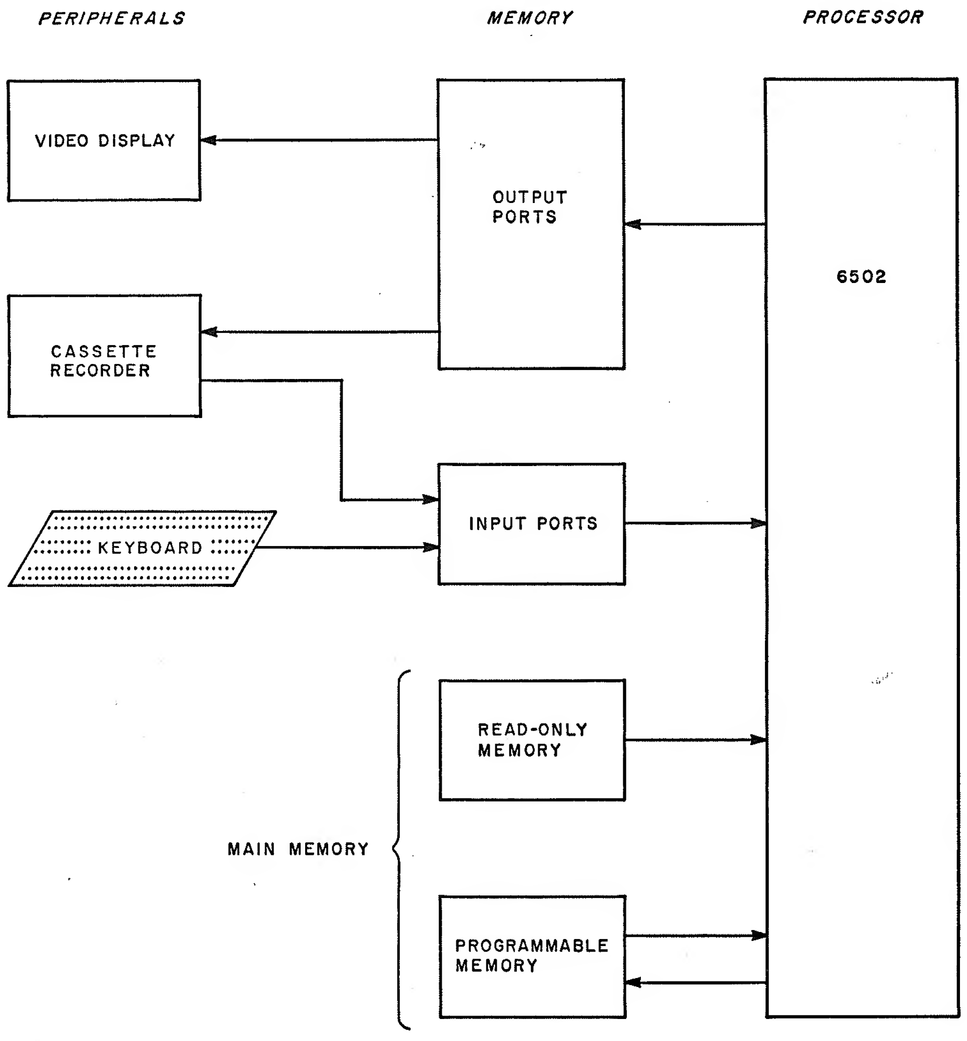


Figure 1.2: *A summary of the 6502 microprocessor's access to data in main memory and through I/O (input and output) ports. The arrows indicate the flow of data.*

A video screen connected to your computer looks like memory to the 6502, so the 6502 can read from and write to the screen. The keyboard is scanned by I/O (input/output) ports that are decoded to look like any other programmable memory address, so the 6502 can look at the keyboard just by looking at a particular place in memory. Thus, the 6502 can interact directly with memory only, but because all I/O devices are mapped to addresses in memory, the 6502 can interact with the user. See figure 1.3.

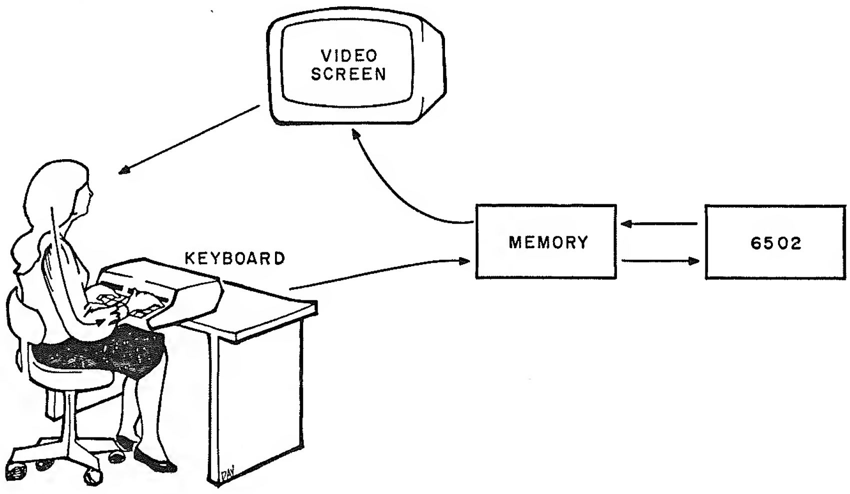


Figure 1.3: *How the 6502 interacts with the user. Arrows indicate the flow of data.*

The Operating System

Thus far we have discussed your machine's hardware. But the Apple, Atari OSI, and PET computers feature more than hardware. For example, all these computers have an operating system (stored in ROM) which includes the I/O software routines that are needed to use the screen and the keyboard. We are not particularly concerned with how these subroutines work, but I assume your system does have such routines.

There are many other subroutines in your computer's operating system. Your system's documentation should tell you what subroutines are available and provide their addresses. All of this means power for you, the programmer. The more you know about your computer, the more you can make it do. Because the software in this book was developed to run on a number of systems, I chose not to use routines available in your machine's ROM, no matter how powerful they might be, unless I could be sure that they would be available in the operating systems of the Apple, the Atari, the OSI, and the PET computers. In other words, the software in this book does not take full advantage of the power in your operating system. But the software you write, which need only run on your system, should exploit to the fullest the power of your computer's ROM routines.

BASIC

One of the most important features of your computer is the BASIC interpreter in ROM. This interpreter is a program that enables your computer to understand commands given in BASIC. Your system's documentation should tell you what commands are legal in the particular dialect of BASIC implemented on your machine. BASIC is an easy language to learn and you can do a lot with it.

Unfortunately, not every dialect of BASIC is the same. A program written in BASIC that runs on machine A may not run on machine B. BASIC is a common language, but not a standard one. Is there any language that *is* standard from system to system?

6502 Code

The central processor is the computer's heart. The Apple, Atari, OSI, and PET computers all use the 6502 microprocessor. Every microprocessor has a certain *instruction set*, or group of instructions, which the microprocessor can execute. These instructions are at a much lower level than the BASIC commands with which you may be familiar. For example, in BASIC you can have a single line in a program to PRINT "HELLO." It would take a sequence of many 6502 instructions to perform the same function.

However, a sequence of microprocessor instructions will run on any computer featuring that microprocessor. Thus, if you write a program consisting of 6502 instructions to perform some function, that program should run on any 6502-based computer. It won't run on an 8080-based computer, a Z80-based computer, or a 6800-based computer, but it should run on an Apple, a PET, an Atari, an OSI, or any other system built around a 6502. 6502 programs can also run much faster than equivalent programs written in BASIC and can be smaller than BASIC programs. The programs presented in this book are all written in 6502 code, and require only half of the memory available on a computer containing 8,000 bytes of programmable memory, thus leaving more than enough room for your own programs.

Chapter 2:

Introduction to Assembler

Ever watch a juggler or a good juggling team? The balls, pins, or whatever are in the air in such intricate patterns that you can hardly follow them, let alone duplicate the performance yourself. It's beautiful, but not magic; just an application of some simple rules. I've learned to juggle recently, and although I'm still a rank beginner, I've taught my two hands to keep three balls moving through the air. Yet neither hand knows very much. A hand will toss a ball into the air, and then it will catch a ball. The other hand will toss a ball into the air, and then it will catch a ball. That's all. My hands perform only two operations: toss and catch. Yet with those two primitive operations I can put on a pleasant little performance.

Assembly-language programming is not so different from juggling. Like juggling, programming enables you to put on an impressive or baffling performance. In its simplest terms, juggling is nothing more than taking something from one place and putting it someplace else. The same thing is true of the central processor: the 6502 takes something from one place and puts it someplace else.

In fact, programming the 6502 is easier than juggling in several ways. First, the 6502 is obviously much faster than even the most skillful juggler. In the time it takes me to pick up a ball with one hand and place that ball somewhere else, the 6502 can get something from one place and put it someplace else hundreds of thousands of times. Sleight of hand requires quickness, and the 6502 is quick.

The 6502 even gives me a helping hand. When I try to juggle, I must keep the balls moving with nothing but my two hands. But my home computer has three hands (registers A, X, and Y in the 6502) and thousands of pockets (8,000 bytes or more of programmable memory).

A byte is 8 bits of data that may be loaded together into a register. A register holds 1 byte. Each location in memory holds 1 byte. The 6502 can affect only 1 byte in one operation. But because the 6502 can perform hundreds of thousands of operations each second, it can affect hundreds of thousands of bytes each second.

Binary

In the final analysis, any value is stored within the computer as a series of bits. If we wish, we may specify a byte by its bit pattern: such a representation uses only ones and zeroes, and is called binary. For example, the number 25 in binary is 00011001.

In binary, each bit indicates the presence or absence of some value. Each bit represents twice as much value, or significance, as the bit to its right, so the right-most bit is the least significant, and the left-most bit is the most significant. Table 2.1 gives the significance of each bit in an 8-bit byte:

Table 2.1: *Bit significance in an 8-bit byte.*

Bit Number:	b7	b6	b5	b4	b3	b2	b1	b0
Bit Significance:	128	64	32	16	8	4	2	1

The right-most bit (called bit 0) tells us whether we have a one in our byte. The bit to its left (bit 1) tells us whether we have a two; the bit to *its* left tells us whether we have a four...and the leftmost bit (bit 7) tells us whether we have a 128 in our byte.

To determine the bit pattern for a given value — say, 25 — determine first what powers of two must be added to equal your value. For instance, 25 = 16 + 8 + 1, so 25 in binary is 00011001.

Twenty-five can be expressed in other ways as well. Rather than specify every number as a pattern of eight ones and zeros, we often express numbers in hexadecimal representation.

Hexadecimal

Unlike binary, which requires a group of eight characters to represent an 8-bit value, hexadecimal notation allows us to represent an 8-bit value with a group of only two characters. These characters are not limited to 0 and 1, but may include any digit from 0 to 9, and any letter from "A" to "F." That gives us a set of sixteen characters, which is just right because we want to represent numbers in base 16.

(Hexadecimal stands for 16: hex for six, and decimal for ten. Six plus ten equals sixteen.)

To represent a byte in hexadecimal notation, divide the 8-bit byte into two 4-bit units (sometimes called *nybbles*). Each of these 4-bit units has a value of from 0 to 15 (decimal), which we express with a single hexadecimal digit. A decimal 10 is a hexadecimal $A. (The dollar sign indicates that a number is in hexadecimal representation.) Table 2.2 gives the conversions of decimal to hexadecimal for decimal numbers 0 thru 15.

Table 2.2: *Hexadecimal character set.*

Hexadecimal Character		Decimal Equivalent
$0	=	0
$1	=	1
$2	=	2
$3	=	3
$4	=	4
$5	=	5
$6	=	6
$7	=	7
$8	=	8
$9	=	9
$A	=	10
$B	=	11
$C	=	12
$D	=	13
$E	=	14
$F	=	15

Appendix A1, *Hexadecimal Conversion Table*, shows the hexadecimal representation of every number from 0 to 255 decimal.

In this book, object code, the only code that the machine can execute directly, will generally be presented in hexadecimal, and a thorough understanding of hexadecimal will help you to interpret instructions and follow some of the 6502's actions. Even the sketchiest understanding of hexadecimal math, however, should be sufficient for you to follow and use the programs in this book.

ASCII Characters

Instead of a number from 0 to 255, an 8-bit byte can be used to represent an upper or lower case letter of the alphabet, a punctuation mark, or a printer-control character such as a carriage return. A string of such bytes may represent a word, a message, or even a complete document. Appendix A2, *ASCII Character Codes*, gives the hexadecimal value for any ASCII character. ASCII stands for American Standard Code for Information Interchange, and is the closest thing the industry has to a standard set of character codes. If you want to store the letter "A" in some location in memory, you can see from Appendix A2 that you must store a $41 in that location.

Whether a given byte is interpreted as a number, an ASCII character, or something else depends entirely on the program using that byte. Just as beauty is in the eye and mind of the beholder, so is the meaning of a given byte determined by the program that sees and uses it.

The Instruction Cycle

A microprocessor such as the 6502 can't do anything without being told. It only knows 151 instructions, called opcodes (operation codes). Each opcode is 1 byte long. An opcode may command the 6502 to take something from one register and to put it someplace in memory, to load some register with the contents of some location in memory, or to perform some other equally simple operation. See Appendix A4 for a list of opcodes for the 6502 microprocessor.

What do 6502s do all day? They work while programmers play. The 6502 gets an opcode, performs the specified operation, gets the next opcode, performs the specified operation, gets the next opcode, performs the...

You get the picture.

How does the 6502 know where to find the next opcode? The 6502 has a 16-bit register called the PC (program counter). The PC holds the address of some location in memory. When the 6502 starts its instruction cycle, it gets the opcode stored at the memory location specified by the PC. Then it performs the operation specified by that opcode. When it has executed that instruction, it makes the PC point to the next opcode and starts on a new instruction cycle by getting the opcode whose address is now in the PC.

Figure 2.1 shows a flowchart for the instruction cycle of the 6502 microprocessor.

"That's it? That's all the 6502 does?" you ask.

That's it. But with the right program in memory, we can make the 6502 dance.

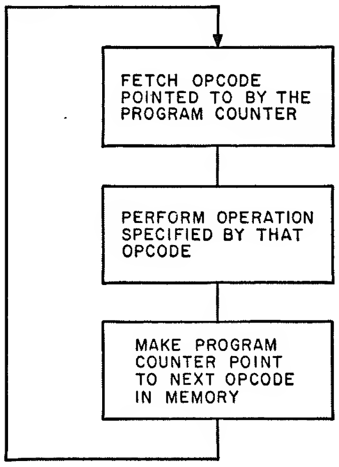

FETCH OPCODE POINTED TO BY THE PROGRAM COUNTER
PERFORM OPERATION SPECIFIED BY THAT OPCODE
MAKE PROGRAM COUNTER POINT TO NEXT OPCODE IN MEMORY

Figure 2.1: *The 6502 instruction cycle.*

Machine Language

A machine-language program is nothing more than a series of machine-language instructions stored in memory. If the PC in the 6502 can be made to hold the address of the start of your program, then we say that the PC is *pointing* to your program. When the 6502 starts its instruction cycle, it will *fetch* the first opcode in your program, and then perform the operation specified by that opcode. At this point, we say that your program is *running*.

Each machine-language instruction is stored in memory as a 1-byte opcode, which may be followed by 1 or 2 bytes of operand. Thus, a 6502 machine-language program might be "A9 05 20 02 04 A2 F5 60."

Just a bunch of numbers! (Hexadecimal numbers, in this case.) But it is exactly these numbers that the machine understands; hence the term, machine language.

Assemblers

Machine language is easy to read — if you're a machine. But programmers are people. So programming tools called assemblers have been developed, which take more readable assembly-language *source code* as input and produce *listings* and *object code* as output. The listing is the assembler's output intended for a human reader. The object code is a series of 6502 machine-language instructions intended to be stored in memory and executed by the 6502.

For each chapter in this book that presents a program, there is an appendix at the back of the book containing an assembler listing and a hexdump of the same program. The assembler listing includes both source and object code, making it easy for you to read the program; the hexdump shows you what the object code for that program actually looks like in your computer's memory. Figure 2.2 shows how an assembler is used to produce an assembler listing for the programmer and object code for the processor.

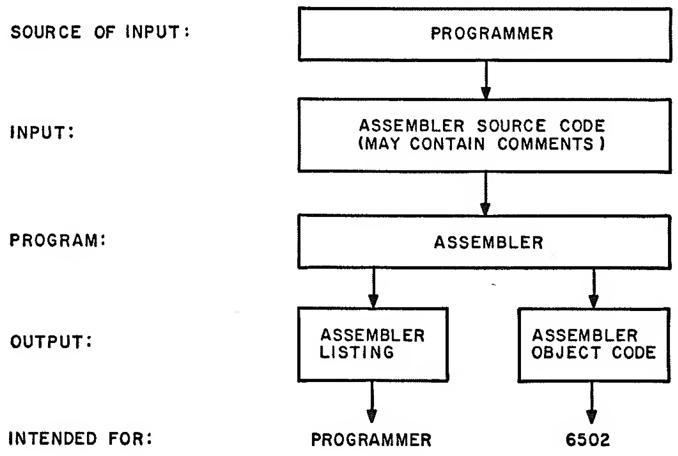


Figure 2.2: *From programmer to object code. The assembler takes source code as input and produces an assembler listing and object code as output.*

The programs in this book have all been produced on the OSI 6500 Assembler/Editor, running under the OSI 65-D Disk Operating System, on an OSI C-IP machine with 24 K bytes of programmable memory and one 5-inch floppy disk. It is likely that the source code presented in this book will assemble immediately or with only minor modification on other 6500 assemblers. (Incidentally, the source code in each chapter of this book should fit into the workspace of a computer with much less than 24 K bytes of user memory, if you delete many of the comments. But then, of course, your listings will be a lot less readable.)

But you don't write a listing; an assembler produces a listing. What you write is assembly-language source code.

Source Code

An assembly-language source program consists of one or more lines of assembly-language source code. A line of assembly-language source code consists of up to four fields:

LABEL MNEMONIC OPERAND COMMENT

The mnemonic, required in all cases, is a group of three letters chosen to suggest the function of a given machine-language instruction. For example, the mnemonic *LDA* stands for *LoaD Accumulator*. *LDX* stands for *LoaD X* register. *TXA* means *T*ransfer the *X* register to the *A*ccumulator. 6502 mnemonics are not nearly as meaningful as BASIC commands, but they're a big improvement over the machine-language opcodes. See Appendix A3 for a list of 6502 mnemonics.

Some operations require an operand field. For example, the operation *load accumulator* requires an operand, because the line of source code must specify what you wish to load into the accumulator.

The label and comment fields are optional. A label lets you operate on some location in memory by a name that you have assigned to it. Comments are not included in the object code that will be assembled from your program, but they make your source code and your listings much more meaningful to a human reader. When you write a program, even if no one but yourself will ever read it, try to choose your labels and comments so that someone else can understand the purpose of each part of the program. Such careful documentation will save you a lot of time weeks or months down the road, when you might otherwise reread your program and have no idea why you included some unlabeled, uncommented line of source code.

Loading a Register

Let's write a simple program to load a register with a number — say, to load the accumulator with the number "10." Since we want to load the accumulator, we'll use the LDA instruction. (If we wanted to load the X register, we would use the LDX instruction, and if we wanted to load the Y register, we'd use LDY.) We know what mnemonic to write into our first line of source code. But a glance at Appendix A6, *6502 Opcodes by Mnemonic and Addressing Mode*, shows that LDA has many addressing modes. What operand shall we write into this line of source code?

We know that we want to load the accumulator with a "10," and not with any other number, so we can use the immediate addressing mode to load a "10" directly into the accumulator. We'll use a "#" sign to indicate the immediate mode:

Example I

```
LDA #10
```

Example 1 is a legitimate line of source code containing only two fields: a mnemonic and an operand. The mnemonic, LDA, means "load the accumulator." But load it with what? The operand tells us what to load into the accumulator. The "#" sign specifies that this operation is to take place in the immediate mode, which means we want to load the accumulator with a constant to be found in this line of source code, rather than with data or a variable to be found in some location in memory. Then the operand specifies the constant to be loaded into the accumulator, in this case "10."

Constants

A constant is any value that is known by the programmer and "hard-wired" into the code. A constant does not change during the execution of a program. If a value changes during the execution of a program, then it is a variable, and one or more memory locations must be allocated to hold the current value of each variable.

There are several kinds of constants. Any number is a constant. The number "7," for example, is a constant: a seven now will still be a seven this afternoon. A character is another kind of constant: the letter "A" will still be the letter "A" tomorrow. But a variable, such as one called FUEL, will change during the course of a program (such as a lunar lander simulation), so it is not a constant.

In Example 1, note that the "#" sign is the only punctuation in the operand field. In the absence of special punctuation marks (such as the dollar sign indicating a hexadecimal number and the apostrophe indicating an ASCII character representation), any numbers given in this book are in decimal.

What object code will be assembled from this line of source code? Let's hand-assemble it and see. Appendix A6 shows us that the opcode for load accumulator, immediate mode, is $A9. So the first byte of object code for this instruction will be $A9. The second byte must specify what the 6502 should load into the accumulator. We want to load register A with a decimal 10, which is $0A. So the object code assembled from Example 1 is: A9 0A.

When these 2 bytes of object code are executed by the 6502, it will result in the accumulator holding a value of $0A, or decimal 10. In effect, we've just told a juggler: put a "10" in your right hand.

What if we wanted to load the accumulator with the letter "M," rather than with a number? We'd still use LDA to load the accumulator, and we'd still use the immediate mode of addressing, specifying in the operand the constant to be loaded into the accumulator. Either of the following two lines of source code will work:

Example 2

```
LDA #'M
```

or

```
LDA #$4D
```

In each line of source code above, the mnemonic and the "#" sign tell us we're loading the accumulator in the immediate mode — ie: with a constant. The operand following the "#" sign specifies the constant. An apostrophe indicates that an ASCII character follows, whereas a "$" sign indicates that a hexadecimal number follows. Appendix A2 shows that an ASCII "M" = $4D; they are simply two representations of the same bit pattern. So the two lines of source code above are equivalent; they will both assemble into the same object code: A9 4D.

Which of the two lines of source code is more readable? If a constant will be used in a program as an ASCII character, then represent it in your source code as an ASCII character.

Storing the Register

Now let's say we want to store the contents of the accumulator someplace in memory. Every location in memory has a unique address (just like houses do), ranging from $0000 to $FFFF. Suppose we decide to store the contents of the accumulator at memory location $020C. We could do it with the following line of source code:

Example 3

```
STA $020C
```

Example 3 will assemble into these 3 bytes of machine language: 8D 0C 02.

According to the Appendix A6, the 6502 opcode for "store accumulator, absolute mode" (STA) is $8D.

When the 6502 fetches the opcode "8D," it knows that it must store the contents of the accumulator at the address specified by the next 2 bytes. This is why it is called absolute mode. Absolute mode is used when specifying an exact memory location in an instruction.

In the example above, that address seems wrong. It looks like the machine-language operand is specifying address $0C02, because the bytes are in that order: "0C" followed by "02." But we want to operate an address $020C. Is something wrong here?

Low Byte First

You and I might think something is wrong when the address $020C is written as an "0C" followed by an "02" but you and I are people. We don't think like the 6502. When you and I write a number, we tend to write the most significant digit first and the least significant digit last. But the 6502 doesn't work that way. When the 6502 interprets two sequential bytes as an address, the first byte must contain the less significant part of the address (the "low byte"), and the second byte must contain the more significant part of the address (the "high byte"). All addressing modes that require a 2-byte operand require that the 2 bytes be in this order: less significant byte first, followed by the more significant byte.

However, not all addressing modes require a 2-byte operand.

Zero-Page Addressing

Memory is divided into pages, where a page is a block of 256 contiguous addresses. The page from $0000 to $00FF is called the zero page, because all addresses in this page have a high byte of zero. The zero-page addressing mode takes advantage of this fact. Source code assembled using the zero-page addressing mode requires only 1 byte in the operand, because the opcode specifies the zero page mode of addressing, and the high byte of the operand is unnecessary because it is understood to be zero. Thus, you can specify an address in the zero page by the absolute or by the zero-page addressing mode, but the zero-page mode will let you do it using one less byte.

If you want to use some location in the zero page to hold a number, you might decide to use location $00F4. We could write:

Example 4

```
STA $00F4
```

or

```
STA $F4
```

We could then assemble either line of source code using the absolute addressing mode: 8D F4 00. Or we could assemble either line of source code using the zero-page mode: 85 F4.

The opcode "85" means "store accumulator, zero page." Where in the zero page? At location $F4 in the zero page, the same location whose absolute address is $00F4.

Symbolic Expressions

Let's say you want to copy the 3 bytes at memory locations $0200, $0201, and $0202 to $0300, $0301, and $0302, respectively. We could write these lines of source code:

Example 5

```
LDA $0200
STA $0300
LDA $0201
STA $0301
LDA $0202
STA $0302
```

This alternately loads a byte into the accumulator, then stores the contents of the accumulator into another byte in memory. Note that loading a register from a location in memory changes the register, but leaves the contents of the memory location unchanged.

Or we could write the following code, which refers to addresses as symbolic expressions:

Example 6

```
1   ORIGIN = $0200
2   DEST   = $0300
3   LDA    ORIGIN
4   STA    DEST
5   LDA    ORIGIN + 1
6   STA    DEST + 1
7   LDA    ORIGIN + 2
8   STA    DEST + 2
```

In Example 6, lines 1 and 2 are assembler directives, which equate the labels "ORIGIN" and "DEST" with the addresses $0200 and $0300, respectively. Other lines of source code following these *equates* may then refer to these addresses by their labels, or refer to any address as a symbolic expression consisting of labels and, optionally, constants and arithmetic operators. The source code above will cause an assembler to generate exactly the same object code as the source code in Example 5, but Example 6, whose operands consist of symbolic expressions, is much more readable than Example 5, whose operands are given in hexadecimal.

Some Exercises

1) Write the 6502 instructions necessary to load the accumulator with the value 127, to load the X register with the letter "r," and to load the Y register with the contents of address $BO92.

2) Write the 6502 instructions necessary to copy the byte at address $0043 to the address $0092.

Chapter 3:

Loops and Subroutines

Indexed Addressing

Although readable, Example 6 is not very efficient, because it requires two lines of source code to move each byte. If we want to move 50 or 100 bytes must we then write 100 or 200 lines of source code?

Indexed addressing comes in quite handily here. Instead of specifying the absolute or zero-page address on which an operation is to be performed, we can specify a *base address* and an *index* register. The 6502 will add the value of the specified index registers to the base address, thereby determining the address on which the operation is to be performed. Thus, if we want to move 9 bytes from an origin to a destination, we could do it in the following manner, using the indexed addressing mode with X as the index register:

Example 7

```
          ORIGIN = $0200
          DEST   = $0300

INIT      LDX #0              Initialize X register to zero, so we'll start
                              with the first byte in the block.
GET       LDA ORIGIN,X        Get Xth byte in origin block.
PUT       STA DEST,X          Put it into the Xth position in the
                              destination block.
ADJUST    INX                 Adjust X for next byte by incrementing
                              (adding 1) to the X register.
```

```
TEST     CPX #9          Done 9 bytes yet?
BRANCH   BNE GET         If not, go back and get next byte...
```

We will use Example 7 in the following sections to introduce several new instructions and addressing modes. Example 7 includes six lines of source code to move 9 contiguous bytes of data. If we tried to move 9 bytes of data with the techniques used in Examples 5 and 6, it would have taken eighteen lines of source code. So with indexed addressing, we've saved ourselves twelve lines of code. But how do these lines work? The lines are labeled so we can look at them one-by-one.

The instruction labeled INIT loads the X register in the immediate mode with the value zero. After executing the line INIT, the 6502 has a value of zero in the X register. We don't know anything about what's in the other registers.

GET loads the accumulator with the Xth byte above the address labeled ORIGIN. The first time the 6502 encounters this line, the X register will hold a value of zero, so the 6502 will load the accumulator with the zeroth byte above the address labeled ORIGIN (ie: it will load the accumulator with the contents of the memory location ORIGIN).

In any line of source code, a comma in the operand indicates that the operation to be performed shall use an indexed addressing mode. A comma followed by an "X" indicates that the X register will be the index register for an instruction, whereas a comma followed by a "Y" indicates that the Y register will be the index for an instruction. There are a number of indexed addressing modes. Two of these are absolute indexed and zero-page indexed. The line GET in Example 7 uses the absolute indexed addressing mode if ORIGIN is above the zero page; if ORIGIN is in the zero page then the line labeled GET can be assembled using the zero-page indexed addressing mode. Zero-page indexed addressing, like zero-page addressing, requires only 1 byte in the operand.

In zero-page indexed and in absolute indexed addressing, the operand field specifies a base address. The 6502 will operate on an address it determines by adding to the base address the value of the specified index register (X or Y). Only if the specified index register has a value of zero will the 6502 operate on the base address itself; in all other cases the 6502 will operate on some address higher in memory.

So we've loaded the accumulator with the byte at ORIGIN. Now the 6502 reaches the line labeled PUT in Example 7. This line tells the 6502 to store the accumulator in the Xth byte above DEST. We haven't done anything to change X since the line INIT set it to zero, so X still holds a value of zero. Therefore, the 6502 will store the contents of the accumulator in the zeroth byte above DEST (ie: in DEST itself).

At this point, we have succeeded in moving 1 byte from ORIGIN to DEST. X is still zero. Now comes the part that makes indexing worthwhile. The line labeled ADJUST is the shortest line of source code we've seen yet, consisting only of the mnemonic INX, which means "increment the X register." Since the X register was zero, when this line is executed the X register will be left holding a value of one.

Compare Register

In Example 7, the line labeled TEST compares the value in the X register with the number "9." There are three compare instructions for the 6502, one for each register. CMP compares a value with the contents of the accumulator; CPX compares a value with the contents of the X register, and CPY compares a value with the contents of the Y register.

We can use these compare instructions to compare any register with any value in memory, or, in the immediate mode, to compare any register with any constant. Such comparisons enable us to test for given conditions. For example, in Example 7, the line labeled TEST tests to see if we've moved 9 bytes yet. If the X register holds the value "9," then we have moved 9 bytes. (Walk through the loop yourself. When you have moved the zeroth through the eighth bytes above ORIGIN to the zeroth through the eighth positions above DEST, then you have moved 9 bytes.)

A compare instruction never changes the contents of a register or of any location in memory. Thus, the X register does not change when the line labeled TEST is executed by the 6502. What may change, however, are some of the 6502's status flags.

Status Flags

In addition to the 6502's general-purpose registers (A, X, and Y), the 6502 contains a special register P, the processor status register. Individual bits in the processor status register are set or cleared each time the 6502 performs certain operations. These bits, or hardware flags, are:

C	bit 0:	Carry Flag
Z	bit 1:	Zero Flag
I	bit 2:	Interrupt Flag
D	bit 3:	Decimal Flag
B	bit 4:	Break Flag
	bit 5:	Undefined
V	bit 6:	Overflow Flag
N	bit 7:	Negative Flag

In this book, we will not discuss the use of all the flags in the processor status register. In this quick course in assembly-language programming, and in the software subsequently presented in this book, the three flags we will deal with are C, the carry flag; Z, the zero flag; and N, the negative flag.

A compare operation (CMP, CPX, or CPY) does not change the value of registers A, X, or Y, but it does affect the carry, zero, and negative flags.

For example, if a register is compared with an equal value, the zero flag, Z, will be set; otherwise, Z will be cleared. If an instruction sets bit 7 of a register or an address, the negative flag of the status register will also be set; conversely, if an instruction clears bit 7 of a register or an address, the negative flag will be cleared. Similarly, mathematical and logical operations set or clear the carry flag, which acts as a ninth bit in all arithmetic and logical operations. Table 3.1 summarizes the effects of a compare instruction on the status flags.

Table 3.1: *Status flags affected by compare instructions. Note that if you wish to test the status of the carry flag after a compare, you must set it (using the instruction SEC) before the compare. When testing the N flag, think of the inputs as signed 8-bit values.*

	Carry Flag*	Negative Flag	Zero Flag
Compare a register with an *equal* value and you	set C,	clear N, and	set Z.
Compare a register with a *greater* value and you	clear C,	clear N, and	clear Z.
Compare a register with a *lesser* value and you	set C,	clear N, and	clear Z.

Conditional Branching

We can have a program take one action or another, depending on the state of a given flag. For example, two instructions, BEQ, (*B*ranch on result *EQ*ual) and BNE (*B*ranch on result *N*ot *E*qual) cause the 6502 to *branch*, or jump to a new instruction, based on the state of the zero flag. An instruction which causes the 6502 to branch based on the state of a flag is called a conditional branch instruction. Other conditional branch instructions are based on the state of other status flags and are given in table 3.2.

*If you wish to test the status of the carry flag after a compare, you must set it (using the instruction SEC) before the compare.

Table 3.2: *Conditional branch instructions.*

Flag	Instruction	Description	Opcode
C	BCC	Branch if carry clear.	90
C	BCS	Branch if carry set.	B0
N	BPL	Branch if result positive.	10
N	BMI	Branch if result negative.	30
Z	BEQ	Branch if result equal. (Zero Flag set).	F0
Z	BNE	Branch if result not equal. (Zero flag clear.)	D0
V	BVC	Branch if overflow flag clear.	50
V	BVS	Branch if overflow flag set.	70

The line labeled TEST in Example 7 compares the X register to the value "9;" this sets or clears the zero flag. The line labeled BRANCH then takes advantage of the state of the zero flag, by branching back to the line labeled GET if the result of that comparison was not equal. But if Y did equal "9," then the result of the comparison would have been equal, and the 6502 would *not* branch back to GET. Instead, the 6502 would execute the instruction following the line labeled BRANCH.

Loops

Example 7 shows a program loop. We cause the 6502 to perform a certain operation many times, by initializing and then incrementing a counter, and testing the counter each time through the loop to see if the job is done.

There's a lot of power in loops. What would we have to add or change in Example 7 so that it moves not 9, but 90 bytes from one place to another? Happily, we wouldn't have to add anything, and we'd only have to change the operand in the line labeled TEST. Instead of comparing the X register with 9, we'd compare it with 90. See Example 8.

Example 8

Move 90 bytes from origin to destination.

```
ORIGIN = $0200
DEST   = $0300
```

```
INIT      LDX #0            Initialize X register to zero, so we'll start
                            with the first byte in the block.
GET       LDA ORIGIN,X      Get Xth byte in origin block.
PUT       STA DEST,X        Put it into the Xth position in the
                            destination block.
ADJUST    INX               Adjust X for next byte.
TEST      CPX #90           Done 90 bytes yet?
BRANCH    BNE GET           If not, get next byte...
```

Writing loops lets us write code that is not only compact, but easily tailored to meet the demands of a particular application. We couldn't do that, however, without indexing and branching.

Loops can be tricky, though. What's wrong with this loop?

Example 9

```
          ORIGIN = $0200
          DEST   = $0300

INIT      LDX #0            Initialize X register to zero, so we'll start
                            with the first byte in the block.
GET       LDA ORIGIN,X      Get Xth byte in origin block.
PUT       STA DEST,X        Put it into the Xth position in the
                            destination block.
TEST      CPX #9            Done 9 bytes yet?
BRANCH    BNE GET           If not, get next byte...
```

Examine Example 9 very carefully. How does it differ from Example 7? It lacks the line labeled ADJUST, which increments the X register. What will happen when the 6502 executes the code in Example 9? It will initialize X to zero; it will get a byte from ORIGIN and move it to DEST. Then it will compare the contents of register X to 9. Register X won't equal 9, so it will branch back to GET, where it will do *exactly what it did the first time through the loop*, because X will still equal zero. Until the X register equals 9, the 6502 will branch back to GET. But nothing in this loop will ever change the value of X! So the 6502 will sit in this loop forever, getting a byte from ORIGIN and putting it in DEST and determining that the X register does not hold a 9...

Now look at Example 10. Will it cause the 6502 to loop, and if so, will the 6502 ever exit from the loop? Why, or why not?

Example 10

```
                ORIGIN = $0200
                DEST   = $0300

INIT            LDX #0                  Initialize X register to zero, so we'll start
                                        with the first byte in the block.
GET             LDA ORIGIN,X            Get Xth byte in origin block.
PUT             STA DEST,X              Put it into the Xth position in the
                                        destination block.
ADJUST          INX                     Adjust X for next byte.
TEST            CPX #9                  Done 9 bytes yet?
BRANCH          BNE INIT                If not, get next byte...
```

Relative Addressing

All conditional branch instructions use the relative addressing mode, and they are the only instructions to use this addressing mode. Like the zero page and zero-page indexed addressing mode, the relative addressing mode requires only a 1-byte operand. This operand specifies the relative location of the opcode to which the 6502 will branch if the status register satisfies the condition required by the branch instruction. A relative location of 04 means the 6502 should branch to an opcode 4 bytes beyond the next opcode, if the given condition is satisfied. Otherwise, the 6502 will proceed to the next opcode.

Because the operand in a conditional branch instruction is only 1 byte, it is not possible for a conditional branch instruction to cause a branch more than 127 bytes forward or 128 bytes backward from the current value of the program counter. (A branch backward is indicated if the relative address specified is negative; forward if it's positive. A byte is negative if bit 7 is set. A byte is positive if bit 7 is clear. Thus, a value of 00 is considered positive.) However, an instruction called JMP allows the programmer to specify an unconditional branch to any location in memory. Therefore, if we have a short conditional branch followed by an unconditional jump, we may achieve in two instructions a conditional branch to any location in memory.

Unconditional Branch

Just as BASIC has its GOTO command, which causes an unconditional branch to a specified line in a BASIC program, the 6502 has its JMP instruction, which unconditionally branches to a specified address. A program may loop forever by JMP'ing back to its starting point.

Look at Example 11. Unless a line of code within the loop causes the 6502 to branch to a location outside of the loop, the 6502 will sit in this loop forever.

Example 11

Endless Loop:

```
START   xxxxxxxxxx      some
        xxxxxxxxxx      instructions
        xxxxxxxxxx
        JMP START
```

Indirect Addressing

A JMP instruction may be written in either the absolute addressing mode or the indirect addressing mode. Absolute addressing is used in Example 11. The operand is the address to which the 6502 should jump. But in the indirect mode (which is always signified by parentheses in the operand field) the operand specifies the address of a *pointer*. The 6502 will jump to the address specified by the pointer; it will not jump to the pointer itself.

The line of code "JMP (POINTR)" will cause the 6502 to jump to the address specified by the 2 bytes at POINTR and POINTR+1. Thus, if POINTR = $0600, and the 6502 executes the instruction "JMP (POINTR)" when memory location $0600 holds $00 and $0601 holds $20, then the 6502 will jump to address $2000. (Remember, addresses are always stored in memory with the low byte first.)

How Branching Works

Incidentally, all branches, whether relative, absolute, or indirect, work by operating on the contents of the PC (program counter). Before any branch instruction is executed, the PC holds the address of the current opcode. A branch instruction changes the PC, so that in the next instruction cycle the 6502 will fetch not the opcode following the current opcode, but the opcode at the location specified by the branch instruction. Then execution will continue normally from the new address.

Relocatability

Often I implement short unconditional branches as:

```
        CLC
        BCC     PLACE
```

rather than as:

```
        JMP     PLACE
```

This is because the first method (relying as it does on relative rather than absolute addressing) will still work even if you relocate the code in which it is contained. Making your code relocatable will save you time and trouble when you try to move your programs around in memory and still want them to work.

To relocate code containing the second example, you'd have to change the operand field because the absolute address of PLACE will have changed. To relocate code containing the first example, you wouldn't have to change a thing.

Subroutines

Perhaps the two most powerful instructions available to the assembly-language programmer are the JSR (*J*ump to *S*ub*R*outine) and the RTS (*R*e*T*urn from *S*ubroutine). These instructions (equivalent to GOSUB and RETURN in BASIC) enable us to organize chunks of code as building blocks called subroutines.

Think of the subroutine as a job. Your computer can do more work for you if it knows how to do more jobs. Once you teach the 6502 how to do a given job, you won't have to tell it twice. Let's say you're writing a program in which the same operation must be performed at various times within a program. In every location within your program where the operation is required, you could include code to perform that operation. On the other hand, you could write code in one place to perform that operation, but write that code as a subroutine, and then *call* that subroutine whenever necessary from the main, or calling program. A call to a subroutine causes that routine to execute. When finished, it returns to the instruction following the call in the main program.

It only takes one line of code to call a subroutine. JSR SUB will call the subroutine located at the address labeled SUB. After the 6502 fetches and executes the JSR opcode, the next opcode it fetches will be at the address labeled SUB, in this example. So far it looks like an unconditional JMP. The 6502 will fetch and execute opcodes from the addresses following SUB, until it encounters an RTS instruction.

When the 6502 fetches an RTS instruction, it returns to its caller, jumping to the first opcode following the JSR instruction that called the subroutine. In effect, when a line of code calls a subroutine, the 6502 remembers where it is before it jumps to the new location. Then when it encounters an RTS instruction, it knows the address to which it should return because it remembers where it came from. It then continues to fetch opcodes from the point following the JSR instruction. Figure 3.1 illustrates this procedure. Note that the same subroutine may be called from many different points in the same program, and will always return to the opcode following the JSR instruction that called it.

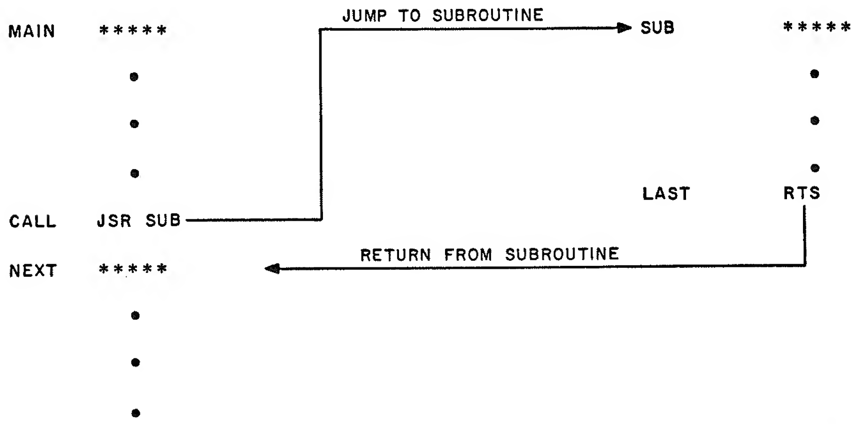


Figure 3.1: *Jump to and return from subroutine. When the processor encounters a JSR (jump to subroutine) instruction, the next instruction executed is the first instruction of the subroutine. Here, the subroutine SUB is called from MAIN. The last instruction executed in a subroutine must be an RTS (return from subroutine) instruction. Here, the instruction at label LAST in subroutine SUB returns control to the next instruction following the call to the subroutine in the main program, the instruction labeled NEXT. The subroutine SUB can be called anywhere in the program MAIN when the particular function of SUB is needed.*

Subroutines allow you to structure your software. With structured software, you can make changes to many programs just by changing one subroutine. If, for example, all programs that print characters do so by calling a single-character-print subroutine, then any time you improve that subroutine you improve the printing behavior of all your programs. Changing something only once is a tremendous advantage over having to change something in many different (usually undocumented) places within a piece of code. For these reasons, all of the software in this book uses subroutines.

Dummies

A *dummy subroutine* is a subroutine consisting of nothing but an RTS instruction. A line of code in a program can call a dummy subroutine and nothing will happen; the 6502 will return immediately, with its registers unchanged.

So why call a dummy subroutine?

A call to a dummy subroutine provides a "hook," which you may use later to call a functional subroutine. While developing a program, I may have many lines of code that call dummy subroutines. Later, when I write the lower-level subroutines, it's easy to change my program so that it calls the functional subroutines rather than the dummy subroutines. Trying to insert a subroutine call to a program lacking such a hook can make you wish for a "memory shoehorn," which might let you squeeze 3 extra bytes of code into the same address space.

The Stack

In addition to the addressing modes that enable the 6502 to access addressable memory, one addressing mode lets the 6502 access a 256-byte portion of memory called the *stack*.

You may think of this stack as a stack of trays in a cafeteria. The only way a tray can be added is to place it on top of the existing stack. Similarly, the only way to get a tray from the stack is to remove one from the top. This is the LIFO (Last-In, First-Out) method. The last tray placed onto the stack must be the first tray removed.

In our case, when an item is placed onto the top of the stack, it is called a *push*, and when an item is removed from the top of the stack, it is called a *pop*. The last item onto the stack is said to be at the *top* of the stack.

For example, let's say we want to place two items onto the stack. (Each item has an 8-bit value, perhaps a number or an ASCII character; see figure 3.2a.) First we push item 1 onto the stack, as illustrated in figure 3.2b. All positions above item 1 on the stack are said to be *empty*, the item 1 is on the top of the stack.

Now, push item 2 onto the stack (see figure 3.2c). What happens? Item 2 is now at the top of the stack, not item 1, although item 1 is still on the stack.

Next, to get item 2 back off the stack, we do a pop (see figure 3.2d). This makes item 1 the top of the stack again. Finally, another pop will remove item 1 from the stack, leaving the stack completely empty. Note that we had to pop item 2 from the stack before we could get to item 1 again. This is the LIFO principle.

The instruction PHA lets you push the contents of the accumulator onto the stack. PLA lets you load the accumulator from the top of the stack (a pop). PHP lets you push the processor status register onto the stack. PLP lets you load the processor status register from the stack.

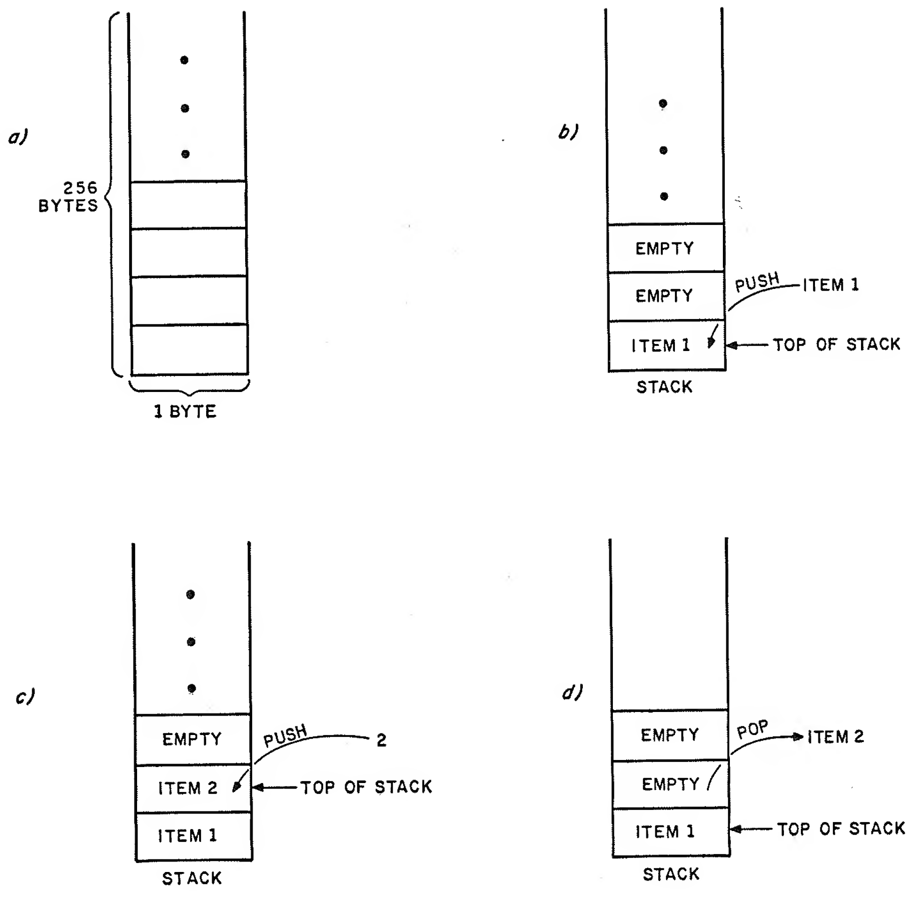


Figure 3.2: *Pushing and popping the stack.*

The stack is a very convenient "pocket" to use when you want to store one or a few bytes temporarily without using an absolute place in memory. Subroutines may pass information to the calling routines by using the stack, but be careful: if a subroutine pushes data onto the stack, and fails to pop that data from the stack before executing an RTS instruction, then that subroutine will *not* return to its caller. This happens because when the 6502 executes a JSR instruction, it pushes the return address—that is, the address of the opcode following the JSR instruction—onto the stack. A subroutine can return to its caller only because its return address is on the stack. If its return address is not at the top of the stack when the subroutine executes an RTS, it will not return to its caller. So a subroutine should always restore the stack before trying to return.

Chapter 4:

Arithmetic and Logic

Character Translation

As demonstrated by Examples 7 and 8, indexed addressing is handy for performing a given operation (such as a move) on a contiguous group of bytes. But it also has another important application: table lookup. For example, let's say you and a friend have decided to write notes to one another using a substitution code. For every letter, number, and punctuation mark in a message, you've agreed to substitute a different character. A "W" will be replaced with a "Y;" a semicolon may be replaced with a "9," etc.

You each have the same table showing you what to substitute for each character that may appear in a message. So you write a note to your friend in English, and then, using this table (which might be in the form of a Secret Agent Decoding Ring) you code, or encrypt, your note. You send the note in its encrypted form to your friend. Anyone else looking at the note would just see garbage, but your friend knows that a message can be found in it. So he gets his copy of the character translation table (which may be in *his* Secret Agent Decoding Ring), and he translates the encrypted message back into English, looking up the characters that correspond to each character in the coded message.

Children often enjoy coding and decoding messages in this way, but I find it about as much fun as filling out forms — which is no fun at all. Unfortunately, programming often involves character translation. Fortunately, I don't have to do it myself. I let my computer perform any necessary character translation by having it do what our two secret agents were doing: look up answers in a table.

Example 12
Character Translation Subroutine

```
XLATE     TAX                       Use character to be translated as an in-
                                    dex into the table.
          LDA TABLE,X               Look up value in table.
          RTS                       Return to caller, bearing translated
                                    character in A and original character in
                                    X.
```

Transfer Register

In Example 12, the subroutine XLATE assumes when it is called that the accumulator holds the byte to be translated. This byte might be a letter, a number, a punctuation mark, a control code, or a graphic character, but however you think of it, it's an 8-bit value. Line 1 of XLATE transfers that 8-bit value from the accumulator to the X register, using the register-transfer instruction TAX.

Register-transfer instructions operate only on registers; they do not affect addressable memory. These instructions allow the contents of one register to be copied, or transferred, to another. The results of a transfer leave the source register unchanged, and the destination register holding the same value as the source register. The 6502's register-transfer instructions are:

TAX	Transfer accumulator to X register.
TAY	Transfer accumulator to Y register.
TXA	Transfer X register to accumulator.
TYA	Transfer Y register to accumulator.

Register transfers do not affect the status flags.

These instructions let you transfer A to X or Y, or to transfer X or Y to A. But how would you transfer X to Y, or Y to X? (Hint: it will take two lines of source code, each line an instruction from the list above.)

Table Lookup

In Example 12, line 2 of XLATE actually performs the character translation by looking up the desired data in a table. The label, TABLE, identifies the base address for a table that we've previously entered into memory. The indexed addressing mode allows line 2 to get the Xth byte above the base address (ie: to get the Xth byte of the table). When that line is executed, the table lookup is complete. The 6502 has looked up and now holds in the accumulator the Xth byte in the table. Now all the 6502 must do is return to its caller, bearing the translated character in A and the original character in X. It accomplishes this with the RTS instruction.

Now you can perform this character translation at any point in any program with just one line of source code:

```
JSR XLATE
```

Table lookup gives me great flexibility as a programmer. If a program uses a table lookup and for some reason I want the program to behave differently, I will probably only have to change some values in the table; it's unlikely that I'll have to change the table lookup code itself. If I've set up my table well, I might not have to change anything in the program except the data in the table.

Table lookup is therefore a very fast and flexible means of performing data translation. But the cost of that speed and flexibility can be size. You might be able to solve any problem with the right tables in memory, but not if you can't afford the memory necessary to hold all those tables. It's great when a program can just look up the answers it needs, but sometimes a program will actually have to *compute* its answers.

Arithmetic Operations

The 6502 can perform the following 8-bit arithmetical operations:

Shift
Rotate
Increment
Decrement
Add
Subtract

To understand how the 6502 operates on a byte, you must *think of the bits* in that byte. Even if the byte represents a number or a letter, don't think about what you can do to that number or letter. Think about what you can do to the pattern of bits in that byte.

What *can* you do to those bits?

Shift

You can shift the bits in a byte one position to the left or to the right. An ASL (Arithmetic Shift Left) operates on a byte in this manner: it moves each bit one bit to the left; it moves the leftmost bit (bit 7) into the carry flag, and it sets the rightmost bit (bit 0) to zero. See figure 4.1.

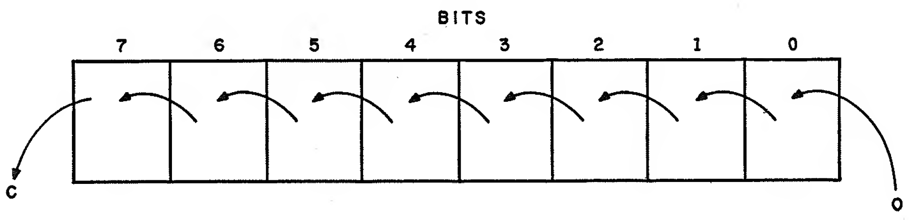


Figure 4.1: *Effect of the ASL instruction.*

For example, if the byte at location TMP has the following bit pattern:

```
address TMP      0   1   0   1   0   1   1   0
```

then after the instruction "ASL TMP" is executed, the data would look like:

```
address TMP      1   0   1   0   1   1   0   0
```

with the carry flag being set to the previous value of bit 7, in this case 0. If the same instruction is again executed, the data becomes:

```
address TMP      0   1   0   1   1   0   0   0
```

and the carry flag is set to 1.

A LSR (Logical Shift Right) has just the opposite effect of the ASL. All bits are shifted to the right towards the carry flag, introducing zeroes through bit 7. See figure 4.2.

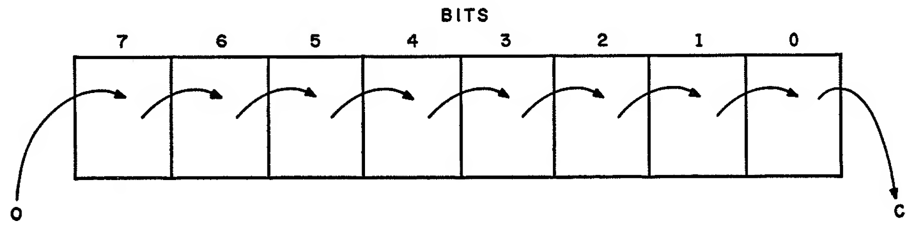


Figure 4.2: *Effect of the LSR instruction.*

For example, if the byte at location TMP is as originally given above, then after the instruction "LSR TMP" is executed, the data at TMP becomes:

```
address TMP    0  0  1  0  1  0  1  1
```

with the carry flag being set to the previous value of bit 0, in this case zero. If the same instruction is executed again, the data becomes:

```
address TMP    0  0  0  1  0  1  0  1
```

with the carry flag set to 1.

Because a number is represented in binary (each bit represents a successive power of two), some arithmetic operations are simple. To divide a byte by two, simply shift it right; to multiply a value in a byte by two, simply shift it left.

Rotate

You can also rotate the bits in a byte to the left or to the right *through* the carry flag. Unlike shifting, rotating a byte preserves all the information originally contained by a byte.

Figure 4.3 shows how a ROL (rotate left) instruction works. For instance, let's say the data at address TMP is originally the same as in previous examples:

```
address TMP    0  1  0  1  0  1  1  0
```

and let's say that the carry flag is set (ie: it holds a 1).

After a "ROL TMP" instruction is executed, the data becomes:

```
address TMP    1  0  1  0  1  1  0  1
```

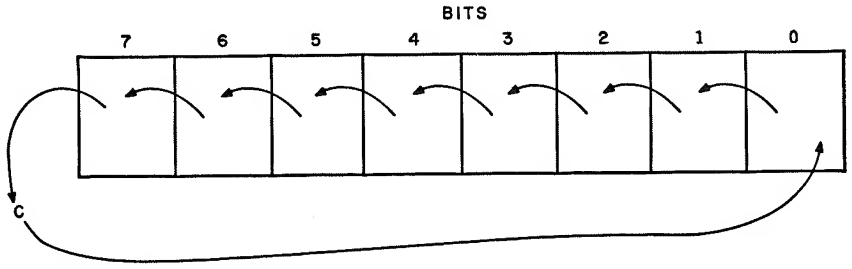


Figure 4.3: *Effect of the ROL instruction.*

and the carry bit is set to the previous value of bit 7, namely 1. Notice that bit 0 in TMP now holds the original contents of the carry flag, and the carry flag holds the original contents of bit 7. Otherwise, everything looks just the same as in the ASL operation. After a second execution of the instruction "ROL TMP," the data becomes:

```
address TMP     0   1   0   1   1   0   1   1
```

with the carry flag set to 1.

In a rotate left instruction, bit 0 is always set from the carry flag. (In the ASL instruction, bit 0 is always set to 0.) If this had been an ASL instruction, what would the bit pattern at TMP be?

Figure 4.4 shows how a ROR (rotate right) instruction works. It is similar to ROL, except that the carry flag is set *from* bit 0, and bit 7 is set from the carry flag.

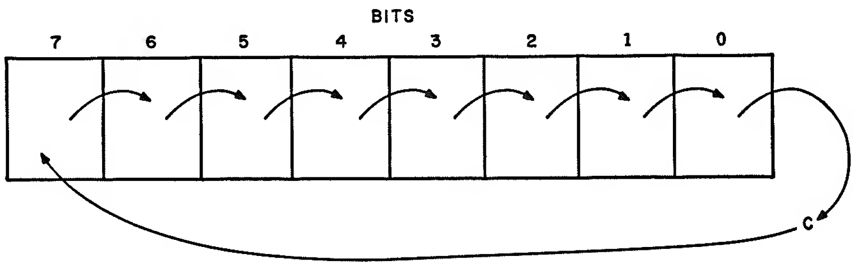


Figure 4.4: *Effect of the ROR instruction.*

Rotate a byte left nine times and you'll still have the original byte. The same is true if you rotate a byte right nine times. But *shift* a byte left nine times, or right nine times, and you know what you've got left? Nothing!

Increment, Decrement

You can increment or decrement a byte in three ways: using the INC and DEC instructions to operate on a byte in memory, using INX and DEX to operate on the X register, or using INY and DEY to operate on the Y register. None of these instructions affects the carry flag. They do affect the zero flag: Z is set if the result of an increment or decrement is zero; otherwise Z is cleared. The negative flag is set if the result of an increment or decrement is a byte with bit 7 set; otherwise N is cleared.

Note that if you increment a register or address holding $FF, it will hold zero. And similarly, if you decrement a register or address holding a zero, it will hold $FF.

You cannot increment or decrement the accumulator, but you can add or subtract a byte from the accumulator.

Addition

Example 13 shows how to add a byte from the location labeled NUMBER to the accumulator:

Example 13

CLC	Clear the carry flag.
ADC NUMBER	Add the contents of location NUMBER to the accumulator.

After these instructions are executed, the accumulator will hold the low 8 bits of the result of the addition. If, following the addition, the carry flag is set, then the result of the addition was greater than 255; if the carry flag is clear, then the result was less than 256, and, therefore, the accumulator is holding the full value of the result. Remember, the carry flag must be cleared before performing the ADC instruction.

Subtraction

Subtraction is as easy as addition. To subtract a byte from the accumulator, first set the carry flag (using the SEC instruction) and then subtract from the accumulator a constant or the contents of some address, using the instruction SBC (subtract with carry):

SEC	Set the carry flag.
SBC OPERND	Subtract from accumulator the value of OPERND.

If the operand is greater than the initial value of the accumulator, the subtract operation will clear the carry flag; otherwise the carry flag will remain set. In either case, the accumulator will bear the 8-bit result.

Thus, you clear the carry flag before adding and set the carry flag before subtracting. If the carry flag doesn't change state, then the accumulator bears the entire result. But if the addition or subtraction changes the state of the carry flag, then your result is greater then 255 (for an addition) or less than zero (for a subtraction).

Decimal Mode

The processor status register includes a bit called the *decimal flag*. If the decimal flag is set, then the 6502 will perform addition and subtraction in decimal mode. If the decimal flag is clear, then the 6502 will perform addition and subtraction in binary mode. Decimal mode means the bytes are treated as BCD (Binary Coded Decimal), meaning that the low 4 bits of a byte represent a value of 0 thru 9, and the high 4 bits of the byte represent a value of 0 thru 9. Neither *nybble* (4 bits) may contain a value of A-F. So, each nybble represents a decimal digit.

The instructions SED and CLD set the decimal flag and clear it, respectively. Unless you'll be operating with figures that represent dollars and cents, you won't need to use the decimal mode. All software in this book assumes that the decimal mode is not used.

Decimal 255 is the biggest value that can be represented by a binary-coded byte, but decimal 99 is the biggest value that can be represented by a byte using Binary Coded Decimal.

Logical Operations

What if you want to set, clear, or change the state of one or more bits in a byte without affecting the other bits in that byte? Input and output operations often demand such "bit-twiddling," which can be performed by the 6502's logical operations ORA, AND, and XOR.

Setting Bits

The ORA instruction lets you set one or more bits in the accumulator without affecting the state of the other bits. ORA logically OR's the accumulator with a specified byte, or *mask*, setting bit n in the accumulator if bit n in the accumulator is initially set *or* if bit n in the mask is set, or if both of these bits are set. A logical OR will leave bit n of the accumulator clear only if bit n is initially clear in both the accumulator and the mask. Table 4.1 shows a *truth table* for the logical operator OR. A truth table gives all possible combinations of 2 bits that can be operated upon (in this case, ORed) and the results of these combinations.

Table 4.1: *Truth table for the logical OR operand.*

Bit 1		Bit 2		Result
0	OR	0	=	0
0	OR	1	=	1
1	OR	0	=	1
1	OR	1	=	1

For example, suppose we executed the instruction "ORA #$80." Here the mask is $80, or the bit pattern 10000000. This instruction would therefore set bit 7 of the accumulator while leaving all other bits unchanged. So, if the accumulator had a value of 00010010 before the above instruction was executed, it would have the value of 10010010 afterwards.

Another example would be "ORA #3." Since a decimal 3 becomes 00000011 when converted to an 8-bit binary mask, the above instruction would set bits 0 and 1 in the accumulator, leaving bits 2 thru 7 unchanged.

How would you set the high 4 bits in the accumulator? The low 4 bits?

Clearing Bits

You can clear one or more bits in the accumulator without affecting the state of the other bits through the use of the AND instruction. AND performs a logical AND on the accumulator and the mask specified by the operand. AND will set bit n of the accumulator only if bit n of the accumulator is set initially *and* bit n is set in the mask. If bit n is initially clear in the accumulator or if bit n is clear in the mask, then AND will clear bit n in the accumulator. Table 4.2 gives the truth table for the logical AND operation.

Table 4.2: *The truth table for the logical AND.*

Bit 1		Bit 2		Result
0	AND	0	=	0
0	AND	1	=	0
1	AND	0	=	0
1	AND	1	=	1

For instance, the line of source code "AND #1" will clear all bits except bit 0 in the accumulator; bit 0 will remain unchanged. "AND #$F0" will clear the low 4 bits of the accumulator, leaving the high 4 bits unchanged. Select the right mask, and you can clear any bit or combination of bits in the accumulator without affecting the other bits in the accumulator.

Toggle Bits

The exclusive OR operation, XOR, lets you "flip," or toggle, one or more bits in the accumulator (ie: change the state of one or more bits without affecting the state of other bits). XOR will set bit n of the accumulator if bit n is set in the accumulator but not in the mask, or if bit n is set in the mask but not in the accumulator. If bit n has the same state in both the accumulator and in the mask, then XOR will clear bit n in the accumulator. Table 4.3 shows the truth table for this operation.

Table 4.3: *The truth table for the exclusive OR (XOR).*

Bit 1		Bit 2		Result
0	XOR	0	=	0
0	XOR	1	=	1
1	XOR	0	=	1
1	XOR	1	=	0

To toggle bit n in the accumulator, simply XOR the accumulator with a mask which has bit n set but all other bits clear. Bit n will change state in the accumulator, but all other bits in the accumulator will remain unchanged.

The logical operators, combined with the 6502's relative branch instructions, make it possible for a program to take one action or another depending on the state of a given bit in memory. Let's say you want a piece of code that will take one action (Action A) if a byte, called FLAG, has bit 6 set; yet take another action (Action B) if that bit is clear. The code of Example 14 shows one way to ignore all other bits in FLAG, and still preserve FLAG.

Example 14

```
LDA FLAG          Get flag byte.
AND #$40          Clear all bits but bit 6.
BEQ PLAN.B
```

```
PLAN.A          xxxxx           Take Action A, since bit 6 was set
                                in flag.
                  .
                  .
                  .
PLAN.B                          Take Action B, since bit 6 was
                                clear in flag.
```

What good are flags? Let me give an example. The flag on a rural mailbox may be either raised or lowered to indicate that mail is or is not awaiting pickup. Raising and lowering those flags requires a little bit of effort (no pun intended), but it enables the mail carrier to complete the route much more quickly than would be possible if every mailbox had to be checked every time around. Presumably, this provides better service for everyone on the route.

That mail carrier's routine is a very sophisticated piece of programming. If we think of the mail carrier as a person following a program, then we can see some of the power and flexibility that come from the use of flags.

The mail carrier's program has two parts: *What must be done at the post office* and *What must be done on the route*. At the post office, the mail carrier sorts the mail, bundles letters for the same address and puts the bundles for a given route into a mail sack in some order. This sorting at the post office means the mail carrier on the route can make his or her rounds more quickly, because no further sorting and searching is required. (We won't go into sorting and searching in this book; that's a volume in itself. For a helpful reference see Donald E Knuth's *Searching and Sorting*.)

Now comes the second part of the mail carrier's program: *What must be done on the route*. The mail carrier picks up the mail sack and leaves the post office. Driving down country roads, the mail carrier sees a mailbox ahead. *Do I have any mail for the people at this address? If so*, the mail carrier's mental program says, *I'll slow down and deliver it. But what if I don't have any mail now for these people? Do I just keep driving? Do I go to the next address?*

Not if I want to keep my job.

The mail carrier looks a little more closely at the mailbox. *Is the flag up or down? If it's down, I can just drive by, but if the flag is up I must stop and pick up the outgoing mail.*

A flag is just a single bit of information, but by interpreting and responding to the state of flags, even a simple program can respond to many changing conditions. If your computer has 8,000 bytes of programmable memory, that means it has 64,000 bits of memory. Conceivably, you could use most of those bits as flags, perhaps simulating the patterns of outgoing mail in a community of more than 50,000 households.

But you didn't buy a computer to play post office. And you know enough now to follow the programs presented in the following chapters. These programs will include examples of all the instructions and programming techniques presented in this very fast course in assembly-language programming. The programs in the following chapters will also give you some tools to use in developing your own programs.

(Incidentally, there is one 6502 instruction which doesn't do anything at all. The instruction NOP performs NO operation. Why would you want to perform no operation? Occasionally, it's handy to replace an unwanted instruction with a dummy instruction. When you want to disable some code, simply replace the unwanted code with NOP's. A NOP is represented in memory by $EA.)

Chapter 5:

Screen Utilities

Now let's consider how to display something on the video screen. On the Apple, Atari, OSI, and PET computers, the video-display circuitry scans a particular bank of memory, called the display memory. Every address in the display memory represents, or is mapped to, a different screen location (hence the term *memory-mapped display*). For each character in the display memory, the display circuitry puts a particular image, or graphic, on the screen (hence the term *character graphics*). To display a character in a given screen location, you need only store that character in the one address within display memory that corresponds to the desired screen location.

To know which address corresponds to a given screen location you must consult a display-memory map. Appendices B1 thru B4 describe how display memory is mapped on the Apple, Atari, OSI, and PET computers. Note that two different systems may have two different addresses for the same screen location. Also note how burdensome it can be to look up the addresses of even a few screen locations just to display a few characters on the video screen.

Rather than address the screen in an absolute manner, we'd like to be able to do so indirectly. Ideally, we'd like a software-controlled "hand" that we can move about the screen. Then we could pick up the character under the hand, or place a new character under the hand, without being concerned with the absolute address of the screen location under the hand at the moment. Such a hand can be implemented quite easily as a zero-page pointer.

Pointers

A pointer is just a pair of contiguous bytes in memory. Since 1 byte contains 8 bits, a pointer contains 16 bits, which means a pointer can specify any one of more than 65,000 (specifically: 2^{16}) different addresses.

A pointer can specify, or point to, only one address at a time. The low byte of a pointer contains the 8 LSB (least-significant bits) of the address it specifies, and the high byte of the pointer contains the 8 MSB (most-significant bits) of the address it specifies.

Let's say we want a pointer at location $1000. We must allocate 2 bytes for the pointer, which means it will occupy the bytes at $1000 and $1001. $1000 will hold the low byte, and $1001 will hold the high byte. If we want this pointer to specify address $ABCD, then we may set it as follows:

```
POINTR = $1000                  This assembler directive equates the label
                                POINTR with the value $1000. (It's POINTR
                                and not POINTER only because the assembler
                                used in preparing this book chokes on labels
                                longer than six characters — a common, if
                                arbitrary, limitation.)
LDA #$CD        A9  CD          Set the
STA POINTR      8D  00   10     low byte.
LDA #$AB        A9  AB          Set the
STA POINTR+1    8D  01   10     high byte.
```

Now POINTR points to $ABCD.

Although a pointer may be anywhere in memory, it becomes especially powerful when it's in the zero page (the address space from 0000 to $00FF). The 6502's indirect addressing modes allow a zero-page pointer to specify the address on which certain operations may be performed. A zero-page pointer must be located in the zero page, but it may point to any location in memory. For example, a zero-page pointer may be used to specify the address in which data will be loaded or stored. Since display memory looks like any other random-access memory to the processor, we may implement our television hand as a zero-page pointer.

TV.PTR

We want a zero-page pointer that can point to particular screen locations. Let's call it TV.POINTER, or TV.PTR for short. Whenever we examine or modify the screen, we'll do it through the TV.PTR.

Because the TV.PTR must be in the zero page, let's place it at $0000, meaning it will occupy the bytes at $0000 and at $0001. We can do that with the following assembler directive:

```
TV.PTR = $0
```

TV.PUT

The TV.PTR always specifies the current location on the screen. Thus, to display a graphic at the current location on the screen, we need only load the accumulator with the 8-bit code for that graphic and then execute the following two lines of code:

```
LDY #0           A0  00
STA (TV.PTR),Y   91  00
```

The two lines of above code are sufficient to display a given graphic in the current screen location. But what if you want to display a given *character* in the current screen location? The ASCII code for a character is not necessarily the same as your system's display code for that character's *graphic*. To display an "A" in the current screen location, we cannot simply load the accumulator with an ASCII "A" (which is $41) and then execute the two lines of above code, because the graphic "A" may have a different display code on your system. Instead of displaying an "A," we might display something else. Of the four computers considered in this book, only the Ohio Scientific Challenger I-P has a one-to-one correspondence between any character's ASCII code and that character's graphic code. The Atari, the PET, and the Apple computers lack such a one-to-one correspondence.

How then can we display a given ASCII character in the current screen location? We can do it by assuming that there exists a subroutine called FIXCHR, which will "fix" any given ASCII code, by translating it to its corresponding graphic or display code. FIXCHR will be different for each system, so we won't go into its details here (see the appendix pertaining to your computer for a description and listing of FIXCHR for your system). At this point we will assume only that FIXCHR exists, and that if we call it with an ASCII character in the accumulator, it will return with the corresponding display code in the accumulator.

We already know how to display a given graphic in the current screen location. With FIXCHR we now know how to display any given ASCII *character* in the current screen location. And since displaying any given ASCII character in the current screen location is something we're likely to do more than once, let's make it a subroutine. We'll call that subroutine TV.PUT since it will let us *put* a given ASCII character up on the TV screen:

```
TV.PUT     JSR FIXCHR             Convert ASCII character to your
                                  system's display code for that character.
           LDY #0                 Put that graphic in the
           STA (TV.PTR), Y        current screen location.
           RTS                    Return to caller.
```

The Screen Location

However, these examples of modifying and examining screen locations through the TV.PTR will work only if the TV.PTR is actually pointing at a screen location. Therefore, before executing code such as the examples given above, we must be sure the TV.PTR points to a screen location.

There are several ways to do this. If you want to write code that will run on only one machine (or on several machines whose display memory is mapped the same way), then you can use the immediate mode to set the TV.PTR to a given address on the screen. Let's say you want to set the TV.PTR to point to the third column of the fourth row (counting right and down from an origin in the upper-left corner). If you have an Ohio Scientific Challenger I-P, then you can consult your system's documentation and determine that address $D062 in display memory corresponds to your desired screen location. $D0 is the high byte of this screen location; $62 is the low byte of this screen location. Thus, you can set TV.PTR with the following lines of code:

```
LDA #$62        A9  62  Set
STA TV.PTR      85  00  low byte.
LDA #$D0        A9  D0  Set
STA TV.PTR+1    85  01  high byte.
       .
       .
       .
       .
       .
```

This code is fast and relocatable. But it's not very convenient to have to look up a display address every time we write code that displays something on the screen. It would be much more convenient if we could address the screen as a series of X and Y coordinates. Why not have a subroutine that sets the TV.PTR for us, provided we supply it with the desired X and Y coordinates?

TVTOXY

TVTOXY is a subroutine that sets the value of the TV.PTR to the display address whose X and Y coordinates are given by the X and Y registers. (Note that we count the columns and rows from zero.) To make the TV.PTR point to the third column from the left in the fifth row from the top, a calling program need only include the following code:

```
LDY #2          The leftmost column is column zero, so the third column is
                column two.
LDY #4          The topmost row is row zero, so the fifth row is row four.
JSR TVTOXY      Set TV.PTR to screen location whose X and Y coordinates are
                given by the X and Y registers.
      .
      .
      .
```

How will TVTOXY work? We could have TVTOXY do just what we were doing: look up the desired address in a table. A computer can look up data in a table very quickly, but the speed may not be worth it if the table requires a lot of memory. If we don't mind waiting a little longer for TVTOXY to do its job, we can have TVTOXY *calculate* the desired value of TV.PTR, rather than look it up in a table. But how can you calculate the address of a given X and Y location on the screen?

You can't do it without data. But you don't need a large amount of data to determine the address of a given X,Y location in screen memory; you need only have access to the following facts:

HOME	The address of the character in the upper-left corner of the screen (ie: the lowest address in screen memory).
ROWINC	ROW INCrement: the address difference from one row to the next.

Knowing the values of HOME and ROWINC for a given system, you can calculate the address corresponding to any X,Y location:

HOME	Address of character in upper-left corner
+ X Register	+ X coordinate
+ (Y Register)×ROWINC	+ (Y coordinate)×ROWINC
TV.PTR	Address of screen location at column X, row Y.

Run through this calculation for several screen locations and compare the results with the addresses you look up in the display-memory map for your system. (Remember that we count columns and rows from zero, not from one.) Now if TVTOXY can run through this calculation for us, we'll never have to look at a display-memory map again; we can write all our display code in terms of cartesian coordinates.

But we shouldn't be satisfied with TVTOXY if it only runs through the above calculation. After all, what happens if TVTOXY is called and the Y register holds a very large number? If the Y register is greater than the number of rows on the screen, then the above calculation will set the TV.PTR to an address outside of display memory. We don't want that. Maybe a calling program will have a bug and call TVTOXY with an illegal value in X or in Y. If TVTOXY doesn't catch the error, the calling program may end up storing characters in memory that is not display memory. It might end up over-writing part of itself, which would almost certainly invite long and arduous debugging.

I hate debugging. I know I'm going to make mistakes, but I'd like my software to catch at least some bugs before they run amuck. So let's have TVTOXY check the legality of X and Y before blindly calculating the value of TV.PTR.

How can TVTOXY check the legality of X and Y? How big can X or Y get before it's too big? We need some more data:

TVCOLS	The number of columns on the display screen, counting from zero.
TVROWS	The number of rows on the display screen, counting from zero.

Now TVTOXY requires the following four facts about the host computer:

```
HOME
ROWINC
TVROWS
TVCOLS
```

If we store these facts about the host system in a particular block of memory, then TVTOXY need only consult that block of memory to learn all it needs to know about the screen. TVTOXY can then work as follows:

TVTOXY

```
TVTOXY      SEC              Is X out of range?
            CPX TVCOLS
            BCC X.OK         If not, leave it alone.
                             If X is out of range, give
            LDX TVCOLS       it its maximum legal value.
                             Now X is legal.

X.OK        SEC              Is Y out of range?
            CPY TVROWS
            BCC Y.OK         If not, leave it alone.
                             If Y is out of range, give
            LDY TVROWS       it its maximum legal value.
                             Now Y is legal.

Y.OK        LDA HOME         Set TV.PTR = HOME.
            STA TV.PTR
            LDA HOME+1
            STA TV.PTR+1

            TXA              Add X to TV.PTR.
            CLC
            ADC TV.PTR
            BCC COLSET
            INC TV.PTR+1
            CLC

COLSET      CPY #0           Add Y*ROWINC to TV.PTR.
            BEQ EXIT
LOOP        CLC
            ADC ROWINC
            BCC NEXT
            INC TV.PTR+1
NEXT        DEY
            BNE LOOP
EXIT        STA TV.PTR
            RTS              Return to caller.
```

TVDOWN, TVSKIP, TVPLUS

Using TVTOXY, we can set TV.PTR to a screen location with any desired X,Y coordinates. But it would also be convenient to be able to modify TV.PTR relative to its current value. For example, after placing a character on the screen, we might want to make TV.PTR point to the next screen location to the right, or perhaps to the screen location directly below the current screen location. We might even want to make TV.PTR skip over several screen locations to make it point to "the nth screen location from here," where "here" is the current screen location. For these occasions, the subroutines TVDOWN, TVSKIP, and TVPLUS come in handy.

TVDOWN, TVSKIP, TVPLUS

```
TVDOWN      LDA ROWINC       Move TV.PTR down by one row.
            CLC
            BCC TVPLUS       Unconditionally branch.

TVSKIP      LDA #1           Skip one screen location by increment-
                             ing TV.PTR.

TVPLUS      CLC              Add the contents of the accumulator
            ADC TV.PTR       to the two zero-page bytes
            BCC NEXT         comprising the TV.PTR.
            INC TV.PTR+1

NEXT        STA TV.PTR

            RTS              Return to caller.
```

Note that the routines TVDOWN and TVSKIP make use of the routine TVPLUS, which assumes that the accumulator has been set to the number of locations to be skipped. For TVDOWN and TVSKIP, the accumulator is set to ROWINC and 1, respectively.

Right now TVPLUS might not seem long enough to be worth making into a subroutine. Any program that calls TVPLUS could perform the addition itself, at a cost of only a few bytes, and at a saving of several machine cycles in the process. However, we may make TVPLUS more sophisticated later on.

For example, we could enhance TVPLUS so it performs error checking automatically, to ensure that TV.PTR will never point to an address outside of screen memory. Such error checking would be very burdensome for every calling program to perform, but if and when we insert it into TVPLUS, every caller will automatically get the benefit of that modification.

VUCHAR

With TV.PUT we can display an ASCII character in the current screen location, and with TVSKIP we can advance to the next screen location. So why not combine the two, creating a subroutine that displays in the current screen location the graphic for a given ASCII character, and then automatically advances TV.PTR so it points to the next screen location? This would make it easy for a calling program to display a string of characters in successive screen positions. Since this subroutine will let the user *view* a *char*acter, let's call it VUCHAR:

```
VUCHAR    JSR TV.PUT          Display, in the current screen location,
                              the graphic for the character whose
                              ASCII code is in the accumulator.
          JSR TVSKIP          Advance to the next screen location.
          RTS
```

We could even squeeze VUCHAR into the code presented above for TVDOWN, TVSKIP, and TVPLUS, by inserting one new line of source code immediately above TVSKIP. (See Appendix C1, the assembler listing for the Screen Utilities, which also includes some error checking within TVPLUS.)

VUBYTE

With the screen utilities presented thus far, we can display a character on the screen in the current location, but we don't have a utility to display a *byte* in hexadecimal representation. Let's make one.

We'll call this utility VUBYTE, since it will let the user *view* a given *byte*. With VUBYTE, a calling program must take only three steps to display a byte in hexadecimal representation anywhere on the screen:

1) Set a zero-page pointer (TV.PTR) to point to the screen location where the byte should be displayed; 2) load the accumulator with the byte to be displayed; and then 3) call VUBYTE.

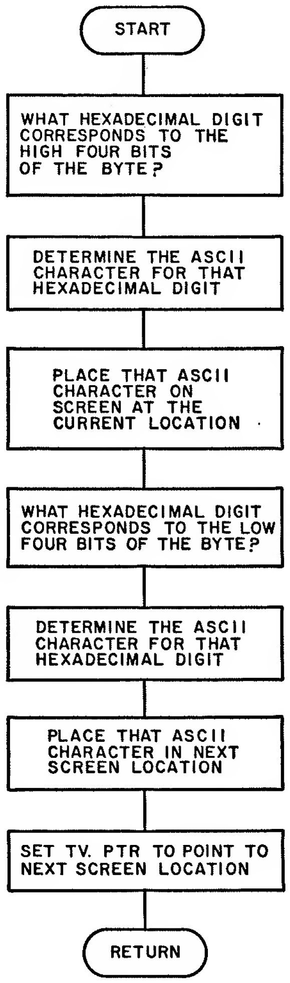

START
WHAT HEXADECIMAL DIGIT CORRESPONDS TO THE HIGH FOUR BITS OF THE BYTE?
DETERMINE THE ASCII CHARACTER FOR THAT HEXADECIMAL DIGIT
PLACE THAT ASCII CHARACTER ON SCREEN AT THE CURRENT LOCATION
WHAT HEXADECIMAL DIGIT CORRESPONDS TO THE LOW FOUR BITS OF THE BYTE?
DETERMINE THE ASCII CHARACTER FOR THAT HEXADECIMAL DIGIT
PLACE THAT ASCII CHARACTER IN NEXT SCREEN LOCATION
SET TV. PTR TO POINT TO NEXT SCREEN LOCATION
RETURN

Figure 5.1: *Flowchart of the routine VUBYTE, which displays a byte in hexadecimal representation on the video screen.*

VUBYTE will display the given byte as two ASCII characters in the current position on the screen, and when VUBYTE returns, TV.PTR will be pointing to the screen location immediately following the two screen locations occupied by the displayed characters.

VUBYTE need only determine the ASCII character for the hexadecimal value of the 4 MSB (most-significant bits), store that ASCII character in the screen location pointed to by TV.PTR, then display the ASCII character for the hexadecimal value of the accumulator's 4 LSB (least-significant bits) in the next screen location. See figure 5.1 for a flowchart outlining this.

VUBYTE seems to be asking for a utility subroutine to return the ASCII character for a given 4-bit value. Let's call this subroutine ASCII. ASCII will return the ASCII character for the hexadecimal value represented by the 4 least-significant bits in the accumulator. It will ignore the 4 most-significant bits in the accumulator.

If we assume that ASCII exists, then we can write VUBYTE:

VUBYTE

```
VUBYTE      PHA             Save accumulator.

            LSR A           Move 4 MSB
            LSR A           into positions
            LSR A           occupied by
            LSR A           4 LSB.

            JSR ASCII       Determine ASCII for accumulator's 4
                            LSB (which were its 4 MSB).

            JSR VUCHAR      Display the ASCII character in the cur-
                            rent screen location and advance to next
                            screen location.

            PLA             Restore original value of accumulator.

            JSR ASCII       Determine ASCII for accumulator's 4
                            LSB (which were its 4 LSB).

            JSR VUCHAR      Display this ASCII character just to the
                            right of the other ASCII character and
                            advance to next screen location.

            RTS             Return to caller.
```

Of course, ASCII doesn't exist yet. So let's write it, and then VUBYTE should be complete.

ASCII

```
ASCII     AND #$0F      Clear the 4 MSB in accumulator.

          CMP #$0A      Is accumulator greater than 9?
          BMI DECIML
          ADC #6        If so, it must be A thru F. Add $36 to
                        accumulator to convert it to correspond-
                        ing ASCII character. (We'll add $36 by
                        adding $6 and then adding $30.)

DECIML    ADC #$30      If accumulator is 0 thru 9, add $30 to it
                        to convert it to corresponding ASCII
                        character.

          RTS           Return to caller, bearing the ASCII char-
                        acter corresponding to the hexadecimal
                        value initially in the 4 LSB of the ac-
                        cumulator.
```

TVHOME, CENTER

Now we can display a character or a byte at the current screen location, and we can set the current screen location to any given X,Y coordinates or modify it relative to its current value. It would also be handy if we could set the TV.PTR to certain fixed locations: locations that more than one calling program might need as points or origin. For example, a calling program might need to set the TV.PTR to the HOME location (position 0,0), or to the CENTER of the screen:

TVHOME, CENTER

```
TVHOME    LDX #0        Set TV.PTR to the leftmost column
          LDY #0        of the top row
          JSR TVTOXY    of the screen.

          RTS           Then return to caller.
```

```
CENTER      LDA TVROWS      Load A with total rows.
            LSR A           Divide it by two.
            TAY             Y now holds the number of the central
                            row on the screen.

            LDA TVCOLS      Load A with total columns.
            LSR A           Divide it by two.
            TAX             X now holds the number of the central
                            column on the screen.

                            Now X and Y registers hold X, Y coor-
                            dinates of center of screen.

            JSR TVTOXY      Set the TV.PTR to X,Y coordinates.

            RTS             Return to caller.
```

TVPUSH, TV.POP

The screen utilities presented thus far enable us to set or modify the current position on the screen. We might also want to save the current position on the screen and then restore that position later. We can do this by pushing TV.PTR onto the stack and then pulling it from the stack:

TVPUSH

```
TVPUSH      PLA             Pull return address from stack.

            TAX             Save it in X...
            PLA
            TAY             ...and in Y.

            LDA TV.PTR+1    Get TV.PTR
            PHA             and save
            LDA TV.PTR      it on
            PHA             the stack.

            TYA             Place return
            PHA             address back...
            TXA
            PHA             ... on stack.

            RTS             Then return to caller.
```

TVPOP

```
TV.POP          PLA                 Pull return address from stack.
                TAX                 Save it in X...
                PLA
                TAY                 ...and in Y.

                PLA                 Restore...
                STA TV.PTR          ...TV.PTR
                PLA                   ...from
                STA TV.PTR+1            ...stack.

                TYA                 Place return
                PHA                 address back...
                TXA
                PHA                 ... on stack.

                RTS                 Then return to caller.
```

Now a calling program can save its current screen position with one line of source code: "JSR TVPUSH." That calling program can then modify TV.PTR and later restore it to its saved value with one line of source code: "JSR TV.POP."

CLEAR SCREEN

Now that we can set TV.PTR to any X,Y location on the screen, and display any byte or character in the current location, let's write some code to clear all or part of the screen. One subroutine, CLR.TV, will clear all of the video screen for us while preserving the zero page. A second routine, CLR.XY, will start from the current screen location and clear a rectangle, whose X,Y dimensions are given by the X,Y registers. Thus, a calling program can call CLR.TV to clear the whole screen; or a calling program can clear any rectangular portion of the screen, leaving the rest of the screen unchanged, just by making TV.PTR point to the upper left-hand corner of the rectangle to be cleared, and then calling CLR.XY with the X and Y registers holding, respectively, the width and height of the rectangle to be cleared.

```
CLR.TV      JSR TVPUSH              Save the zero-page bytes that will be
                                    changed.
            JSR TVHOME              Set the screen location to upper-left cor-
                                    ner of the screen.
```

```
        LDX TVCOLS       Load X,Y registers with
        LDY TVROWS       X,Y dimensions of the screen.
        JSR CLR.XY       Clear X columns, Y rows from current
                         screen location.
        JSR TV.POP       Restore zero-page bytes that were
                         changed.
        RTS              Return to caller, with screen clear and
                         with zero page preserved.

CLR.XY  STX COLS         Set the number of columns to be
                         cleared.
        TYA
        TAX              Now X holds the number of rows to be
                         cleared.
CLRROW  LDA BLANK        Load accumulator with your system's
                         graphic code for a blank.
        LDY COLS         Load Y with number of columns to be
                         cleared.
CLRPOS  STA (TV.PTR),Y   Clear a position by writing a blank into
                         it.
        DEY              Adjust index for next position in the
                         row.
        BPL CLRPOS       If not done with row, clear next posi-
                         tion...
        JSR TVDOWN       If done with row, move current screen
                         location down by one row.
        DEX              Done last row yet?
        BPL CLRROW       If not, clear next row...
        RTS              If so, return to caller.
COLS    .BYTE 0          Variable: holds number of columns to
                         be cleared.
```

There are many more screen utilities you could develop, but the utilities presented in this chapter are a good basic set. Now programs can call the following subroutines to perform the following functions:

ASCII:	Return ASCII character for 4 LSB in A.
CENTER:	Set current screen position to center of screen.
CLR.TV:	Clear the entire video display, preserving TV.PTR.
CLR.XY:	Clear a rectangle of the screen, with X,Y dimensions specified by the X,Y registers.
TVDOWN:	Move current screen position down by one row.

TVHOME:	Set current screen position to the upper-left corner of the screen.
TVPLUS:	Add A to TV.PTR.
TV.POP:	Restore previously saved screen position from stack.
TVPUSH:	Save current screen location on stack.
TV.PUT:	Display ASCII character in A at current screen location.
TVSKIP:	Advance to next screen location.
TVTOXY:	Set current screen position to X,Y coordinates given by X,Y registers.
VUBYTE:	Display A, in hexadecimal form, at current screen location. Advance current screen location past the displayed byte.
VUCHAR:	Display A as an ASCII character in current screen location; then advance to next screen location.

With these screen utilities, a calling program can drive the screen display without ever dealing directly with screen memory or even with the zero page. The calling program need not concern itself with anything other than the current position on the screen, which can be dealt with as a concept, rather than as a particular address hard-wired into the code.

Chapter 6:

The Visible Monitor

Hand Assembling Object Code

An assembler is a wonderful software tool, but what if you don't have one? Is it possible to write 6502 code without an assembler?

You bet!

Not only is it possible to write machine code by hand, but *all* of the software in this book was originally assembled and entered into the computer by hand. In fact, I hand assembled my code long after I had purchased a cassette-based assembler, because I could hand assemble a small subroutine faster than I could load in the entire assembler.

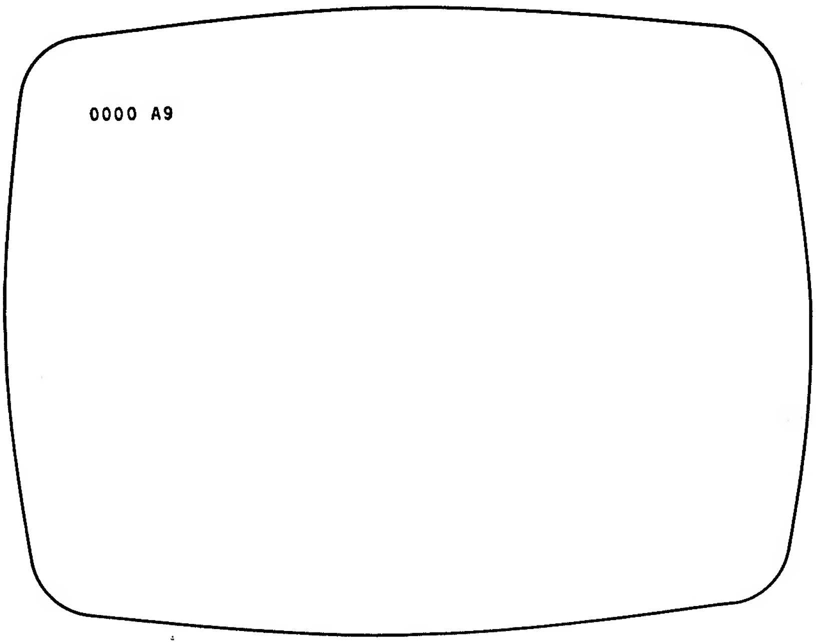
Hand assembling code imposes a certain discipline on the programmer. Because branch addresses must be calculated by counting forward or backward in hexadecimal, I tried to keep my subroutines very small. (How far can *you* count backward in hexadecimal?) I wrote programs as many nested subroutines, which I could assemble and test individually, rather than as monolithic, in-line code. This is a good policy even for programmers who have access to an assembler, but it is essential for any programmer who must hand assemble code.

Yet once you've written a program consisting of machine-language instructions, how can you enter it into memory? You can read your program on paper, but how can you present it to the 6502?

A program called a *machine-language monitor* allows you to examine and modify memory. It also allows you to execute a program stored in memory. The Apple and Ohio Scientific computers each feature a machine-language monitor in ROM (read-only memory). The Atari computers feature a machine-language monitor in a plug-in program cartridge. Your system's documentation should tell you how to use the features of your monitor, but let's take a closer look at one monitor in particular, the Ohio Scientific 65V monitor. Because it is stored in read-only memory in the OSI Challenger I-P, I will refer to it as the OSI ROM monitor.

A Minimal Machine-Language Monitor

You can invoke the OSI ROM monitor quite easily by pressing the BREAK key and then the "M" key. The monitor clears the video screen and presents the display shown in figure 6.1.



```
0000 A9
```

Figure 6.1: *Ohio Scientific ROM (read-only memory) monitor display.*

The display consists of two fields of hexadecimal characters: an address field and a data field. Figure 6.1 indicates that $A9 is the current value of address $0000.

The OSI ROM monitor has two modes: *address mode* and *data mode*. When the monitor is in address mode, you can display the contents of any address simply by typing the address on the keyboard. Each new hexadecimal character will roll into the address field from the right. To display address $FE0D, you simply type the keys F, E, 0, and then D.

To change the contents of an address, you must enter the *data* mode. When the

OSI ROM monitor is in the data mode, hexadecimal characters from the keyboard will roll into the data field on the screen. For your convenience, when the monitor is in the data mode you can step forward through memory (ie: increment the displayed address) by depresssing the RETURN key. Unfortunately, this convenience is not available in address mode, and neither mode allows you to step backward through memory (ie: to decrement the address field).

Beware: the OSI ROM monitor can mislead you. If the monitor is in the data mode and you type a hexadecimal character on the keyboard, that character will roll into the data field on the screen. Presumably that hexadecimal character also rolls into the memory location displayed on the screen. Yet, this might not be the case. In fact, the OSI ROM monitor displays the data you *intended* to store in an address, rather than the actual contents of that address. If you try to store data in a read-only memory address, for example, the OSI ROM monitor will confirm that you've stored the intended data in the displayed address, yet if you actually inspect that address (by entering address mode and typing in the address), you'll see that you changed nothing. This makes sense — you can't write to read-only memory. But the OSI ROM monitor leads you to think that you can.

The OSI ROM monitor can be confusing in other ways. For example, the display does not tell you whether you're in data mode or address mode; you've got to remember at all times which mode you last told the monitor to use. Furthermore, to escape from address mode you must use one key, while to escape from data mode you must use another key. Therefore you must always remember two escape codes as well as the current mode of the monitor.

Furthermore, the OSI ROM monitor does not make it very easy for you to enter ASCII data into memory. To enter an ASCII message into memory, you must consult an ASCII table (such as Appendix A2 in this book), look up the hexadecimal representation of each character in your message, and then enter each of those ASCII characters via two hexadecimal keystrokes. Then, once you've got an ASCII message in memory, the OSI ROM monitor won't let you read it as English text; you'll have to view that message as a series of bytes in hexadecimal format, and then look up, again in Appendix A2 or its equivalent, the ASCII characters defined by those bytes. That won't encourage you to include a lot of messages in your software — even though meaningful prompts and error messages can make your software much easier to maintain and use.

Finally, it is worth examining the way the OSI ROM monitor executes programs in memory. When you type "G" on the Ohio Scientific Challenger I-P, the OSI ROM monitor executes a JMP (unconditional jump) to the displayed address. That transfers control to the code selected, but it does so in such a way that the code must end with another unconditional jump if control is to return to the OSI ROM monitor. This forces you to write programs that end with a JMP, rather than subroutines that end with an RTS.

Programs that end with a JMP are not used easily as building blocks for other programs, whereas *subroutines* are incorporated quite easily into software structures of ever-greater power. So wouldn't it be nice if a machine-language monitor executed a JSR to the displayed address? This would call the displayed address as a subroutine, encouraging users to write software as subroutines, rather than as code that jumps from place to place. Such a monitor might actually encourage good programming habits, inviting the user to program in a structured manner, rather than daring the user to do so. In this chapter we'll develop such a monitor.

Objectives

If you've spent any time using a minimal machine-language monitor, you've probably thought of some ways to improve it. Based on my own experience, I knew that I wanted a monitor to be:

1) Accurate

The data field should display the actual contents of the displayed address, not the *intended* contents of that address.

2) Convenient

It should be possible to step forward or backward through memory, in any mode. It should also be possible to enter ASCII characters into memory directly from the keyboard, without having to look up their hexadecimal representations first, and it should be possible to display such characters as ASCII characters, rather than as bytes presented as pairs of hexadecimal digits.

3) Encourage Structured Programming

The monitor should *call* the displayed address as a subroutine, rather than *jump* to the displayed address. This will encourage the user to write subroutines, rather than monolithic programs that jump from place to place.

4) Simplify Debugging

The monitor should load the 6502 registers with user-defined data before calling the displayed address. Thus a user can initially test a subroutine with different values in the registers. Then, when the called subroutine returns, the monitor should display the new contents of the 6502 registers. Thus, by seeing how it changes or preserves the values of the 6502 registers, the user could judge the performance of the subroutine.

Because my objective was to make the 6502 registers visible to the user by displaying the 6502 registers before and after any subroutine call, I've chosen to call this monitor the *Visible Monitor*. Figure 6.2 shows its display format.

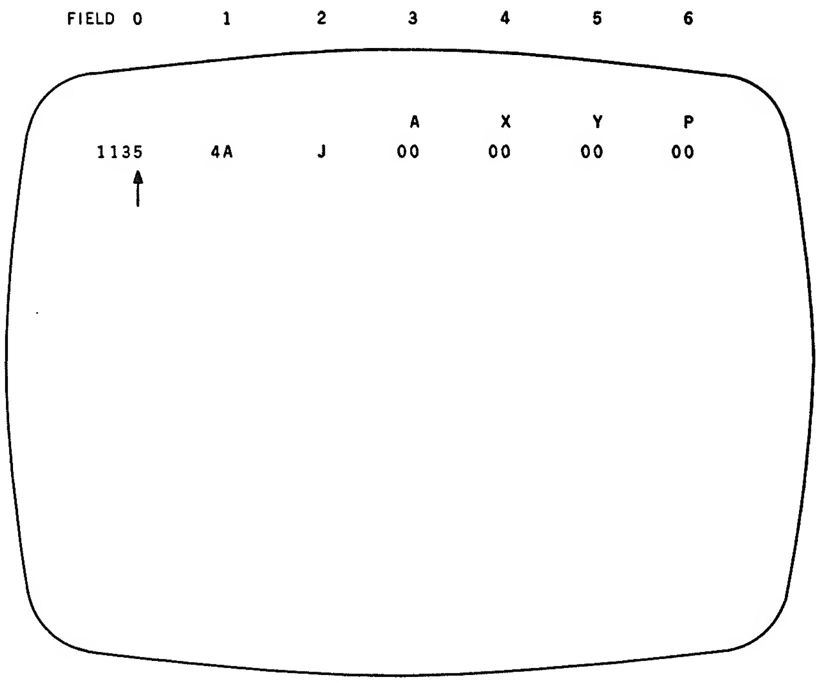


Figure 6.2: *Visible Monitor Display with fields numbered.*

VISIBLE MONITOR DISPLAY

The Visible Monitor Display

Notice that the display in figure 6.2 has seven fields, not two as in the OSI ROM monitor display. The first two fields (fields 0 and 1) are the same as the two fields in the OSI ROM monitor — that is, they display an address and a hexadecimal representation of the contents of that address. Field 2 is a graphic representation of the contents of the displayed address. If that address holds an ASCII character, then the graphic will be the letter, number, or punctuation mark specified by the byte. Otherwise, that graphic will probably be a special graphic character from your computer's nonstandard (ie: nonASCII) character set.

Fields 3 thru 6 represent four of the 6502 registers: A (the Accumulator), X (the X Register), Y (the Y Register), and P (the Processor Status Register). When you type

G to execute a program, the 6502 registers will be loaded with the displayed values before the program is called; when control returns to the monitor, the contents of the 6502 registers at that time will be displayed on the screen.

In addition to the seven fields mentioned above, the Visible Monitor's display includes an arrow pointing up at one of the fields. In order to modify a field, you must make the arrow point to that field. To move the arrow from one field to another, I've chosen to use the GREATER THAN (>) and LESS THAN (<) keys. Touching the GREATER THAN key will move the arrow one field to the right, and depressing the LESS THAN key will move the arrow one field to the left. (If my computer had a cursor pad, I would use the cursor-left and the cursor-right keys to move the arrow from field to field, but it doesn't have a cursor pad, so GREATER THAN and LESS THAN have to fill the bill. You may assign the field-movement functions to any keys on your system, but GREATER THAN and LESS THAN are reasonable choices, because they look like arrows pointing right and left, respectively.)

I've chosen to use the space bar to step forward through memory and the return key to step backward through memory, but you may choose other keys if you prefer (eg: the "+" and "−" keys). The space bar seems reasonable to me for stepping forward through memory, because on a typewriter I press the space bar to bring the *next* character into view; RETURN seems reasonable for stepping backward through memory because RETURN is almost synonymous with "back up," and that's what I want it for: to back up through memory. With such a display and key functions, we ought to have a very handy monitor.

Data

Before we develop the structure and code of the Visible Monitor, let's decide what variables and pointers it must have.

The Visible Monitor must have some way of knowing what address to display in field 0. It can do this by maintaining a pointer to the currently selected address. Because it will specify the currently selected address, let's call this pointer SELECT. Then, when the user presses the spacebar, the Visible Monitor need only increment the SELECT pointer. When the user presses RETURN, the Visible Monitor need only decrement the SELECT pointer. That will enable the user to step forward and backward through memory.

The user will also want to modify the 6502 register images. Since there are four register images shown in figure 6.2, let's have 4 bytes, one for each register image. If we keep them in contiguous memory, we can refer to the block of register images as REGISTERS, or simply as REGS (since REGISTERS is longer than six characters, the maximum label length acceptable to the assembler used in the preparation of this book).

Finally, the Visible Monitor must keep track of the current field. Since there can only be one current field at a time, we can have a variable called FIELD, whose value tells us the number of the current field. Then, when the user wants to select the next field, the Visible Monitor need only increment FIELD, and when the user wants to move the arrow to the previous field, the Visible Monitor need only decrement FIELD. If FIELD gets out of bounds (any value that is not 0 thru 6), then the Visible Monitor should assign an appropriate value to FIELD. The following code declares these variables in the form acceptable to an OSI 6500 Assembler:

Variables

```
SELECT      .WORD 0       This points to the currently selected
                          byte.
REG.A       .BYTE 0       REG.A holds the image of Register A
                          (the Accumulator).
REG.X       .BYTE 0       REG.X holds the image of Register X.
REG.Y       .BYTE 0       REG.Y holds the image of Register Y.
REG.P       .BYTE 0       REG.P holds the image of the Processor
                          Status Register.
FIELD       .BYTE 0       FIELD holds the number of the current
                          field.
            REGS = REG.A
```

Structure

I want to keep the Visible Monitor highly modular, so it can be easily extended and modified. I have therefore chosen to develop the Visible Monitor according to the structure shown in figure 6.3. Clearly, the Visible Monitor loops. It places the monitor *display* on the screen. It then *updates* the information in that display by getting a keystroke from the user and performing an action based on that keystroke. It does this over and over.

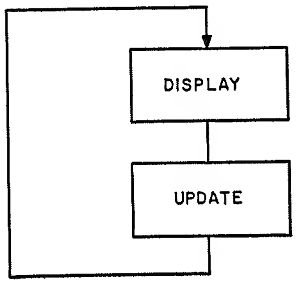


Figure 6.3: *A simple structure for interactive display programs.*

With this flowchart as a guide, we can now write the source code for the top level of the Visible Monitor:

```
                              VISMON

VISMON        PHP                Save caller's status flags.
LOOP          JSR DSPLAY         Put monitor display on screen.
              JSR UPDATE         Get user request and handle it.
              CLC
              BCC LOOP           Loop back to display...
```

This is only the top level of the Visible Monitor; it won't work without two subroutines: DSPLAY and UPDATE. So it looks as if we've traded the task of writing one subroutine for the task of writing two. But by structuring the monitor in this way, we make the monitor much easier to develop, document, and debug.

Which subroutine should we write first? Let's start with the DSPLAY module, since the display is visible to the user, and the Visible Monitor must meet the user's needs. Once we know how to drive the display, we can write the UPDATE routine.

Monitor Display

Figure 6.2 shows the display we want to present on the video screen. As you can see, this display consists of three lines of characters: the label line, the data line, and the arrow line. The label line labels four of the fields in the data line, using the characters A, X, Y, and P. The data line displays an address, the contents of that address (both in hexadecimal representation and in the form of a graphic), and then displays the values of the four registers in the 6502. Underneath the data line, the arrow line provides one arrow pointing up at one of the fields in the data line.

Since the display is defined totally in terms of the label line, the data line, and the arrow line, we are ready now to diagram the top level of monitor display. See figure 6.4.

With the flowchart in figure 6.4 as a guide, we can now write source code for the top level of the DSPLAY subroutine:

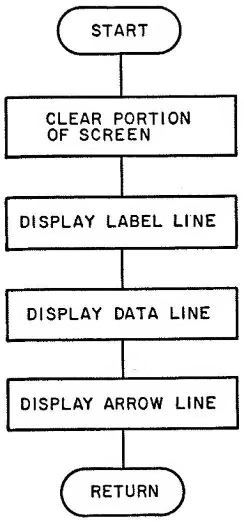


Figure 6.4: *Routine to display the monitor information.*

DSPLAY

```
DSPLAY      JSR CLRMON      Clear monitor's portion of screen.
            JSR LINE.1      Display the Label Line.
            JSR LINE.2      Display the Data Line.
            JSR LINE.3      Display the Arrow Line.
            RTS             Return to caller.
```

Now instead of one subroutine (DSPLAY), it looks as if we must write four subroutines: CLRMON, LINE.1, LINE.2, and LINE.3. But as the subroutines grow in number, they shrink in difficulty.

Before we put up any of the monitor's display, let's clear that portion of the screen used by the monitor's display. Then we can be sure we won't have any garbage cluttering up the monitor display.

Since we already have a utility to clear X columns and Y rows from the current location on the screen, CLRMON can just set TV.PTR to the upper-left corner of the screen, load X and Y with appropriate values, and then call CLR.XY. Here's source code:

```
CLRMON          LDX #2          Set TV.PTR to column 2, row 2 of
                LDY #2          screen.
                JSR TVTOXY
                LDX #25         We'll clear 25 columns
                LDY #3          and 3 rows.
                JSR CLR.XY      Here we clear them.
                RTS             Return to caller.
```

Display Label Line

The subroutine LINE.1 must put the label line onto the screen. We'll store the character string "A X Y P" somewhere in memory, at a location we may refer to as LABELS. Then LINE.1 need only copy 10 bytes from LABELS to the appropriate location on the screen. That will display the LABEL line for us:

LINE.1

```
LINE.1          LDX #13         X-coordinate of Label "A".
                LDY #2          Y-coordinate of Label "A".
                JSR TVTOXY      Place TV.PTR at coordinates given by
                                X,Y registers.
                LDY #0          Put labels on the screen:
                STY LBLCOL      Initialize label column counter.
LBLOOP          LDA LABELS,Y    Get a character and
                JSR VUCHAR      put its graphic on the screen.
                INC LBLCOL      Prepare for next character.
                LDY LBLCOL      Use label column as an index.
                CPY #10         Done last character?
                BNE LBLOOP      If not, do next one.
                RTS             Return to caller.
LABELS          .BYTE 'A X '    These are the characters
                .BYTE 'Y P'     to be copied to the screen.
LBLCOL          .BYTE 0         This is a counter.
```

Display Data Line

Displaying the data line will be more difficult than displaying the label line, for two reasons. First, the data to be displayed will change from time to time, whereas the labels in the label line need never change. Second, most fields in the data line display data in hexadecimal representation. To display 1 byte as two hexadecimal digits requires more work than is needed to display 1 byte as one ASCII character. However, we have a screen utility (VUBYTE) to do that work for us. In fact, we have enough screen utilities to make even the display of seven fields of data quite straightforward. Following, then, is the display data-line routine:

LINE.2

```
LINE.2     LDX #2          Load X register with X-coordinate for
                           start of data line.
           LDY #3          Load Y register with Y-coordinate for
                           data line.
           JSR TVTOXY      Set TV.PTR to point to the start of the
                           data line.
           LDA SELECT+1    Display high byte of the
           JSR VUBYTE      currently selected address.
           LDA SELECT      Display low byte of the
           JSR VUBYTE      currently selected address.
           JSR TVSKIP      Skip one space after address field.
           JSR GET.SL      Look up value of the currently selected
                           byte.
           PHA             Save it.
           JSR VUBYTE      Display it, in hexadecimal format, in
                           field 1.
           JSR TVSKIP      Skip one space after field 1.
           PLA             Restore value of currently selected byte.
           JSR VUCHAR      Display that byte, in graphic
                           form, in field 2.
           JSR TVSKIP      Skip one space after field 2.
                           Display 6502 register images in fields 4
                           thru 7:
           LDX #0
VUREGS     LDA REGS,X      Look up the register image.
           JSR VUBYTE      Display it in hexadecimal format.
           JSR TVSKIP      Skip one space after hexadecimal field.
           INX             Get ready for next register...
           CPX #4          Done 4 registers yet?
           BNE VUREGS      If not, do next one...
           RTS             If all registers displayed, return.
```

Get Currently Selected Byte

Note that the subroutine LINE.2, which puts up the second line of the Visible Monitor's display, does not itself "know" the value of the currently selected byte. Rather, it calls a subroutine, GET.SL, which returns the contents of the address pointed to by SELECT. That makes life easy for LINE.2, but how does GET.SL work?

If SELECT were a zero-page pointer, GET.SL could be a very simple subroutine and take advantage of the 6502's indirect addressing mode:

```
GET.SL    LDY #0              Get the zeroth byte above
          LDA (SELECT),Y      the address pointed to by SELECT.
          RTS                 Return to caller.
```

However, SELECT is not a zero-page pointer; it's up in page $12. And the 6502 doesn't have an addressing mode that will let us load a register using any pointer not in the zero page. So how can we see what's in the address pointed to by SELECT?

We can do it in two steps. First, we'll set a zero-page pointer equal in value to the SELECT pointer, so it points to the same address; and then, since we already know how to load the accumulator using a zero-page pointer, we'll load the accumulator using the zero-page pointer that now equals SELECT. Let's call that zero-page pointer GETPTR, since it will allow us to *get* the selected byte. Using such a strategy, GET.SL can look like this:

```
GET.SL    LDA SELECT          Set GETPTR equal to
          STA GETPTR          SELECT: first the low byte;
          LDA SELECT+1        then the
          STA GETPTR+1        high byte.
          LDY #0              Get the zeroth byte above
          LDA (SELECT),Y      the address pointed to by GETPTR.
          RTS                 Return to caller, with A bearing the con-
                              tents of the address specified by
                              SELECT.
```

This second attempt at GET.SL will load the accumulator with the currently selected byte, even when SELECT is not in the zero page. However, beware because by setting GETPTR equal to SELECT, GET.SL changes the value of GETPTR. This can be very dangerous. What, for example, if some other program were using GETPTR for something? That other program would be sabotaged by GET.SL's actions. If we let GET.SL change the value of GETPTR, then we must make sure that no other program ever uses GETPTR.

Such policing is hard work — and almost impossible if you want your software to run on a system in conjunction with software written by anyone else. Since I want the Visible Monitor to share your system's ROM input/output routines, and since I have no way of knowing what zero-page addresses those routines may use, I must refrain from using any of those zero-page bytes myself. When I have to use zero-page bytes — as now, so that GET.SL can use the 6502's indirect addressing mode — I must restore any zero-page bytes I've changed.

Therefore, GET.SL must be a four-part subroutine, which will: 1) save GETPTR; 2) set GETPTR equal to SELECT; 3) load the accumulator with the contents of the address pointed to by GETPTR; and finally, 4) restore GETPTR to its original value. This larger, slower, but infinitely safer version of GET.SL looks like this:

```
GET.SL    LDA GETPTR          Save GETPTR
          PHA                 on stack and
          LDX GETPTR+1        in X register.

          LDA SELECT          Set GETPTR
          STA GETPTR          equal to
          LDA SELECT+1        SELECT.
          STA GETPTR+1

          LDY #0              Get the contents of the
          LDA (GETPTR),Y      byte pointed to by SELECT,
          TAY                 and save it in Y register.

          PLA                 Restore GETPTR
          STA GETPTR          from stack
          STX GETPTR+1        and from X register.
          TYA                 Restore contents of current byte from
                              temporary storage in Y to A.
          RTS                 Return with contents of currently
                              selected byte in accumulator and with
                              the zero page preserved.
```

Display Arrow Line

This routine displays an up-arrow directly underneath the current field:

LINE.3

```
LINE.3      LDX   #2          Set TV.PTR to
            LDY   #4          beginning of
            JSR   TVTOXY      arrow line.
            LDY   FIELD       Look up current field.
            SEC               If it is out of bounds,
            CPY   #7          set it to
            BCC FLD.OK        default field
            LDY #0            (the address field).
            STY FIELD
FLD.OK      LDA   FIELDS,Y    Look up column number for current
                              field.
            TAY               Use that column number as an index in-
                              to the row.
            LDA   ARROW       Load accumulator with your system's
                              graphic code for up-arrow.
            STA (TV.PTR),Y    Store up-arrow code in the Yth column
                              of the arrow line.
            RTS               Return to caller.
FIELDS      .BYTE 3,6,8       This data area shows which column
            .BYTE $0B,$0E     should get an up-arrow to indicate
            .BYTE $11,$14     any one of fields 0 thru 6. Changing one
                              of these values will cause the up-arrow
                              to appear in a different column when in-
                              dicating a given field.
```

Now that we have all the routines we need for the monitor display, let us look at how they fit together to form a structure. Here is the hierarchy of subroutines in DSPLAY:

```
MONITOR DISPLAY
        DISPLAY LABEL LINE
        DISPLAY DATA LINE
                GET.SL
                VUBYTE
                     ASCII
                     TVPLUS
                TVSKIP
        DISPLAY ARROW LINE
```

When DSPLAY is called, it will clear the top four rows of the screen, display labels, data, the arrow, and then return. How long do you think it will take to do all this? The code may look cumbersome, but the display is *quick*!

Monitor Update

The UPDATE routine is the monitor subroutine that executes functions in response to various keys. The basic key functions we want to implement are as follows:

Key	Function
GREATER THAN	Move arrow one field to the right.
LESS THAN	Move arrow one field to the left.
SPACEBAR	Increment address being displayed. (Step forward through memory.)
RETURN	Decrement address being displayed. (Step backward through memory.)

If the arrow is in fields 1, 3, 4, 5, or 6, then, for

keys 0 thru 9, A thru F	Roll a hexadecimal character into the field pointed to by the arrow.

If the arrow is under field 2 (the graphic field) then, for

All keys	Enter the key's character into field 2 (ie: enter the key's character into the displayed address).

Since the video display need not be refreshed (redisplayed within a given time) by the processor, the UPDATE routine need not return within a given amount of time. The UPDATE routine, therefore, can wait indefinitely for a new character from the keyboard, and then take appropriate action.

We can diagram these functions as shown in figure 6.5. You add additional functions to this routine by adding additional code to test the input character. You then call the appropriate function subroutine which you write.

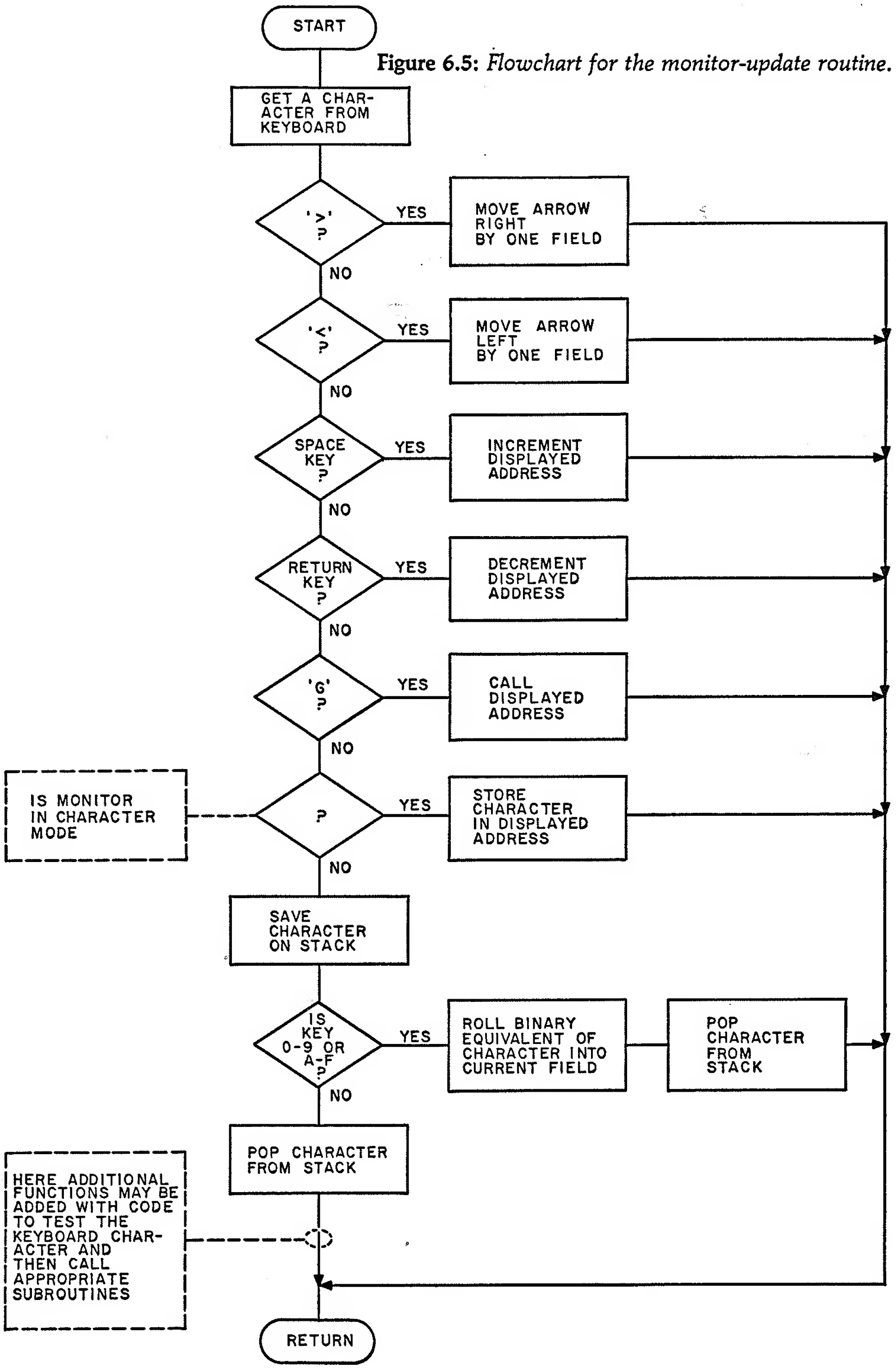

START
GET A CHARACTER FROM KEYBOARD
'>' ?
YES
MOVE ARROW RIGHT BY ONE FIELD
NO
'<' ?
YES
MOVE ARROW LEFT BY ONE FIELD
NO
SPACE KEY ?
YES
INCREMENT DISPLAYED ADDRESS
NO
RETURN KEY ?
YES
DECREMENT DISPLAYED ADDRESS
NO
'G' ?
YES
CALL DISPLAYED ADDRESS
NO
IS MONITOR IN CHARACTER MODE
?
YES
STORE CHARACTER IN DISPLAYED ADDRESS
NO
SAVE CHARACTER ON STACK
IS KEY 0-9 OR A-F ?
YES
ROLL BINARY EQUIVALENT OF CHARACTER INTO CURRENT FIELD
POP CHARACTER FROM STACK
NO
POP CHARACTER FROM STACK
HERE ADDITIONAL FUNCTIONS MAY BE ADDED WITH CODE TO TEST THE KEYBOARD CHARACTER AND THEN CALL APPROPRIATE SUBROUTINES
RETURN

Figure 6.5: *Flowchart for the monitor-update routine.*

Get a Key

First we need a way to get a key from the keyboard. I assume that your system has a read-only memory routine to perform this function. Place the address of that routine (see the appropriate appendix for your system) into a pointer called ROMKEY located at address $1008. Once you have set the ROMKEY pointer, you can get a key by calling a subroutine labeled GETKEY, which simply transfers control to the ROM routine whose address you placed in ROMKEY:

```
GETKEY      JMP (ROMKEY)
```

Now that we have a way to get a key from the keyboard, we should be able to write source code for the monitor-update routine:

Update

```
UPDATE      JSR GETKEY       Get a character from the keyboard.
IF.GRTR     CMP #'>          Is it the GREATER THAN key?
            BNE IF.LSR       If not, perform next test.
NEXT.F      INC FIELD        If so, select the next field.
            LDA FIELD        If arrow was at the right-most field,
            CMP #7           place it underneath the left-most
            BNE EXIT.1       field.
            LDA #0
            STA FIELD
EXIT.1      RTS              Then return.
IF.LSR      CMP #'<          Is it the LESS THAN key?
            BNE IF.SP        If not, perform next test.
PREV.F      DEC FIELD        If so, select previous field:
            BPL EXIT.2       the field to the left of the
            LDA #6           current field. If arrow was at
            STA FIELD        left-most field, place it under
                             right-most field.
EXIT.2      RTS              Then return.
IF.SP       CMP #SPACE       Is it the space bar?
            BNE IF.CR        If not, perform next test.
INC.SL      INC SELECT       If so, step forward through
            BNE EXIT.3       memory, by incrementing the
            INC SELECT+1     pointer that specifies the displayed
                             address.
EXIT.3      RTS              Then return.
IF.CR       CMP #CR          Is it carriage return?
            BNE IFCHAR       If not, perform next test.
```

```
DEC.SL        LDA SELECT          If so, step backward through
              BNE NEXT.1          memory by decrementing the
              DEC SELECT+1        pointer that selects the
NEXT.1        DEC SELECT          address to be displayed.
              RTS                 Then return.
IFCHAR        LDX FIELD           Is arrow underneath the
              CPX #2              character field (field 2)?
              BNE IF.GO           If not, perform next test.
                                  Put the contents of A into the currently
                                  selected address.
PUT.SL        TAY                 Use Y to hold the character we'll put in
                                  the selected address.
              LDA TV.PTR          Save zero-page pointer TV.PTR
              PHA                 on stack and in X before we
              LDX TV.PTR+1        use it to put character in selected ad-
                                  dress.
              LDA SELECT          Set TV.PTR equal to SELECT,
              STA TV.PTR          so it points to the
              LDA SELECT+1        currently selected
              STA TV.PTR+1        address.
              TYA                 Restore to A the character we'll put in
                                  the selected address.
              LDY #0              Store it in the
              STA (TV.PTR),Y      selected address.
              STX TV.PTR+1        Restore TV.PTR to
              PLA                 its original value.
              STA TV.PTR
              RTS                 Return to caller, with character origi-
                                  nally in A now in the selected address
                                  and with zero page unchanged.
              RTS                 Then return.
IF.GO         CMP #'G             Is it 'G' for GO?
              BNE IF.HEX          If not, perform next test.
GO            LDY REG.Y           If so, load the 6502 registers
              LDX REG.X           with their displayed images.
              LDA REG.P
              PHA
              LDA REG.A
              PLP
              JSR CALLSL          Call the subroutine at the selected ad-
                                  dress.
              PHP                 When subroutine returns,
              STA REG.A           save register values in register
              STX REG.X           images.
```

```
            STY REG.Y
            PLA
            STA REG.P
            RTS              Then return to caller.
CALLSL      JMP (SELECT)     Call the subroutine at the selected ad-
                             dress.
IF.HEX      PHA              Save keyboard character.
            JSR BINARY       If accumulator holds ASCII character
                             for 0 thru 9 or A thru F, BINARY
                             returns the binary representation of that
                             hexadecimal digit. Otherwise BINARY
                             returns with A = FF and the minus flag
                             set.
            BMI OTHER        If accumulator did not hold a hexa-
                             decimal character, perform next test.
            TAY
            PLA
            TYA
ROLLIN      LDX FIELD        Roll A into a hexadecimal field.
            BNE NOTADR       Is arrow underneath the address field
                             (field 0)? If not, the arrow must be
                             under another hexadecimal field.
ADRFLD      LDX #3           Since arrow is underneath the address
LOOP.1      CLC              field, roll accumulator's hexadecimal
            ASL SELECT       digit into the address field by rolling it
            ROL SELECT+1     into the pointer that selects the
            DEX              displayed address.
            BPL LOOP.1
            TYA
            ORA SELECT
            STA SELECT
            RTS              Then return.
NOTADR      CPX #1           Is arrow underneath field 1?
            BNE REGFLD       If not, it must be underneath a register
                             image.
ROL.SL      AND #$0F         Roll A's 4 LSB into contents
            PHA              of currently selected byte.
            JSR GET.SL       Get the contents of the selected
            ASL A            address and shift left 4 times.
            ASL A
            ASL A
            ASL A
            AND #$F0
            STA TEMP         Save it in a temporary variable.
```

```
                PLA                 Get original A's 4 LSB and
                ORA TEMP            OR them with shifted contents of
                                    selected address.
                JSR PUT.SL          Store the result in the selected
                RTS                 address and return.

TEMP            .BYTE 0             This byte holds the temporary variable
                                    used by ROL.SL.
REGFLD          DEX                 The arrow must be underneath a
                DEX                 register image — field 3, 4, 5, or 6.
                DEX
                LDY #3
LOOP.2          CLC                 Roll accumulator's hexadecimal digit
                ASL REGS,X          into appropriate register image...
                DEY
                BPL LOOP.2
                ORA REGS,X
                STA REGS,X
                RTS                 ...Then return.
OTHER           PLA                 Restore the raw keyboard character that
                                    we saved on the stack.
                CMP#'Q              Is it 'Q' for Quit?
                BNE NOT.Q           If not, perform next test.
                PLA                 If so, return to
                PLA                 the caller of
                PLP
                RTS                 VISMON.
NOT.Q           JSR DUMMY           Replace this call to DUMMY with a call
                                    to any other subroutine that extends the
                                    functionality of the Visible Monitor.
DUMMY           RTS                 Return to caller.
```

ASCII to BINARY Conversion

The Visible Monitor's UPDATE subroutine requires a subroutine called BINARY, which will determine if the character in the accumulator is an ASCII 0 thru 9 or A thru F, and, if so, return the binary equivalent. On the other hand, if the accumulator does not contain an ASCII 0 thru 9 or A thru F, BINARY will return an error code, $FF. Thus:

If accumulator holds	**BINARY will return**
$30 (ASCII "0")	$00
$31 (ASCII "1")	$01
$32 (ASCII "2")	$02
$33 (ASCII "3")	$03
$34 (ASCII "4")	$04
$35 (ASCII "5")	$05
$36 (ASCII "6")	$06
$37 (ASCII "7")	$07
$38 (ASCII "8")	$08
$39 (ASCII "9")	$09
$41 (ASCII "A")	$0A
$42 (ASCII "B")	$0B
$43 (ASCII "C")	$0C
$44 (ASCII "D")	$0D
$45 (ASCII "E")	$0E
$46 (ASCII "F")	$0F
Any other value	$FF

We could solve this problem with a table, BINTAB, for BINary TABle. If BINTAB is at address $2000, then $2000 would contain a $FF, as would $2001, $2002, and all addresses up to $202F, because none of the ASCII codes from $00 thru $2F represent any of the characters 0 thru 9 or A thru F. On the other hand, address $2030 would contain 00, because $30 (its offset into the table) is an ASCII zero, so $2030 gets its binary equivalent: $00, a binary zero. Similarly, since $31 is an ASCII '1,' address $2031 would contain a binary '1:' $01. $2032 would contain a $02; $2033 would contain a $03, and so on up to $2039, which would contain a $09.

Addresses $203A thru $2040 would each contain $FF, because none of the ASCII codes from $3A thru $40 represent any of the characters 0 thru 9 or A thru F. On the other hand, address $2041 would contain a $0A, because $41 is an ASCII 'A' and $0A is its binary equivalent: a binary 'A.' By the same reasoning, $2042 would contain $0B; $2043 would contain $0C, and so on up to $2046, which would contain $0C, and so on up to $2046, which would contain $0F. Addresses $2047 thru $20FF would contain $FFs because none of the values $47 thru $FF is an ASCII 0 thru 9 or A thru F.

To use such a table, BINARY need only be a very simple routine:

```
BINARY    TAY                     Use ASCII character as an index.
          LDA BINTAB,Y            Look up entry in BINary TABle.
          RTS                     Return with it.
```

This is a typical example of a fast and simple table lookup code. But it requires a 256-byte table. Perhaps slightly more elaborate code can get by with a smaller table, or do away altogether with the need for a table. Such code must calculate, rather than look up, its answers. Let's look closely at the characters we must convert.

Legal inputs will be in the range $30 thru $39 or the range $41 thru $46. An input in the range $30 thru $39 is an ASCII 0 thru 9, and subtracting $30 from such an input will convert it to the corresponding binary value. An input in the range $41 thru $46 is an ASCII A thru F, so subtracting $36 will convert it to its corresponding binary value. For example, $41 (an ASCII 'A') minus $36 equals $0A (a binary 'A'). Any value not in either of these ranges is illegal and should cause BINARY to return a $FF.

Given these input/output relationships, BINARY need only determine whether the character in the accumulator lies in either legal range, and if so perform the appropriate subtraction, or, if the accumulator is not in a legal range, then return a $FF.

Here's some code for BINARY which makes these judgments, thus eliminating the need for a table:

```
BINARY   SEC             Prepare to subtract.
         SBC #$30        Subtract $30 from character.
         BCC BAD         If character was originally less than $30,
                         it was bad, so return $FF.
         CMP #$0A        Was character in the range $30 thru
                         $39?
         BCC GOOD        If so, it was a good input, and we've
                         already converted it to binary by sub-
                         tracting $30, so we'll return now with
                         the character's binary equivalent in the
                         accumulator.
         SBC #7          Subtract 7.
         CMP #$10        Was character originally in the range
                         $41 thru $46?
         BCS GOOD        If so, it was a good input, and we've
                         already converted it to binary by sub-
                         tracting $37, so we'll return now with
                         the character's binary equivalent in the
                         accumulator.
BAD      LDA #$FF        Indicate a bad input by returning
         RTS             minus, with A holding $FF.
GOOD     LDX #0          Indicate a good input by returning
         RTS             plus, with A holding the character's
                         binary equivalent.
```

Visible Monitor Utilities

The Visible Monitor makes the following subroutines available to external callers:

BINARY	Determine whether accumulator holds the ASCII representation for a hexadecimal digit. If so, return binary representation for that digit. If not, return an error code ($FF).
CALLSL	Call the currently selected address as a subroutine.
DEC.SL	Select previous address, by decrementing SELECT pointer.
GETKEY	Get a character from the keyboard by calling machine's read-only memory routine indirectly.
GET.SL	Get byte at currently selected address.
GO	Load registers from displayed images and call displayed address. Upon return, restore register images from registers.
INC.SL	Select next byte (increment SELECT pointer).
PUT.SL	Store accumulator at currently selected address.
VISMON	Let user give the Visible Monitor commands until user presses 'Q' to quit.

Figure 6.6 illustrates the hierarchy of the various routines of the Visible Monitor, some of which are detailed in later chapters.

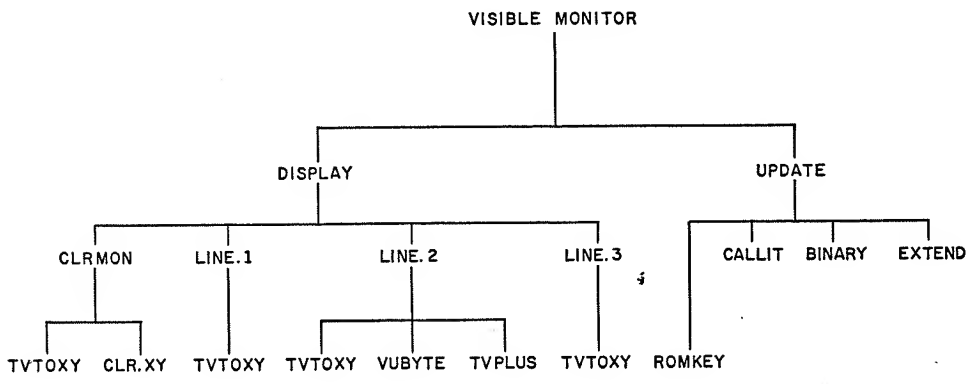


Figure 6.6: *A hierarchy of the routines of the Visible Monitor.*

Using the Visible Monitor

Use the minimal machine-language monitor on your computer to enter the Visible Monitor into memory; then have your monitor pass control to the Visible Monitor. The Visible Monitor display should appear in the upper portion of your video display. If it's not fully visible, adjust the value HOME in the screen parameters (HOME is the pointer at $1000). Use the GREATER THAN and LESS THAN character keys to move the arrow from field to field. Place the arrow under field 0 and roll hexadecimal characters into the address. Select an address in the lower portion of screen memory and use the Visible Monitor to place characters on the screen. Enter characters to the screen using both field 1 (the hexadecimal data field), and field 2 (the character field).

Select the address of the TVT routine in your system. Press G to call that subroutine. You should see the character in the accumulator print on the screen. Try exploring other memory locations. Try writing to a read-only memory address. Why doesn't that work? Try writing to the upper portion of the screen. Why doesn't that work?

Chapter 7:

Print Utilities

The Visible Monitor is a useful tool for examining and modifying memory, but at the moment it's mute: it can't "talk" to you except through the limited device of the fields in its display. You can use the Visible Monitor's character entry feature to place ASCII characters directly into screen memory, thus putting messages on the screen manually. However, as yet we have no subroutines to direct a complete message, report, or other string of characters to the screen, to a printer, or to any other output device.

Most programs require some means of directing messages to the screen, thus providing the user with the basis for informed interaction, or to a printer, thus providing a record of that interaction. This chapter presents a set of print utilities to perform these functions.

Fortunately, there are subroutines in your computer's operating system to perform character output. The Apple, Atari, OSI and PET computers each feature a routine to print a character on the screen, thus simulating a TVT (*T*ele*V*ision *T*ypewriter), and they each feature another routine to send a character to the device connected to the serial output port: usually a printer. I don't plan to reinvent those wheels in this chapter. Rather, the chapter's software will funnel all character output through code that calls the appropriate subroutine in your computer's operating system. And since we're going to have code that calls the two standard character output routines, why not provide a hook to a user-written character output routine, as well? Such a feature will make it trivial for you to direct any character output (eg: messages, hexdumps, disassembler listings, etc) to the screen and the printer, or to any special output device you may have on your system, provided that you've written a subroutine to drive that device.

Selecting Output Devices

It should be possible for any program to direct character output to the screen, and/or to the printer, and/or to the user-written subroutine. Therefore, we'll need subroutines to select and deselect (stop using) each of these devices and to select and deselect *all* of these devices. Let's call these routines TVT.ON, TVTOFF, PR.ON, PR.OFF, USR.ON, USR.OFF, ALL.ON, and ALLOFF. With these subroutines, a calling program can select or deselect output devices individually or globally.

The line of source code which will select the TVT as an output device follows:

```
JSR TVT.ON
```

This line will deselect the TVT:

```
JSR TVTOFF
```

That's a pretty straightforward calling sequence.

The select and deselect subroutines will operate on three flags: TVT, PRINTR, and USER. The TVT flag will indicate whether the screen is selected as an output device; the PRINTR flag will indicate whether the printer is selected as an output device; and the USER flag will indicate whether the user-provided subroutine is selected as an output device.

For convenience, we'll have a separate byte for each flag and define a flag as "off" when its value is zero, and "on" when its value is nonzero.

Using this definition of a flag, we can select a given device simply by storing a nonzero value in the flag for that device; we can deselect a device simply by storing a zero in the flag for that device.

The definitions for the flags and listings of the select and deselect subroutines follow:

Device Flags

```
              OFF = 0          When a device flag = zero, that device
                               is not selected.
              ON = $FF         When a device flag = $FF, that device is
                               selected.
TVT           .BYTE ON         This flag is zero if TVT is not selected;
                               nonzero otherwise. Initially, the TVT is
                               selected.
```

PRINTR	.BYTE OFF	This flag is zero if the PRINTR is not selected; nonzero otherwise. Initially, the printer is not selected.
USER	.BYTE OFF	This flag is zero if the user-provided output subroutine is not selected; nonzero otherwise. Initially, the user-provided function is deselected.

Select and Deselect Subroutines

TVT.ON	LDA #ON STA TVT RTS	Select TVT as an output device by setting the flag that indicates the "select" state of the TVT.
TVTOFF	LDA #OFF STA TVT RTS	Deselect TVT as an output device by clearing the flag that indicates the "select" state of the TVT.
PR.ON	LDA #ON STA PRINTR RTS	Select printer as an output device by setting the flag that indicates the "select" state of the printer.
PR.OFF	LDA #OFF STA PRINTR RTS	Deselect printer as an output device by clearing the flag that indicates the "select" state of the printer.
USR.ON	LDA #ON STA USER RTS	Select user-written subroutine as an output device by setting the flag that indicates the "select" state of the output routine provided by the user.
USROFF	LDA #OFF STA USER RTS	Deselect user-written subroutine as an output device by clearing the flag that indicates the "select" state of the output routine provided by the user.
ALL.ON	JSR TVT.ON JSR PR.ON JSR USR.ON RTS	Select all output devices by selecting each output device individually.
ALLOFF	JSR TVTOFF JSR PR.OFF JSR USROFF RTS	Deselect all output devices by deselecting each output device individually.

A General Character-Print Routine

Now that a calling routine can select or deselect any combination of output devices, we need a routine that will output a given character to all currently selected output devices. Let's call this routine PR.CHR, because it will *PR*int a *CH*a*R*acter.

All the software in this book that outputs characters will do so by calling PR.CHR; none of that software will call your system's character-output routines directly. That makes the software in this book much easier to maintain. If you ever replace your system's TVT output routine or its printer-output routine with one of your own, you won't have to change the rest of the software in this book. That software will continue to call PR.CHR. However, if many lines of code in many places called your system's character-output routines directly, then replacing a read-only memory output routine with one of your own would require you to change many operands in many places. Who needs to work that hard? Funneling all character output through one routine, PR.CHR, means we can improve our character output in the future without difficulty.

When it is called, PR.CHR will look at the TVT flag. If the TVT flag is set, it will call your system's TVT output routine. Then it will look at the PRINTR flag. If the PRINTR flag is set, it will call your system's routine that sends a character to the serial output port. Finally, it will look at the USER flag. If the USER flag is set, it will call the user-provided character-output routine. Having done all of this, PR.CHR can return. Figure 7.1 is a flowchart for PR.CHR.

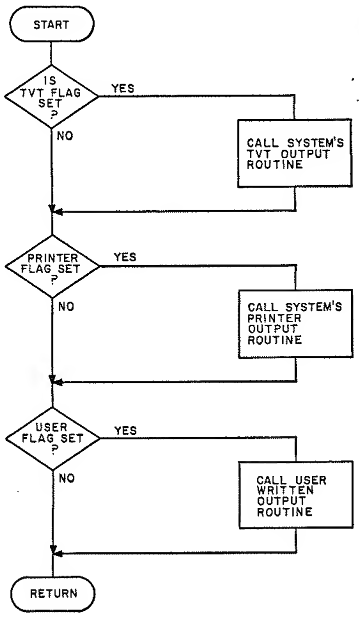

START
IS TVT FLAG SET ?
YES
NO
CALL SYSTEM'S TVT OUTPUT ROUTINE
PRINTER FLAG SET ?
YES
NO
CALL SYSTEM'S PRINTER OUTPUT ROUTINE
USER FLAG SET ?
YES
NO
CALL USER WRITTEN OUTPUT ROUTINE
RETURN

Figure 7.1: *To print a character to all currently selected output devices (PR.CHR, a general character-output routine).*

Output Vectors

If the character output routines are located at different addresses in different systems, how can PR.CHR know the addresses of the routines it must call? It can't. But it can call those subroutines indirectly, through pointers that you set.

You must set three pointers, or *output vectors*, so that they point to the character output routines in your system. A pointer called ROMTVT must point to your system's TVT output routine; a pointer called ROMPRT must point to your system's routine that sends a character to the serial output port; and a pointer called USROUT must point to your own, user-written, character-output routine. (If you have not written a special character-output subroutine, USROUT should point to a dummy routine which is nothing but an RTS instruction.) Then, if you ever relocate your TVT output routine, your printer-output routine, or your user-written output routine, you'll only have to change one output vector: ROMTVT, ROMPRT, or USROUT. Everything else in this book can remain the same.

ROMTVT, ROMPRT, and USROUT need not be located anywhere near PR.CHR. That means we can keep all the pointers and data specific to your system in one place. We can store the output vectors with the screen parameters, in a single block of memory called SYSTEM DATA. See Appendix B1, B2, B3, or B4 for your computer.

The source code of the PR.CHR routine follows:

PR.CHR

```
PR.CHR      STA CHAR      Save the character.
            BEQ EXIT      If it's a null, return without printing it.
            LDA TVT       Is TVT selected?
            BEQ IF.PR     If not, test next device.
            LDA CHAR      If so, send character indirectly to
            JSR SEND.1    system's TVT output routine.
IF.PR       LDA PRINTR    Is printer selected?
            BEQ IF.USR    If not, test next device.
            LDA CHAR      If so, send character indirectly
            JSR SEND.2    to system's printer driver.
IF.USR      LDA USER      Is user-written output subroutine
                          selected?
            BEQ EXIT      If not, test next device.
            LDA CHAR      If so, send character indirectly
            JSR SEND.3    to user-written output subroutine.
EXIT        RTS           Return to caller.
CHAR        .BYTE 0       This byte holds the last character passed
                          to PR.CHR.
```

Vectored Subroutine Calls

```
SEND.1          JMP (ROMTVT)
SEND.2          JMP (ROMPRT)
SEND.3          JMP (USROUT)
```

Specialized Character-Output Routines

Given PR.CHR, a general character-output routine, we can write specific character-output routines to perform several commonly required functions. For example, it's often necessary for a program to print a carriage return and a line feed, thus causing a new line, or to print a space, or to print a byte in hexadecimal format. Let's develop several dedicated subroutines to perform these functions. Since each of these subroutines will call PR.CHR, their output will be directed to all currently selected output devices.

Here are source listings for a few such subroutines: CR.LF, SPACE, and PR.BYT:

PRINT A CARRIAGE RETURN-LINE FEED

```
                CR = $0D            ASCII carriage return character.
                LF = $0A            ASCII line feed character.

CR.LF           LDA #CR             Send a carriage return and a
                JSR PR.CHR          line feed to the currently selected
                LDA #LF             device(s).
                JSR PR.CHR
                RTS                 Return.
```

PRINT A SPACE

```
SPACE           LDA #$20            Load accumulator with ASCII space.
                JSR PR.CHR          Print it to all currently selected output
                                    devices.
                RTS                 Return.
```

PRINT BYTE

```
PR.BYT          PHA                 Save byte.
                LSR A               Determine ASCII for the 4 MSB (most-
                      significant bits) in the
LSR A                 byte:
LSR A
LSR A
JSR ASCII
JSR PR.CHR            Print that ASCII character to the current
                      device(s).
PLA                   Determine ASCII for the 4 LSB (least-
                      significant bits) in the
JSR ASCII             byte that was passed to this subroutine.
JSR PR. CHR           Print that ASCII character to the current
                      device(s).
RTS                   Return to caller.
```

Repetitive Character Output

Since some calling programs might need to output more than one space, a new line, or other character, why not have a few print utilities to perform such repetitive character outputs? In each case, the calling program need only load the X register with the desired repeat count. Then it would call SPACES to print X spaces, CR.LFS to print X new lines, or CHARS to print the character in the accumulator X times. Calling any of these routines with zero in the X register will cause no characters to be printed. To output seven spaces, a calling program would only have to include the following two lines of code:

```
LDX #7
JSR SPACES
```

To output four blank lines, a program would require these two lines of code:

```
LDX #4
JSR CR.LFS
```

To output ten asterisks, a program would need these three lines of code:

```
LDA #'*
LDX #10
JSR CHARS
```

In order to support these calling sequences, we'll need three small subroutines, SPACES, CR.LFS, and CHARS:

Print X Spaces; Print X Characters

```
SPACES      LDA #$20        Load accumulator with ASCII space.
CHARS       STX REPEAT      Initialize the repeat counter.
RPLOOP      PHA             Save character to be repeated.
            LDX REPEAT      Has repeat counter timed out yet?
            BEQ RPTEND      If so, exit. If not,
            DEC REPEAT      decrement repeat counter.
            JSR PR.CHR      Print character to all currently selected
                            output devices.
            PLA
            CLC             Loop back to repeat
            BCC RPLOOP      character, if necessary.
RPTEND      PLA             Clean up stack.
            RTS             Return to caller.
```

Print X New Lines

```
CR.LFS      STX REPEAT      Initialize repeat counter.
CRLOOP      LDX REPEAT      Exit if repeat counter has timed out.
            BEQ END.CR
            DEC REPEAT      Decrement repeat counter.
            JSR CR.LF       Print a carriage return and line feed.
            CLC             Loop back to see if done yet.
            RCC CRLOOP
END.CR      RTS             If done, return to caller.
REPEAT      .BYTE           This byte is used as a repeat counter by
                            SPACES, CHARS, and CR.LFS.
```

Print a Message

Some calling programs might need to output messages stored at arbitrary places in memory. So let's develop a subroutine, called PR.MSG, to perform this function. PR.MSG will print a message to all currently selected output devices. It must get characters from the message in a sequential manner and pass each character to PR.CHR, thus printing it on all currently selected output devices.

But how can PR.MSG know where the message starts and ends?

We could require that the message be placed in a known location, but then

PR.MSG would lose usefulness as it loses generality. We could require that a pointer in a known location be initialized so that it points to the start of the message. But that would still tie up the fixed 2 bytes occupied by that pointer. Or we could have a register specify the location of a pointer that actually points to the start of the message. Presumably a calling program can find some convenient 2 bytes in the zero page to use as a pointer, even if it must save them before it sets them. The calling program can set this zero-page pointer so that it points to the beginning of the message, and then set the X register so that it points to that zero-page pointer. Having done so, the calling program may call PR.MSG. Using the indexed indirect addressing mode, PR.MSG can then get characters from the message.

When PR.MSG has printed the entire message, it will return to its caller.

How will PR.MSG know when it has reached the end of the message? We can mark the end of each message with a special character: call it ETX, for *End* of *TeXt*. And for reasons which will become clear in Chapter 10, *A Disassembler*, we'll also start each message with another special character: TEX, for *TEX*t follows.

If we can develop PR.MSG to work from these inputs, then it won't be hard for a calling program to print any particular message in memory. Let's look at the required calling sequence.

A message, starting with a TEX and ending with an ETX, begins at some address. We'll call the high byte of that address MSG.HI and the low bye of that address MSG.LO. Thus, if the message starts at address \$13A9, MSG.HI = \$13 and MSG.LO = \$A9.

MSGPTR is some zero-page pointer. It may be anywhere in the zero page. If the calling program does not have to preserve MSGPTR, it can print the message to the screen with the following code:

```
JSR TVT.ON          Select TVT as an output device. (Any other currently
                    selected output device will echo the screen output.)
LDA #MSG.LO         Set MSGPTR
STA MSGPTR          so it points
LDA #MSG.HI         to the start
STA MSGPTR+1        of the message.
LDX #MSGPTR         Set X register so it points to MSGPTR.
JSR PR.MSG          Print the message to all currently selected output
                    devices.
```

If the calling program must preserve MSGPTR, it will have to save MSGPTR and MSGPTR+1 before executing the above lines of code and restore MSGPTR and MSGPTR+1 after executing the above lines of code.

That looks like a reasonably convenient calling sequence. So now let's turn our attention to PR.MSG itself and develop it so it meets the demands of its callers.

Print a Message

```
PR.MSG     STX TEMP.X     Save X  register, which specifies message
                          pointer.
           LDA 1,X        Save message pointer.
           PHA
           LDA 0,X
           PHA
LOOP       LDX TEMP.X     Restore original value of X, so it points
                          to message pointer.
           LDA (0,X)      Get next character from message.
           CMP #ETX       Is it the end of message indicator?
           BEQ MSGEND     If so, handle the end of the message...
           INC 0,X        If not, increment the message pointer
           BNE NEXT       so it points to the next
           INC 1,X        character in the message.
NEXT       JSR PR.CHR     Send the character to all currently
                          selected output devices.
           CLC            Get next character
           BCC LOOP       from message.
MSGEND     PLA            Restore message pointer.
           STA 0,X
           PLA
           STA 1,X
           RTS            Return to caller, with MSGPTR pre-
                          served.
TEMP.X     .BYTE 0        This data cell is used to preserve the ini-
                          tial value of X.
```

Print the Following Text

Even more convenient than PR.MSG would be a routine that doesn't require the caller to set any pointer or register in order to indicate the location of a message. But if no pointer or register indicates the start of the message, how can any subroutine know where the message starts?

It can look on the stack.

Why not have a subroutine, called Print-the-Following, which prints the message that follows the call to Print-the-Following. Since Print-the-Following is longer than six characters, let's shorten its name to "PRINT:", letting the colon in "PRINT:" suggest the phrase "the following." A calling program might then print "HELLO" with the following lines of code:

```
JSR TVT.ON          Select TVT as an output device. (Other currently
                    selected output devices will echo the screen output.)

JSR PRINT:
.BYTE TEX
.BYTE "HELLO"
.BYTE ETX
(6502 code follows the ETX)
.
.
.
```

Whenever the 6502 calls a subroutine, it pushes the address of the subroutine's caller onto the stack. This enables control to return to the caller when the subroutine ends with an RTS, because the 6502 knows it can find its return address on the stack. The subroutine PRINT: can take advantage of this fact by pulling its own return address off the stack, and using it as a pointer to the message that should be printed. When it reaches the end of the message, it can place a new return address on the stack, an address that points to the end of the message. Then PRINT: can execute an RTS. Control will then pass to the 6502 code immediately following the ETX at the end of the message. The source code for PRINT: follows:

```
PRINT:      PLA              Pull return address from
            TAX              stack and save it in
            PLA              registers X and Y.
            TAY
            JSR PUSHSL       Save the select pointer, because we're
                             going to use it as a text pointer.
            STX SELECT       Set SELECT = return address.
            STY SELECT+1
            JSR INC.SL       Increment SELECT pointer so it points
                             to TEX character.
LOOP        JSR INC.SL       Increment select pointer so it points to
                             the next character in the message.
            JSR GET.SL       Get character.
            CMP #ETX         Is it end of message indicator?
            BEQ ENDIT        If so, adjust return address and return.
            JSR PR.CHR       If not, print the character to all current-
                             ly selected devices.
            CLC              Then loop to get
            BCC LOOP         next character...
ENDIT       LDX SELECT
            LDY SELECT+1
```

```
                 JSR POP.SL          Restore select pointer to its original
                                     value.
                 TYA                 Push address
                 PHA                 of ETX
                 TXA                 onto the stack.
                 PHA
                 RTS                 Return (to byte immediately following
                                     ETX).
```

Saving and Restoring the SELECT Pointer

Now that a number of subroutines are accessing the contents of memory with the SELECT utilities (GET.SL, PUT.SL, INC.SL and DEC.SL) we should provide yet another pair of SELECT utilities to enable the subroutines to save and restore the SELECT pointer. With such save and restore functions, any subroutine can use the SELECT pointer to access memory, without interfering with the use of the SELECT pointer by other subroutines. PUSHSL will push the SELECT pointer onto the stack and POP.SL will pop the SELECT pointer off the stack. PUSHSL and POP.SL will each preserve X,Y, and the zero page.

Save Select Pointer
(Preserving X,Y, and the Zero Page)

```
PUSHSL           PLA                 Pull return address from stack and
                 STA RETURN          store it temporarily in RETURN.
                 PLA
                 STA RETURN+1
                 LDA SELECT+1        Push select pointer onto stack.
                 PHA
                 LDA SELECT
                 PHA
                 LDA RETURN+1        Push return address back onto stack.
                 PHA
                 LDA RETURN
                 PHA
                 RTS                 Return to caller. (Caller will find select
                                     pointer on top of the stack.)
```

Restore Select Pointer (Preserving X,Y, and the Zero Page)

```
POP.SL      PLA              Save return address temporarily.
            STA RETURN
            PLA
            STA RETURN+1
            PLA              Restore select pointer from stack.
            STA SELECT
            PLA
            STA SELECT+1
            LDA RETURN+1     Place return address back on stack.
            PHA
            LDA RETURN
            PHA
            RTS              Return to caller.
RETURN      .WORD 0          This pointer is used by PUSHSL and
                             POP.SL to preserve their return ad-
                             dresses.
```

Conclusion

With the print utilities presented in this chapter, it should be easy to write the character-output portions of many programs, making it possible for calling programs to select any combination of output devices and to send individual characters, bytes, or complete messages to those devices. The calling programs will be completely insulated from the particular data representations used by the print utilities. The calling programs do not need to know the nature or location of the output-device flags or the addresses of the output vectors; they need only know the addresses of the print utilities.

Similarly, although the print utilities use subroutines that operate on the SELECT pointer, the print utilities themselves never access the SELECT pointer directly. They are completely insulated from the nature and location of the SELECT pointer. As long as they know the addresses of the SELECT utilities, the print utilities can get the currently selected byte, select the next or the previous byte, save the SELECT pointer onto the stack, and restore the SELECT pointer from the stack. If at some point we should implement a different representation of "the currently selected byte," we need only change the SELECT utilities; the print utilities, and all other programs which use the SELECT utilities need never change.

Insulating blocks of code from the internal representation of data in other blocks of code makes all the code much easier to maintain.The following print utilities are available to external callers:

CHARS	Send the character in the accumulator "X" times to all currently selected output devices.
CR.LF	Cause a new line on all currently selected devices.
CR.LFS	Cause "X" new lines on all currently selected devices.
PR.BYT	Print the byte in the accumulator, in hexadecimal representation.
PR.CHR	Print the character in the accumulator on all currently selected devices.
PR.MSG	Print the message pointed to by a zero-page pointer specified by X.
PRINT:	Print the message following the call to "PRINT:".
SPACE	Send a space to all currently selected output devices.
SPACES	Send "X" spaces to all currently selected output devices.

Exercises

1) Write a printer test program, which sends every possible character from $00 to $FF to the printer.

2) Rewrite the printer test program so that it prints just one character per line.

Chapter 8:

Two Hexdump Tools

The Visible Monitor allows you to examine memory, but only 1 byte at a time. You'll quickly feel the need for a software tool that will display or print out the contents of a whole block of memory. This is especially useful if you wish to debug a program. You can't debug a program if you're not sure what's in it. A hexdump tool will show you what you've actually entered into the computer, by displaying the contents of memory in hexadecimal form.

I've developed two kinds of hexdump programs, each for a different type of output device. When I'm working at the keyboard, I want a hexdump routine that dumps from memory to the *screen*, a line or a group of lines at a time. But for documentation and for program development or debugging away from the keyboard, I want a hexdump routine that dumps to a *printer*.

Most of the code required to dump from memory will be the same, whether we direct output to the screen or to the printer. However, there are enough differences between the two output devices that it is convenient to have two hexdump programs, one for the screen and one for the printer. Let's call them TVDUMP and PRDUMP.

TVDUMP

TVDUMP should be very responsive: when you are using the Visible Monitor, a single keystroke should cause one or more lines to be dumped to the screen. But how can TVDUMP know what lines you want to dump? Since the Visible Monitor allows you to select any address by rolling hexadecimal characters into the address field or by stepping forward and backward through memory, we might as well have

TVDUMP dump memory beginning with the currently selected address.

Since we're basing TVDUMP on the Visible Monitor's currently selected address, we can use some of the Visible Monitor's subroutines to operate on that address. GET.SL will get the currently selected byte, and INC.SL will increment the SELECT pointer, thereby selecting the next byte. The print utilities TVT.ON and PR.BYT will let us select the screen as an output device and print the accumulator in hexadecimal representation.

We ought to have TVDUMP provide a dump that will be easily readable, even on the narrow confines of a twenty-five- or forty-column display. That means we can't display a full hexadecimal line (16 bytes) on one screen line if we want to have a space between each byte. We can provide hexdumps that split each hexadecimal line into two screen lines. See outputs A and B in figure 8.1.

```
                 Output A:

0200   HH  HH  HH  HH  HH  HH  HH  HH  HH
0208   HH  HH  HH  HH  HH  HH  HH  HH  HH

0210   HH  HH  HH  HH  HH  HH  HH  HH  HH
0218   HH  HH  HH  HH  HH  HH  HH  HH  HH

------------------29 columns-------------------


             Output B:

0200
HH  HH  HH  HH  HH  HH  HH  HH
0208
HH  HH  HH  HH  HH  HH  HH  HH

0210
HH  HH  HH  HH  HH  HH  HH  HH
0218
HH  HH  HH  HH  HH  HH  HH  HH

-----------23 columns------------
```

Figure 8.1: *Two TVDUMP formats.*

One way to provide such a hexdump is shown by the flowchart in figure 8.2. Using this flowchart as a guide, let's develop source code to perform the TVDUMP function:

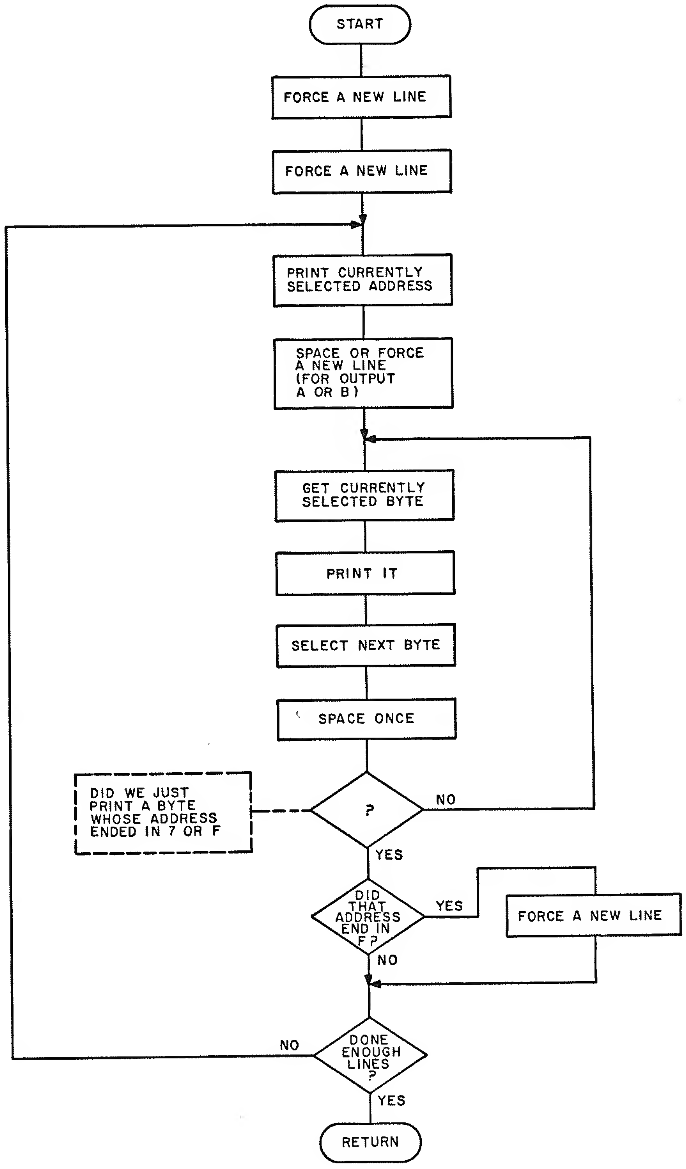

START
FORCE A NEW LINE
FORCE A NEW LINE
PRINT CURRENTLY SELECTED ADDRESS
SPACE OR FORCE A NEW LINE (FOR OUTPUT A OR B)
GET CURRENTLY SELECTED BYTE
PRINT IT
SELECT NEXT BYTE
SPACE ONCE
DID WE JUST PRINT A BYTE WHOSE ADDRESS ENDED IN 7 OR F
?
NO
YES
DID THAT ADDRESS END IN F?
YES
FORCE A NEW LINE
NO
DONE ENOUGH LINES ?
NO
YES
RETURN

Figure 8.2: *Flowchart of the screen Hexdump Program.*

CONSTANTS

CR = $0D	Carriage return.
LF = $0A	Line feed.

REQUIRED SUBROUTINES

GET.SL	Get currently selected byte.
INC.SL	Increment the pointer that specifies the currently selected byte.
PR.BYT	Print the accumulator to currently selected devices, in hexadecimal representation.
SELECT	Pointer to currently selected address.

VARIABLES

COUNTR	.BYTE 0	This byte counts the number of lines dumped by TVDUMP.
HEXLNS	.BYTE 4	Number of hexadecimal lines to be dumped by TVDUMP. (Set this to any number you like. To dump a single hexadecimal line [16 bytes] , set HEXLNS = 1.)

TVDUMP

```
TVDUMP     JSR TVT.ON       Select TVT as an output device.
                            (Other devices will echo the dump.)
           LDA HEXLNS       Set COUNTR to the number of lines
           STA COUNTR       to be dumped by TVDUMP.
           LDA SELECT       Set SELECT to beginning
           AND #$F8         of a screen line (8 bytes)
           STA SELECT       by zeroing 3 LSB in SELECT.
           LDX #2           Skip two lines on the screen.
           JSR CR.LFS
DUMPLN     JSR PR.ADR       Print the selected address.
           JSR CR.LF        Advance to a new line on the screen.
                            (This call to CR.LF may be replaced
                            with a call to SPACE on systems with
                            screens more than 27 columns wide.
                            This will yield the Output A rather than
```

```
                                  Output B.)
DMPBYT        JSR SPACE           Print a space.
              JSR DUMPSL          Dump currently selected byte.
              JSR INC.SL          Select next address by incrementing
                                  select pointer.
              LDA SELECT          Is it the beginning of a new
              AND #07             screen line? (3 LSB = 0?)
              BNE DMPBYT          If not, dump next byte...
              JSR CR.LF           If so, advance to a new line on the
                                  screen.
              LDA SELECT          Does this address mark the beginning of
                                  a new hexadecimal line?
              AND #$0F            (4 LSB of SELECT = 0?)
              BNE IFDONE
              JSR CR.LF           If so, skip a line on the screen.
IFDONE        DEC COUNTR          Dumped last line yet?
              BNE DUMPLN          If not, dump next line.
              JSR TVTOFF          Deselect TVT as an output device.
              RTS                 Return to caller.
```

DUMP CURRENTLY SELECTED BYTE

This subroutine gets the currently selected byte (the byte pointed to by SELECT) and prints it in hexadecimal format on all selected devices.

```
DUMPSL        JSR GET.SL          Get currently selected byte.
              JSR PR.BYT          Print it in hexadecimal format.
              RTS                 Return to caller.
```

PRINT ADDRESS

This subroutine prints, on all selected devices, the currently selected address (ie: the value of the SELECT pointer).

```
PR.ADR        LDA SELECT+1        Get the high byte of SELECT...
              JSR PR.BYT          ...and print it in hexadecimal format.
              LDA SELECT          Get the low byte of SELECT...
              JSR PR.BYT          ...and print it in hexadecimal format.
              RTS                 Then return to caller.
```

PRDUMP

With the subroutine presented thus far in this chapter, we can dump to the screen just by calling TVDUMP. But what if we want to *print* a hexdump? Is a hexdump program that prints any different from one that dumps to the screen? Can we simply select the printer instead of the TVT and leave the rest of the code the same?

We could. But then we wouldn't be taking full advantage of the printer. TVDUMP produces an output that is easily read within the twenty-five or forty columns of a video display. Most printers can output sixty-four columns or more. We should take advantage of the extra width offered by a printer.

We should also recognize the difference in responsiveness between a screen and a hard-copy device. When I'm using a screen-based hexdump, I don't mind hitting a single key every time I want some lines dumped to the screen. But with a printing hexdump, I don't want to strike a key repeatedly to continue the dump. I don't mind striking a number of keys at the beginning in order to specify the memory to be dumped, but once I've done that I don't want to be bothered again. I want to set it and forget it.

When called, a printing hexdump program should announce itself by clearing the screen and displaying an appropriate title (eg: "PRINTING HEXDUMP"). Then it should ask you to specify the starting address and the ending address of the memory to be dumped.

Once it knows what you want to dump, PRDUMP should print a hexdump of the specified block of memory. For your convenience, PRDUMP should tell you what block of memory it will dump; then it should provide a header for each column of data and indicate the starting address of each line of data. (See the "D" appendices.)

Using the flowchart of figure 8.3 as a guide, we can write source code for the top level of the PRINTING HEXDUMP:

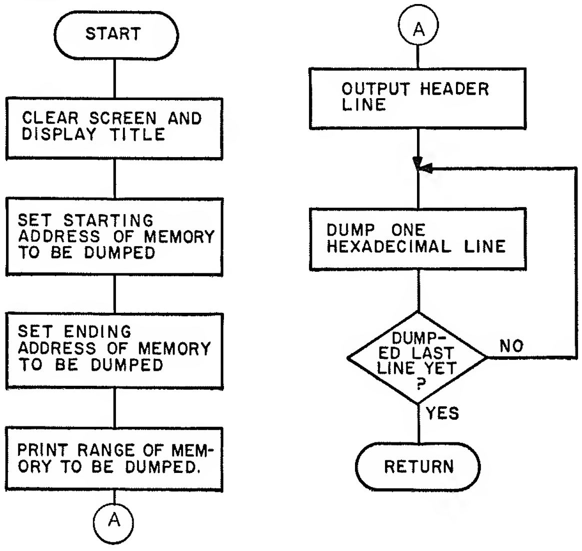

START
CLEAR SCREEN AND DISPLAY TITLE
SET STARTING ADDRESS OF MEMORY TO BE DUMPED
SET ENDING ADDRESS OF MEMORY TO BE DUMPED
PRINT RANGE OF MEMORY TO BE DUMPED.
A
A
OUTPUT HEADER LINE
DUMP ONE HEXADECIMAL LINE
DUMPED LAST LINE YET ?
NO
YES
RETURN

Figure 8.3: *To print a Hexdump.*

```
PRDUMP   JSR TITLE             Display the title.
         JSR SETADS            Let user set start address and end ad-
                               dress of memory to be dumped.
                               (SETADS returns with SELECT=EA,
                               the end address.)
         JSR GOTOSA            Set SELECT=SA, the starting address.
         JSR PR.ON             Select printer as a output device. (Other
                               selected devices will echo the dump.)
         JSR HEADER            Output hexdump header.
HXLOOP   JSR PRLINE            Dump one line. (PRLINE returns minus
                               if it dumped through ending address;
                               otherwise it returns PLUS.)
         BPL HXLOOP            Done yet? If not, dump next line.
         JSR CR.LF             If so, go to a new line.
         JSR PR.OFF            Deselect printer.
         RTS                   Return to caller. Specified memory has
                               been dumped.
TITLE    JSR CLR.TV            Clear the screen.
         JSR TVT.ON            Select screen as an output device.
         JSR PRINT:            Display "Printing Hexdump" on all
                               selected output devices.
         .BYTE TEX             Text string must start with a TEX
                               character...
         .BYTE CR,'PRINTING '
         .BYTE 'HEXDUMP ',CR
         .BYTE LF,LF,
         .BYTE ETX             ...and end with an ETX character.
         RTS                   Return to caller.
```

Get Starting, Ending Address

The printing hexdump program must secure from the user the starting address and the ending address of the memory to be dumped. The subroutine, SETADS, will perform these functions. It will place an appropriate prompt on the screen ("Set Starting Address" or "Set Ending Address") and then allow the user to specify an address.

Putting a prompt on the screen is easy: just select the TVT by calling TVT.ON, call "PRINT:" and follow this call with a TEX (start of text) character, the text of the prompt, and then an ETX (end of text) character. How can we allow the user to specify an address? We could make a subroutine, called GETADR, which gets an address by enabling the user to set some pointer. That sounds mighty familiar — that's what the Visible Monitor does. Conveniently, the Visible Monitor is a subroutine, which returns to its caller when the user presses Q for Quit. Therefore, after putting the appropriate prompt on the screen, SETADS will call the Visible Monitor. When the Visible Monitor returns, the SELECT pointer will specify the requested address.

SET STARTING ADDRESS, ENDING ADDRESS

```
SETADS      JSR TVT.ON        Select TVT as an output device. All
                              other selected output devices will echo
                              the screen output.
            JSR PRINT:        Put prompt on the screen:
            .BYTE TEX
            .BYTE CR,LF,LF
            .BYTE             'SET STARTING ADDRESS '
            .BYTE             'AND PRESS "Q".'
            .BYTE ETX
            JSR VISMON        Call the Visible Monitor, so user can
                              specify a given address.
            JSR SAHERE        Set starting address equal to address set
                              by the user.
SET.EA      JSR PRINT:        Put prompt on the screen:
            .BYTE TEX
            .BYTE CR,LF,LF
            .BYTE             'SET ENDING ADDRESS '
            .BYTE             'AND PRESS "Q".'
            .BYTE ETX
            JSR VISMON        Call the Visible Monitor, so user can
                              specify a given address.
            SEC               If user tried to set an
            LDA SELECT+1      ending address less than
            CMP SA+1          the starting address,
            BCC TOOLOW        make user do it over.
            BNE EAHERE        If SELECT is greater than SA, set
                              EA=SELECT. That will make EA
                              greater than SA.
            LDA SELECT
            CMP SA
            BCC TOOLOW
EAHERE      LDA SELECT+1      Set EA=SELECT...
            STA EA+1
            LDA SELECT
            STA EA
            RTS               ... and return.
SAHERE      LDA SELECT+1      Set SA=SELECT...
            STA SA+1
```

```
                LDA SELECT
                STA SA
                RTS              ...and return.
TOOLOW          JSR PRINT:       Since user set ending address
                .BYTE STX,       too low, print error message:
                .BYTE CR,LF,LR
                .BYTE            'ERROR! '
                .BYTE            'END ADDRESS LESS '
                .BYTE            'THAN START ADDRESS, '
                .BYTE            'WHICH IS '
                .BYTE ETX
                JSR PR.SA        Print starting address. ...and let the user
                                 set
                JMP SET.EA       the ending address again.
SA              .WORD 0          Pointer to starting address of memory to
                                 be dumped.
EA              .WORD $FFFF      Pointer to ending address of memory to
                                 be dumped.
```

Now that the user can set the starting address and the ending address for a hex-dump (or for any other program that must operate on a contiguous block of memory), we should have utilities that print out the starting address, the ending address, or the range of addresses selected by the user. If the user set $D000 as the starting address and $D333 as the ending address, we should be able to call one subroutine that prints "$D000," another that prints "$D333," and a third that prints "$D000 — $D333."

Let's call these subroutines PR.SA, to print the starting address; PR.EA, to print the ending address; and RANGE, to print the range of addresses.

Print Starting Address

The following subroutine prints the value of SA, the starting address, in hexadecimal format:

```
PR.SA           LDA #'$          Print a dollar sign to
                JSR PR.CHR       indicate hexadecimal.
                LDA SA+1         Print high byte of starting address.
                JSR PR.BYT
                LDA SA           Print low byte of starting address.
                JSR PR.BYT
                RTS              Return to caller.
```

Print Ending Address

The following subroutine prints the value of EA, the ending address, in hexadecimal format:

```
PR.EA       LDA #'$         Print a dollar sign to
            JSR PR.CHR      indicate hexadecimal.
            LDA EA+1        Print high byte of ending address.
            JSR PR.BYT
            LDA EA          Print low byte of ending address.
            JSR PR.BYT
            RTS             Return to caller.
```

Print Range of Addresses

```
RANGE       JSR PR.SA       Print starting address.
            LDA #'-         Print a hyphen.
            JSR PR.CHR
            JSR PR.EA       Print ending address.
            RTS             Return to caller.
```

HEADER

We want a routine to print an appropriate header for the hexdump. It should accomplish two tasks: identify the block it will dump, and print a hexadecimal digit at the top of every column of hexdump output. Thus, HEADER should produce the output shown between the following lines:

```
DUMPING HHHH-HHHH

        0 1 2 3 4 5 6 7 8 9 A B C D E F

```

Notice the blank line following the line of hexadecimal characters. This will insure a blank line between the header and the dump itself, making for a more readable output. (See the hexdumps in the D series of appendices which were produced with PRDUMP.)

Here are a few lines of code to print the first line of the header:

```
JSR PRINT:
.BYTE TEX,CR,LF
.BYTE 'DUMPING '
.BYTE ETX
JSR RANGE
JSR CR.LF
```

What about the rest of the header? Since all we want to do is print the hexadecimal digits 0 thru $F, with appropriate spacing between them, the rest of HEADER can just be some code to count from 0 to $F, convert to ASCII, and print:

PRINT HEXADECIMAL DIGITS (Version I)

```
          LDX #7          Print seven spaces.
          JSR SPACES
          LDA #0          Initialize column counter
          STA COLUMN      to zero.
HXLOOP    LDA COLUMN      Convert column counter to
          JSR ASCII       an ASCII character and
          JSR PR.CHR      print it.
          LDX #2          Space twice after the character.
          JSR SPACES
          INC COLUMN      Increment the column counter.
          LDA COLUMN      Loop if counter not greater
          AND #$F0        than $0F.
          BEQ HXLOOP
          LDX #2          Otherwise, skip two lines
          JSR CR.LFS      after the header.
          RTS             Then return.
COLUMN    .BYTE 0         This 1-byte variable is used to count
                          from 00 to $0F.
```

Version 1 of PRINT HEXADECIMAL DIGITS will work, and in only 49 bytes. But that's 49 bytes of code, which among other things must count and branch, and if for some reason one of those bytes is wrong, Version 1 of PRINT HEXADECIMAL DIGITS will probably go directly into outer space. But we could write PRINT

HEXADECIMAL DIGITS in a much more straightforward manner, which, though somewhat more costly in terms of memory required, will be more readable and less likely to run amuck.

PRINT HEXADECIMAL DIGITS need only call "PRINT:", and follow this call with a text string consisting of the desired hexadecimal digits.

PRINT HEXADECIMAL DIGITS (Version 2)

```
JSR PRINT:
.BYTE TEX
.BYTE '          0   1   2   3   4   5   6   7   '
.BYTE           '8   9   A   B   C   D   E   F'
.BYTE CR,LF,LF
.BYTE ETX
RTS
```

Version 2 of PRINT HEXADECIMAL DIGITS requires 60 bytes. But it's more readable than Version 1 of PRINT HEXADECIMAL DIGITS, and it can be modified much more easily: just change the text in the message it prints. You don't have to calculate branch addresses or test the terminal condition in a loop. This is just one example of a programming problem that may be solved in a computation-intensive or a data-intensive manner.

Where other factors are about equal, I prefer data-intensive subroutines, because they're more readable and easier to change. Even in this case, I'm willing to pay the extra 20 bytes for a version of PRINT HEXADECIMAL DIGITS that I don't have to read twice. Hence, PRINT HEXADECIMAL DIGITS Version 2, and not Version 1, will appear in the assembler listings of HEADER in Appendix C5.

PRLINE

Clearly, most of the work of PRDUMP will be performed by the subroutine PRLINE, which dumps one line of memory to the printer. It will stop when it has dumped 16 bytes (one hexadecimal line) or has dumped through the ending address specified by the user.

As we did for TVDUMP, let's use SELECT as a pointer to the first byte that must be dumped by PRLINE. When PRLINE is called, it must see if the currently selected byte (the byte pointed to by SELECT) is at the start of a hexadecimal line. A byte is at the beginning of a hexadecimal line if the 4 LSB (least-significant bits) of its address are zero. Thus, $4ED8 is not the start of a hexadecimal line, but $4ED0 *is*.

If the currently selected byte is not the beginning of a hexadecimal line, PRLINE should space over to the appropriate column for that byte. If the currently selected byte is at the beginning of a hexadecimal line, PRLINE should print the address of the currently selected byte and space twice.

Once it has spaced over to the proper column, PRLINE need only get the currently selected byte, print it in hexadecimal format, space once, and then do the same for the next byte, until it has dumped the entire line or has dumped the last byte requested by the user.

Figure 8.4 gives a flowchart for the following routine:

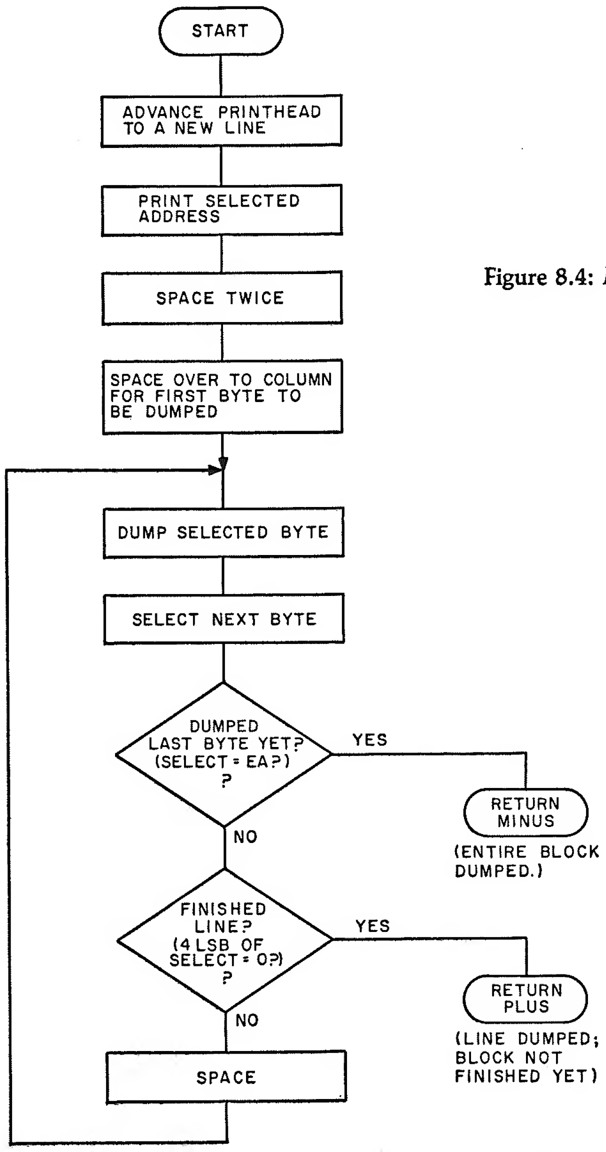

START
ADVANCE PRINTHEAD TO A NEW LINE
PRINT SELECTED ADDRESS
SPACE TWICE
SPACE OVER TO COLUMN FOR FIRST BYTE TO BE DUMPED
DUMP SELECTED BYTE
SELECT NEXT BYTE
DUMPED LAST BYTE YET? (SELECT = EA?) ?
YES
NO
RETURN MINUS
(ENTIRE BLOCK DUMPED.)
FINISHED LINE? (4 LSB OF SELECT = 0?) ?
YES
NO
RETURN PLUS
(LINE DUMPED; BLOCK NOT FINISHED YET)
SPACE

Figure 8.4: *Dump one line to the printer.*

PRLINE

```
PRLINE      JSR CR.LF       Advance printhead to a new line.
            LDA SELECT      Determine starting
            PHA             column
            AND #$0F        for this dump.
            STA COLUMN      Now COLUMN holds the number of the
                            column in which we will dump the first
                            byte.
            PLA             Set SELECT pointer to
            AND #$F0        beginning of a hexadecimal line.
            STA SELECT
            JSR PR.ADR      Print the selected address.
            LDX #3          Space three times — to the
            JSR SPACES      first column.
            LDA COLUMN      Do we dump from the first column?
            BEQ COL.OK      If so, we're at the correct column now.
LOOP        LDX #3          If not, space three
            JSR SPACES      times for each byte not
            JSR INC.SL      dumped.
            DEC COLUMN
            BNE LOOP
COL.OK      JSR DUMPSL      Dump the currently selected byte.
            JSR SPACE       Space once.
            JSR NEXTSL      Select the next byte in memory, unless
                            we've already dumped through the end
                            address.
            BMI EXIT        (MINUS means we've dumped through
                            the end address.)
NOT.EA      LDA SELECT      Dumped entire line?
            AND #$0F        (4 LSB of SELECT = 0?)
            CMP #0          If so, we've dumped the entire line. If
                            not,
            BNE COL.OK      select the next byte and dump it...
EXIT        RTS             PRLINE returns MINUS, with A=$FF,
                            if it dumped through ending address.
                            Otherwise it returns PLUS, with A=0.
```

Select Next Byte

NEXTSL tests to see if SELECT is less than the ending address. If so, it increments SELECT and returns PLUS (with zero in the accumulator). If not, it preserves SELECT and returns MINUS (with $FF in the accumulator).

NEXTSL

```
NEXTSL    SEC                    Prepare to compare.
          LDA SELECT+1           Is high byte of SELECT less than
          CMP EA+1               high byte of end address (EA)?
          BCC SL.OK              If so, SELECT is less than EA, so it may
                                 be incremented.
          BNE NO.INC             If SELECT is greater than EA, don't
                                 increment SELECT.
                                 SELECT is in the same page as EA,
          SEC                    prepare to compare low bytes:
          LDA SELECT             Is low byte of SELECT less than
          CMP EA                 low byte of EA?
          BCS NO.INC             If not, don't increment it.
SL.OK     JSR INC.SL             Since SELECT is less than EA, we may
                                 increment it.
          LDA #0                 Set "incremented" return code and
          RTS                    return.
NO.INC    LDA #$FF               Set "not incremented" return code
          RTS                    and return.
```

Go to Start of Block

GOTOSA sets SELECT = SA, thus selecting the first byte in the block defined by SA and EA:

```
GOTOSA    LDA SA                 Set SELECT
          STA SELECT             equal to
          LDA SA+1               START ADDRESS
          STA SELECT+1           of block.
          RTS
```

Now the two hexdump tools are complete. You may invoke either tool directly from the Visible Monitor by displaying the start address of the given hexdump tool and pressing "G." This will work fine for PRDUMP: you'll get a chance to set the starting address and the ending address that you want to dump, and then you'll see the dump on both the printer and the screen. If you start TVDUMP with a "G" from the Visible Monitor, you'll only get a dump of TVDUMP itself. You won't be able to use TVDUMP to dump any other location in memory. Why? Because TVDUMP dumps from the displayed address, and to start any program with a "G" from the Visible Monitor, you must first display the starting address of that program. Probably you'd like to be able to use TVDUMP to dump other areas in memory. To do so, you must assign a Visible Monitor key (eg: "H") to the subroutine TVDUMP, so that the Visible Monitor will call TVDUMP whenever you press that key. See Chapter 12, *Extending the Visible Monitor.*

Chapter 9:

A Table-Driven Disassembler

With the Visible Monitor you can enter object code into your computer. With hexdump tools you can dump that object code to the screen or to a printer. However, you still can't be sure you've entered the instructions you intended to enter unless you refer back and forth from your hexdump to Appendix A4, *The 6502 Opcode List*. You must verify that every opcode you entered is for the instruction and the addressing mode that you had intended. You must count forward or backward in hexadecimal to make sure that the operands in your branch instructions are correct. If you entered one opcode or operand incorrectly, then even though your handwritten program may be correct, the version in your computer's memory will be wrong.

A disassembler (the opposite of an assembler) can make your life a lot easier by displaying or printing the mnemonics represented by the opcodes you entered into your computer, and by showing you the actual addresses and addressing modes represented by your operands. The disassembler can't know that address 0000 has the label "TV.PTR," but it can let you know that a given instruction operates on address 0000.

A disassembled line includes the following fields:

Field Number	**Field Description**
1.	Mnemonic.
2.	Operand.
3.	Address of opcode.
4.	Opcode in hexadecimal.

5. First byte of operand (if present) in hexadecimal.
6. Second byte of operand (if present) in hexadecimal.

Here's a disassembled line, with each of the fields numbered:

```
1       2       3       4       5       6       (Field Numbers)

JSR     0400    08AC    20      00      04      (Disassembled Line)
```

As with hexdump tools, I find it convenient to have two disassemblers: one for the screen and one for the printer. The screen-oriented disassembler should direct a certain number of disassembled lines to the screen whenever it is called. On the other hand, the printing disassembler should get a starting address and an ending address from the user and print a continuous disassembly of that portion of memory. As before, when I direct output to a printer I want to set it and forget it.

Whether we disassemble to the screen or to a printer, we will disassemble one line at a time. How can a program disassemble a line? The same way a person does. You look at an opcode in memory and then consult a table such as Appendix A4 to determine the operation represented by that opcode. Each operation has two attributes, a mnemonic and an addressing mode. The procedure is simple. Write the mnemonic; then, from the addressing mode determine whether this opcode takes no operand, a 1-byte operand, or a 2-byte operand. If it takes an operand, look at the next byte or two in memory and then write the operand for the mnemonic.

Thus, if you wish to disassemble object code from some place in memory, and you find an $8D at that location, you can determine from Appendix A6 that $8D represents "store accumulator, absolute mode." Therefore, you'll write: "STA," which is the mnemonic for store the accumulator.

The absolute mode requires a 2-byte operand, so you'll look at the 2 bytes following the $8D. If $36 follows the $8D and is itself followed by $D0, then the disassembled line will look like this:

```
STA $D036
```

That's a lot easier to read than the original 3 bytes of object code:

```
8D 36 D0
```

DISASSEMBLY

```
JSR    0400        1E00   20   00   04
JSR    04A0        1E03   20   A0   04
LDA    (0021),Y    1E06   B1   21
CLC                1E08   18
BCC    1E00        1E09   90   F5
```

HEXDUMP

```
        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F

1E00    20 00 04 20 A0 04 B1 21 18 90 F5
```

Figure 9.1: *Disassembly and hexdump of the same object code.*

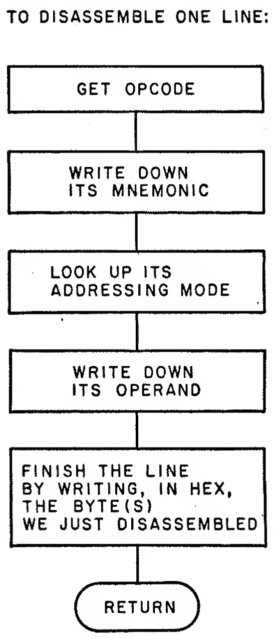

TO DISASSEMBLE ONE LINE:
GET OPCODE
WRITE DOWN ITS MNEMONIC
LOOK UP ITS ADDRESSING MODE
WRITE DOWN ITS OPERAND
FINISH THE LINE BY WRITING, IN HEX, THE BYTE(S) WE JUST DISASSEMBLED
RETURN

Figure 9.2: *Algorithm for disassembling one line of code.*

That looks pretty simple. We can use the SELECT pointer to indicate the current byte within memory, and we'll assume that lower-level subroutines exist or will exist to do the jobs required by DSLINE, which disassembles one line. With those assumptions, we can write source code for DSLINE:

DISASSEMBLE ONE LINE

```
DSLINE          JSR GET.SL       Get currently selected byte.
                PHA              Save it on stack.
                JSR MNEMON       Print the mnemonic represented by that
                                 opcode.
                JSR SPACE        Space once.
                PLA              Restore opcode to accumulator.
                JSR OPERND       Print the operand required by that op-
                                 code.
                JSR FINISH       Finish the line by printing fields 3 thru
                                 6.
                JSR NEXTSL       Select next byte.
                RTS              Return to caller, with SELECT pointing
                                 at the last byte of the operand (or at the
                                 opcode, if it was a 1-byte instruction).
```

Print Mnemonic

We need a subroutine called MNEMON which prints the three-letter mnemonic for a given opcode. How can MNEMON do this? How do we do it? We look it up in a table such as Appendix A4. We could have a similar table in memory and then have MNEMON sequentially look up from the table the three characters comprising the desired mnemonic. That would require a 3-byte mnemonic for each of 256 possible opcodes: a 758-byte table. That's a lot of memory! Perhaps if we organize our data better we'll need less memory.

For example, why include the same mnemonic more than once in the table? Eight different opcodes use the mnemonic LDA; why should I use up 24 bytes to store "LDA" eight times? We could have a table of mnemonic names, which is nothing more than an alphabetical list of the three-letter mnemonics. There are only fifty-six different mnemonics; if we add one pseudo-mnemonic, "BAD," to mean that a given opcode is not valid, then we still have only fifty-seven mnemonics. The table of mnemonic names will therefore require only 171 bytes.

If you have a given opcode, how can you know which mnemonic in the table of mnemonic names corresponds to your opcode? A mnemonic *code* is some number that uniquely identifies a given mnemonic. Let's assume that we have a table of mnemonic codes which gives the mnemonic code for each possible opcode.

Now you can look up in the table of mnemonic codes the mnemonic code corresponding to a given opcode, and then use the mnemonic code as an index to the table of mnemonic *names*. The three sequential characters located in the table of mnemonic names will comprise the mnemonic for your original opcode.

This method requires not one but two tables. The two together, however, require considerably less memory than our first table did. The table of mnemonic codes will be 256-bytes long, since it must have an entry for every possible opcode, including invalid ones. The table of mnemonic names, on the other hand, will be only 171-bytes long, so the two tables together require only 427 bytes. That's 331 bytes or 43 percent less memory than our first table required.

Space saved in tables may not be worth it if large or complicated code is required as an index to those tables, but in this case the code is quite simple:

```
MNEMON     LDX #3          There are three letters in a mnemonic.
           STX LETTER      We'll keep track of the letters by count-
                           ing down to zero.
           TAX             Prepare to use the opcode as an index.
           LDA MCODES,X    Look up the mnemonic code for that op-
                           code. (MCODES is the table of
                           mnemonic codes.)
           TAX             Prepare to use that mnemonic code as
                           an index.
MNLOOP     LDA MNAMES,X    Get a mnemonic character. (MNAMES
                           is the list of mnemonic names.)
           STX TEMP.X      Save X register (since printing will
                           almost certainly change the X register).
           JSR PR.CHR      Print the character to all currently
                           selected devices.
           LDX TEMP.X      Restore X register to its previous value.
           INX             Adjust index for next letter.
           DEC LETTER      If three letters not yet printed,
           BNE MNLOOP      loop back to handle the next one.
           RTS             Otherwise, return to caller.
TEMP.X     .BYTE 0
LETTER     .BYTE 0
```

As you can see, MNEMON requires only 30 bytes of code in machine language: 2 bytes to hold variables and 427 bytes for the two tables (MNAMES and MCODES). The entire subroutine requires 459 bytes, but since most of those bytes are data in tables, comparatively little can go wrong with the program. If the wrong bytes are keyed into the table of mnemonic names, then the disassembler will print one or more incorrect characters in a mnemonic. But MNEMON won't crash! Bad data in means bad data out, but at least MNEMON will run, and a running program is a lot easier to correct than one that crashes and burns.

So again we have a data-intensive, rather than a computation-intensive, subroutine. The tables required by MNEMON are included in Appendix C8.

Print Operand

Now we come to the tricky part: printing the right operand given an opcode at some location in memory. When I disassemble object code by hand, I write the operand in two steps: first I determine the addressing mode of the given opcode, and then, if that addressing mode takes an operand, I write down the proper operand in the proper form. Proper form means including a comma and an X or a Y for every indexed instruction, including parentheses in the proper places for indirect instructions, and printing out all addresses *high* byte first, since that makes it easier to read an address.

OPERND (the subroutine that prints an operand for a given opcode in a given location in memory) will therefore determine the addressing mode for a given opcode, and then call an appropriate subroutine to handle that addressing mode:

OPERND

```
OPERND      TAX             Look up addressing mode code for
            LDA MODES,X     this opcode.
            TAX             X now indicates the addressing mode.
            JSR MODE.X      Call the subroutine that handles address-
                            ing mode "X."
            RTS             Return to caller.
```

MODES is a table giving the addressing mode for each opcode.

Note that OPERND can work only if we have a routine called MODE.X which somehow transfers control to the subroutine that handles addressing mode "X." How can MODE.X do this? One way is to have a table of pointers, in which the Xth pointer points to the subroutine that handles addressing mode "X." MODE.X must then transfer control to the Xth subroutine in this table. It would be nice if the 6502 offered an indexed JSR instruction, which would call the subroutine whose address is the Xth entry in the table. Unfortunately, the 6502 doesn't offer an indexed JSR instruction, so we'll have to simulate one in software.

Fortunately, the 6502 does offer an indirect JMP. If a pointer, called SUBPTR, can be made to point to a given subroutine, then the instruction JMP (SUBPTR) will transfer control to that subroutine. Therefore, MODE.X need only set SUBPTR equal to the Xth pointer in a table of subroutine pointers, and with the instruction

JMP (SUBPTR), it can transfer control to the Xth subroutine in the table.

HANDLE ADDRESSING MODE "X"

```
MODE.X      LDA SUBS,X        Get low byte of Xth pointer in the table
                              of subroutine pointers.
            STA SUBPTR        Set low byte of subroutine pointer.
            INX               Adjust index to get next byte.
            LDA SUBS,X        Get high byte of Xth pointer in the table
                              of subroutine pointers.
            STA SUBPTR+1      Set high byte of subroutine pointer.
            JMP (SUBPTR)      Jump to the subroutine specified by the
                              subroutine pointer. That subroutine will
                              then return to the caller of MODE.X,
                              not to MODE.X itself.
SUBS                          This is a table of pointers, in which the
                              Xth pointer points to the subroutine tha
                              handles addressing mode X.
```

Disassembler Utilities

Given MODE.X, OPERND can call the right subroutine to handle any give addressing mode. Now all we need are thirteen different subroutines, one for each c the 6502's different addressing modes.

Before writing those subroutines, however, let's think for a moment about wha they must do, and see if we can't write a few utility subroutines to perform thos functions. With a proper set of utilities, the addressing mode subroutines themselv need only call the right utilities in the right order.

The following set of utilities seems reasonable:

● ONEBYT:	Print a 1-byte operand.
● TWOBYT:	Print a 2-byte operand.
● RPAREN:	Print a right parenthesis.
● LPAREN:	Print a left parenthesis.
● XINDEX:	Print a comma and then the letter "X."
● YINDEX:	Print a comma and then the letter "Y."

Print a 1-Byte Operand: ONEBYT

```
ONEBYT      JSR INC.SL      Advance to byte following opcode.
            JSR DUMPSL      Print it in hexadecimal.
            RTS             Return to caller.
```

Print a 2-Byte Operand: TWOBYT

A 2-byte operand always specifies an address with the low byte first. To print a 2-byte operand high byte first, we must first print the second byte in the operand and *then* print the first byte in the operand; each, of course, in hexadecimal format.

```
TWOBYT      JSR INC.SL      Advance to first byte of operand.
            LDA GET.SL      Load that byte into accumulator.
            PHA             Save it.
            JSR INC.SL      Advance to second byte of operand.
            JSR DUMPSL      Print it in hexadecimal format.
            PLA             Restore the operand's first byte to the
            JSR PR.BYT      accumulator, and print it in hexa-
                            decimal.
            RTS             Return to caller.
```

ONEBYT and TWOBYT each leave SELECT pointing at the last byte of the operand.

Print Right, Left Parenthesis: RPAREN, LPAREN

RPAREN prints a right parenthesis to all currently selected devices. LPAREN prints a left parenthesis to all currently selected devices.

```
RPAREN      LDA #')         Load accumulator with ASCII code for
                            right parenthesis.
            BNE SENDIT      Send it to all currently selected devices.
LPAREN      LDA #'(         Load accumulator with ASCII code for
                            left parenthesis.
SENDIT      JSR PR.CHR      Send it to all currently selected devices.
            RTS             Return to caller.
```

Index with Register X: XINDEX

XINDEX prints a comma and then the letter "X:"

```
XINDEX      LDA #',          Load accumulator with ASCII code for a
                             comma; then print it to
            JSR PR.CHR       all currently selected devices.
            LDA #'X          Load accumulator with ASCII code for
                             the letter "X;" then print it
            JSR PR.CHR       to all currently selected devices.
            RTS              Return to caller.
```

Index with Register Y: YINDEX

YINDEX prints a comma and then the letter "Y:"

```
YINDEX      LDA #',          Load accumulator with ASCII code for a
                             comma; then print it to all
            JSR PR.CHR       currently selected devices.
            LDA #'Y          Load accumulator with ASCII code for
                             the letter "Y;" then print it
            JSR PR.CHR       to all currently selected devices.
            RTS              Return to caller.
```

So much for the disassembler utilities. Now with a single subroutine call we can print a 1-byte or a 2-byte operand (and, of course, we can print a no-byte operand), and we can print any of the frequently used characters and character combinations. Okay, let's write some addressing mode subroutines:

Addressing Mode Subroutines

Because the 6502 has thirteen different addressing modes, we'll need thirteen different addressing mode subroutines:

Subroutine	Addressing Mode
ABSLUT	Absolute

ABS.X	Absolute,X
ABS.Y	Absolute,Y
ACC	Accumulator
IMPLID	Implied
IMMEDT	Immediate
INDRCT	Indirect
IND.X	Indirect,X
IND.Y	Indirect,Y
RELATV	Relative
ZEROPG	Zero Page
ZERO.X	Zero Page,X
ZERO.Y	Zero Page,Y

The main job for each subroutine will be to print the operand in the proper form. Although a given addressing mode will always have the same number of characters in its operand, unfortunately, different addressing modes may have operands of different lengths. For example, implied addressing mode has no characters in its operand, whereas indirect indexed addressing requires eight characters in its operand, if leading zeros are included.

But no matter how many characters appear in an operand, we want to make sure that field 3 (the address field) always begins at the same column. Therefore, every addressing-mode subroutine will return with A holding the number of characters in the operand, with X holding the number of bytes in the operand, and with SELECT pointing at the last byte in the operand (or at the opcode, if it was a 1-byte instruction). Then FINISH can print an appropriate number of spaces before printing fields 3 thru 6.

Absolute Mode: ABSLUT

To print the operand for an instruction in the absolute mode, we need only print a 2-byte operand. Thus, 8D B2 04 will disassemble as:

```
STA 04B2   8D B2 04
```

```
ABSLUT      JSR TWOBYT
            LDX #2           X holds number of bytes in operand.
            LDA #4           A holds number of characters in
                             operand.
            RTS
```

Absolute, X Mode: ABS.X

To print the operand for an instruction in the absolute, X mode, we must print a 2-byte operand, a comma, and then an "X:"

```
                    LDA D09A,X   BD 9A D0
```

```
ABS.X        JSR ABSLUT       Print the 2-byte operand.
             JSR XINDEX       Print the comma and the "X."
             LDX #2           X holds number of bytes in operand.
             LDA #6           A holds number of characters in
                              operand.
             RTS              Return to caller.
```

Abolute, Y Mode: ABS.Y

To print the operand for an instruction in the absolute, Y mode, we must print a 2-byte operand, a comma, and then a "Y:"

```
                    ORA 02FE,Y   19 FE 02
```

```
ABS.Y        JSR ABSLUT       Print the 2-byte operand.
             JSR YINDEX       Print the comma and the "Y."
             LDX #2           X holds number of bytes in operand.
             LDA #6           A holds number of characters in
                              operand.
             RTS              Return to caller.
```

Accumulator Mode: ACC

To print the operand for an instruction in the accumulator mode, we need only print the letter "A:"

```
                    ROR A   6A
```

```
ACC         LDA #'A         Load accumulator with ASCII code for
                            the letter A.
            JSR PR.CHR      Print it on all currently selected devices.
            LDX #0          X holds number of bytes in operand.
            LDA #1          A holds number of characters in
                            operand.
            RTS             Return to caller.
```

Implied Mode: IMPLID

Implied mode has no operand, so just return:

```
                    CLC   18
```

```
IMPLID      LDX #0          X holds number of bytes in operand.
            LDA #0          A holds number of characters in
                            operand.
            RTS
```

Immediate Mode: IMMEDT

Immediate mode requires a 1-byte operand, which we'll print in hexadecimal format. Thus, it should disassemble the two consecutive bytes "A9 41" as follows:

```
                    LDA #$41   A9 41
```

```
IMMEDT      LDA #'#         Print a '#' sign.
            JSR PR.CHR
            LDA #'$         Print a dollar sign.
            JSR PR.CHR
            JSR ONEBYT      Print 1-byte operand in hexadecimal for-
                            mat.
            LDX #1          X holds number of bytes in operand.
            LDA #4          A holds number of characters in
                            operand.
            RTS             Return to caller.
```

Indirect Mode: INDRCT

To print the operand for an instruction in the indirect mode, we need only print an absolute operand within parentheses. Thus, the three consecutive bytes "6C 00 04" will disassemble as:

```
JMP (0400)   6C 00 04
```

```
INDRCT      JSR LPAREN      Print left parenthesis.
            JSR ABSLUT      Print the 2-byte operand.
            JSR RPAREN      Print the right parenthesis.
            LDX #2          X holds number of bytes in operand.
            LDA #6          A holds number of characters in
                            operand.
            RTS             Return to caller.
```

Indirect, X Mode: IND.X

To print the operand for an instruction in the indirect, X addressing mode, we need to print a left parenthesis, a zero-page address, a comma, the letter "X," and then a right parenthesis. Thus, the two consecutive bytes "A1 3C" will disassemble as:

```
LDA (3C,X)   A1 3C
```

```
IND.X       JSR LPAREN      Print a left parenthesis.
            JSR ZERO.X      Print a zero-page address, a comma, and
                            the letter "X."
            JSR RPAREN      Print a right parenthesis.
            LDX #1          X holds number of bytes in operand.
            LDA #8          A holds number of characters in
                            operand.
            RTS             Return to caller.
```

Indirect, Y Mode: IND.Y

To print the operand for an instruction in the indirect, Y mode, we must print a left parenthesis, a zero-page address, a right parenthesis, a comma, and then the letter "Y." Thus, the two consecutive bytes "B1 AF" will disassemble as:

```
LDA (AF),Y   B1 AF
```

```
IND.Y        JSR LPAREN      Print a left parenthesis.
             JSR ZEROPG      Print a zero-page address.
             JSR RPAREN      Print a right parenthesis.
             JSR YINDEX      Print a comma and then the letter "Y."
             LDX #1          X holds number of bytes in operand.
             LDA #8          A holds number of characters in
                             operand.
             RTS             Return to caller.
```

Relative Mode: RELATV

Relative mode can be tricky. A relative branch instruction specifies a forward branch if its operand is *plus* (in the range of 00 to $7F), but it specifies a backward branch if its operand is *minus* (in the range of $80 to $FF). Therefore, in order to determine the address specified by a relative branch instruction, we must first determine whether the operand is plus or minus, so we can determine whether we're branching forward or backward. Then we must add or subtract the least-significant 7 bits of the operand to or from the address immediately following the operand of the branch instruction; the result of that calculation will be the actual address specified by the branch instruction.

```
RELATV       JSR INC.SL      Select next byte in memory.
             JSR PUSHSL      Save SELECT pointer on stack.
             JSR GET.SL      Get operand byte.
             PHA             Save it on the stack.
             JSR INC.SL      Increment SELECT pointer so it points
                             to the opcode following the relative
                             branch instruction. (Relative branches
                             are relative to the next opcode.)
             PLA             Restore operand byte to accumulator.
             CMP #0          Is it plus or minus?
```

```
              BPL FORWRD      If plus, it means a forward branch.
                              Since operand byte is minus, we'll be
                              branching backward.
              DEC SELECT+1    Branching backward is like branching
                              forward from a location 256 bytes lower
                              in memory.
FORWRD        CLC             Add operand byte to the address
              ADC SELECT      of the opcode following the
              BCC RELEND      branch instruction.
              INC SELECT+1
RELEND        STA SELECT      Now SELECT points to the address
                              specified by the operand of the relative
                              branch instruction. Let's print it.
              JSR PR.ADR
              JSR POP.SL      Restore SELECT pointer.
              LDX #1          X holds number of bytes in operand.
              LDA #4          A holds number of characters in
                              operand.
              RTS             Return to caller, with SELECT pointer
                              once again pointing to the operand byte
                              of the relative branch instruction.
```

Zero-Page Mode: ZEROPG

To print the operand of an instruction that uses the zero-page addressing mode, we could simply print a 1-byte operand. But I find listings more readable when all zero-page addresses are shown with the leading zeros (eg: "00FE" rather than "FE" to represent address $00FE). Therefore, let's print all zero-page operands with a leading zero. That simply requires us to print two ASCII zeros and then to print the 1-byte operand. This will cause the bytes "85 2A" to be disassembled as:

```
STA 002A   85 2A
```

```
ZEROPG        LDA #0          Print two ASCII zeroes to all
              JSR PR.BYT      currently selected devices.
              JSR ONEBYT      Print the 1-byte operand.
              LDX #1          X holds number of bytes in operand.
              LDA #4          A holds number of characters in
                              operand.
              RTS             Return to caller.
```

Zero-Page Indexed Modes: ZERO.X, ZERO.Y

To print the operand of an instruction that uses the zero-page X or zero-page Y addressing mode, we need only print the zero-page address, a comma, and then an "X" or a "Y." Thus, "B5 6C" will disassemble as:

```
LDA 006C,X   B5 6C
```

and "B6 53" will disassemble as:

```
LDX 0053,Y   B6 53
```

```
ZERO.X      JSR ZEROPG      Print the zero-page address.
            JSR XINDEX      Print a comma and the letter "X."
            LDX #1          X holds number of bytes in operand.
            LDA #6          A holds number of characters in
                            operand.
            RTS             Return to caller.
ZERO.Y      JSR ZEROPG      Print the zero-page address.
            JSR YINDEX      Print a comma and the letter "Y."
            LDX #1          X holds number of bytes in operand.
            LDA #6          A holds number of characters in
                            operand.
            RTS             Return to caller.
```

A Pseudo-Addressing Mode for Embedded Text

Now we have subroutines to disassemble machine code in any of the 6502's thirteen legal addressing modes. But what about text embedded in a machine-language program? We know that our programs already include text strings, where each text string begins with a TEX character ($7F) and ends with an ETX ($FF). The disassembler, however, doesn't know anything about embedded text. If we try to disassemble a machine-language program that includes embedded text, the disassembler will assume that the TEX character, and the text string itself, are 6502 opcodes and operands; because it doesn't know about text, it will misinterpret the text string.

Wouldn't it be nice if the disassembler could recognize the TEX character for what it is, and then print out the text string *as text*, rather than as opcodes and operands? When it has finished printing a text string, the disassembler could then resume treating the bytes following the ETX as conventional 6502 opcodes and operands.

Such behavior is not hard to implement. We need only define a pseudo-addressing mode, called TEXT mode, and say that the TEX character is the only opcode that has the TEXT addressing mode. Then we'll write a special addressing mode subroutine, called TXMODE, to print operands that are in the TEXT mode. TXMODE will print an operand in the TEXT mode by printing the text that follows the TEX character and ends with the first ETX character.

Here's some source code to implement such behavior:

```
TXMODE   PLA              Pop return address
         PLA              to OPERND.
         PLA              Pop return address
         PLA              to DSLINE.
TXLOOP   JSR NEXTSL       Advance past TEX pseudo-opcode.
         BMI TXEXIT       Return if reached EA.
         JSR GET.SL       Get the character.
         CMP #ETX         Is it the end of the text string?
         BEQ TXEXIT       If so, we've finished disassembling this
                          line.
         JSR PR.CHR       If not, print the character.
         CLC              Branch back to get
         BCC TXLOOP       the next character.
TXEXIT   JSR CR.LF        Advance to a new line.
         JSR NEXTSL       Advance to next opcode (if SELECT is
                          less than EA).
         RTS              Return to the caller of DSLINE, with
                          SELECT at the first opcode following
                          the text string.
```

Now that we have the desired addressing mode subroutines, we can make up the table of addressing mode subroutines:

```
SUBS          .WORD ABSLUT
              .WORD ABS.X
              .WORD ABS.Y
              .WORD ACC
              .WORD IMPLID
              .WORD IMMEDT
              .WORD INDRCT
```

```
                  .WORD IND.X
                  .WORD IND.Y
                  .WORD RELATV
                  .WORD ZEROPG
                  .WORD ZERO.X
                  .WORD ZERO.Y
```

Each addressing mode subroutine will return with SELECT pointing at the last byte in the instruction, with A holding the number of characters in the operand field, and with X holding the number of bytes in the operand (0, 1, or 2). Each addressing mode subroutine will return to OPERND, which will finish the line by calling FINISH.

Finishing the Line: FINISH

FINISH must space over to the proper column for field 3, which will hold the address of the opcode. Then it must print the address of the opcode and dump 1, 2 or 3 bytes, as necessary. FINISH will end by advancing the printhead to a new line and by advancing SELECT so that it points to the first byte following the disassembled line (unless it has disassembled through EA, the ending address, in which case it will return with SELECT = EA). FINISH returns PLUS if more bytes must be disassembled before EA is reached; it returns MINUS if it disassembled through EA.

```
FINISH      STA OPCHRS      Save the length of the operand,
            STX OPBYTS      in characters and in bytes.
            DEX             If necessary, decrement the
            BMI SEL.OK      SELECT pointer so it
LOOP.1      JSR DEC.SL      points to the opcode.
            DEX
            BPL LOOP.1
SEL.OK      SEC             Space over to the
            LDA ADRCOL      column for the address field:
            SBC #4          Operand field started in column 4...
            SBC OPCHRS      ... and includes OPCHRS characters.
            TAX             So now we need X spaces.
            JSR SPACES      Send enough spaces to reach address
                            column.
            JSR PR.ADR      Print address of opcode.
LOOP.2      JSR SPACE       Space once.
            JSR DUMPSL      Dump selected byte.
            JSR INC.SL      Select next byte.
```

```
                DEC OPBYTS      Completed last byte in instruction?
                BPL LOOP.2      If not, do next byte.
                JSR DEC.SL      Back up SELECT to last byte in
                                operand.
FINEND          JSR CR.LF       Advance to a new line.
                RTS             Return to caller.
OPBYTS          .BYTE           Number of bytes in operand.
OPCHRS          .BYTE 0         Number of characters in operand.
ADRCOL          .BYTE 16        Starting column for address field.
```

Now we can disassemble a line. So let's write the disassemblers, one for the printer and one for the screen. These routines will have much the same structure as TVDUMP and PRDUMP, which direct hexdumps to the printer or to the screen.

Disassemble to Screen: TV.DIS

```
TV.DIS          LDA DISLNS      Initialize line counter with
                STA LINUM       number of lines to be disassembled.
                LDA #$FF        Set end address to $FFFF,
                STA EA          so NEXTSL will always increment
                STA EA+1        the SELECT pointer.
                JSR TVT.ON      Select TVT as an output device. (Other
                                selected devices will echo the
                                disassembly.)
TVLOOP          JSR DSLINE      Disassemble one line.
                DEC LINUM       Completed last line yet?
                BNE TVLOOP      If not, disassemble next line.
                RTS             If so, return.
DISLNS          .BYTE 5         DISLNS holds number of lines to be
                                disassembled by TV.DIS. To disassem-
                                ble one line, set DISLNS=1.
LINUM           .BYTE 0         This variable keeps track of the number
                                of lines yet to be disassembled.
```

Printing Disassembler: PR.DIS

The printing disassembler (PR.DIS) will announce itself by displaying "PRINTING DISASSEMBLER" on the screen, but not on the printer. It will then let the user set the starting and ending addresses, in the same manner as PRDUMP. When the user has specified the block of memory to be disassembled, the PR.DIS will print a disassembly of the specified block of memory, echoing its output to the screen.

```
PR.DIS      JSR PR.OFF        Deselect printer.
            JSR TVT.ON        Select TVT.
            JSR PRINT:        Display title:
            .BYTE TEX
            .BYTE CR,LF
            .BYTE             'PRINTING DISASSEMBLER'
            .BYTE CR,LF,ETX
            JSR.SETADS        Let user set starting address
                              and end address.
            JSR GOTOSA        Set SELECT = Start address.
            JSR PR.ON         Select the printer.
PRLOOP      JSR DSLINE        Disassemble one line.
            BPL PRLOOP        If it wasn't the last line, disassemble the
                              next one.
            RTS               Return to caller.
```

With PR.DIS and TV.DIS, you can disassemble any block of memory, directing the disassembly to the screen or to the printer. See Chapter 12 for guidance on mapping these two disassemblers to function keys in the Visible Monitor.

Chapter 10:

A General MOVE Utility

Many computer programs spend a lot of time moving things from one place to another. Such programs should be able to call a move utility for most of this work. A move utility should:

- Be general enough to move anything of any size from any place in memory to anywhere else.
- Not be upset when the origin block overlaps the destination.
- Have entry points with input configurations convenient to different callers.
- Preserve its inputs.
- Be *fast*.

This routine will be called often. A calling program doesn't want to spend all its time here. The cost of that speed is size, because we'll use straight-line, dedicated code to handle each of several special cases, but even so this move code will weigh in at less than 200 bytes. That's less than three percent of the memory available on a system with 8 K bytes of programmable memory.

Input Configurations

Different callers may find different input configurations convenient, so let's provide more than one entry point, each requiring different parameters to be set. The following two subroutine entry points are likely to meet the needs of most callers:

MOV.EA Move a block, defined by its starting address (SA), its ending

	address (EA), and its destination address (DEST).
MOVNUM	Move a block, defined by its starting address, the number of bytes in the block (NUM), and the destination of the block.

MOV.EA will simply be a "front end" for MOVNUM. It will set NUM = ending address − starting address of the source block.

Handling Overlap

There will be no problem with overlap if we always move from the leading edge of the source block — that is, copy *up* beginning with the highest byte to be moved, and copy *down* beginning with the lowest byte to be moved. This way, if a byte in the source block is overwritten it will already have been copied to its destination.

Going Up?

To avoid overlap, MOVNUM must determine whether it's copying up or down. Therefore, before moving anything it must see if the destination address is greater or lesser than the starting address. Then it can branch to MOVE-UP or MOVE-DOWN as appropriate.

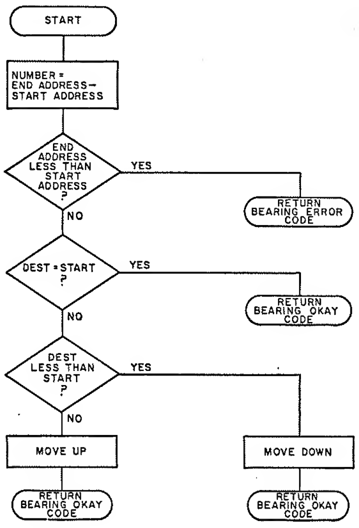


Figure 10.1: *Top level of block move. Flowchart of MOVE.EA and MOV-NUM routines.*

Using the flowchart of figure 10.1 as a guide, let's write source code for the top level of MOV.EA and MOVNUM:

```
          GETPTR = 0           This is the input-page pointer.
          PUTPTR = GETPTR+2    This is the output-page pointer.
MOV.EA    SEC                  Set NUM = EA - SA
          LDX EA+1
          LDA EA
          SBC SA
          STA NUM
          BCS MOVE.1
          DEX
          SEC
MOVE.1    TXA
          SBC SA+1
          STA NUM+1
          BCS MOVNUM           Now NUM = EA - SA.
ER.RTN    LDA #ERROR           If EA less than SA,
          RTS                  return with error code.
MOVNUM    LDY #3               Save the 4 zero-page
SAVE      LDA GETPTR,Y         bytes we'll use.
          PHA
          DEY
          BPL SAVE
          SEC                  Is DEST less than START?
          LDA SA+1
          CMP DEST+1
          BCC MOVEUP           If so, we'll move down.
          BNE MOVEDN           If not, we'll move up.
          LDA SA               SA, destination are in the same
                               page.
          CMP DEST             If SA more than destination, we'll
          BCC MOVEUP           move down. If SA less than destina-
                               tion,
          BNE MOVEDN           we'll move up. If they are equal, we'll
                               return bearing okay code.
OK.RTN    LDY #0               Restore 4 zero-page bytes that were
RESTOR    PLA                  used by the move code.
          STA GETPTR,Y
          INY
          CPY #4               Restored last byte yet?
          BNE RESTOR           If not, restore next one. If so,
          RTS                  return, with move complete and zero
                               page preserved.
NUM       .WORD 0              This 16-bit variable holds the number of
                               bytes to be moved.
```

Optimizing for Speed

Moving a page at a time is the fastest way to move data, and for large blocks we can move most of the bytes this way. Therefore, when moving data we'll move one page at a time until there is less than a page to move; then we'll move a byte at a time until the entire source block is moved. MOVE-UP and MOVE-DOWN must test to see if they have more or less than a page to move, and then branch to dedicated code that either moves a page or moves less than a page.

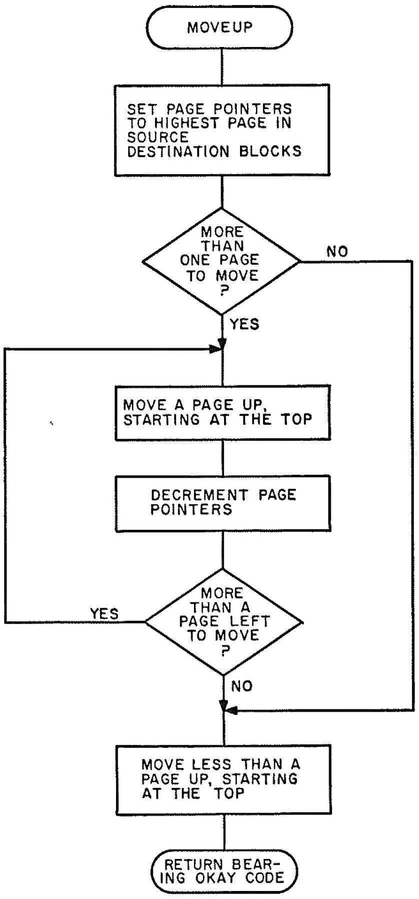

MOVEUP
SET PAGE POINTERS TO HIGHEST PAGE IN SOURCE DESTINATION BLOCKS
MORE THAN ONE PAGE TO MOVE ?
NO
YES
MOVE A PAGE UP, STARTING AT THE TOP
DECREMENT PAGE POINTERS
MORE THAN A PAGE LEFT TO MOVE ?
YES
NO
MOVE LESS THAN A PAGE UP, STARTING AT THE TOP
RETURN BEARING OKAY CODE

Figure 10.2: *Move a block up. Flowchart of the MOVEUP routine.*

MOVE-UP

Using figure 10.2 as a guide, we can write source code for MOVE-UP:

```
MOVEUP    LDA NUM+1         More than one page to move?
          BEQ LESSUP        If not, move less than a page up.
                            To move more than a page, set the page
                            pointers GETPTR and PUTPTR to the
                            highest pages in the source and destina-
                            tion blocks. To do this, treat X as the
                            high byte and Y as the low byte of a
                            pointer, which we'll call (X,Y). First set
                            (X,Y) = NUM − $FF, the relative ad-
                            dress of the highest page in the block.
          LDY NUM+1         Now Y is high byte of block size.
          LDA NUM           Now A is low byte of block size.
          SEC               Prepare to subtract.
          SBC #$FF.         Now A is a low byte of (block size −
                            $FF.)
          BCS NEXT.1
          DEY
NEXT.1    TAX               Now (X,Y) = NUM − $FF.
                            X is low byte, Y is high byte of NUM −
                            $FF.
          STY PUTPTR+1
          TXA
          CLC               Prepare to add.
          ADC SA
          STA GETPTR
          BCC NEXT.2
          INY
NEXT.2    TYA
          ADC SA+1
          STA GETPTR+1      Now GETPTR = SA + NUM − $FF
                            (the last page in the origin block).
          TXA
          CLC               Prepare to add.
          ADC DEST
          STA PUTPTR
          BCC NEXT.3
          INC PUTPTR+1
NEXT.3    LDA PUTPTR+1
          ADC DEST+1
          STA PUTPTR+1      Now PUTPTR = DEST + NUM − $FF
                            (the last page in the destination block).
                            Now the page pointers (GETPTR and
                            PUTPTR) point to the last page in, respec-
                            tively, the origin and destination blocks.
```

```
        LDX NUM+1          Load X with number of pages to move.
PAGEUP  LDY #$FF           Move a page up.
UPLOOP  LDA (GETPTR),Y     Get a byte from origin block.
        STA (PUTPTR),Y     Put it in destination block.
        DEY                Adjust index for next byte down.
        BNE UPLOOP         Loop if not the last byte.
        LDA (GETPTR),Y     Move last byte.
        STA (PUTPTR),Y
        DEC GETPTR+1       Decrement page pointers.
        DEC PUTPTR+1
        DEX                Still more than a page to move?
        BNE PAGEUP         If so, move up another page.
LESSUP  JSR LOPAGE         Set GETPTR, PUTPTR to bottom of
                           origin and destination blocks.
        LDY NUM            Set index to number of bytes to be
                           moved.
SOMEUP  LDA (GETPTR),Y     Move a byte.
        STA (PUTPTR),Y
        DEY                About to move last byte?
        CPY #$FF
        BNE SOMEUP         If not, move another.
        JMP OK.RTN         If so, return bearing "OK" code.
LOPAGE  LDA SA             Set page pointers to the bottom
        STA GETPTR         of the origin and destination
        LDA SA+1           blocks.
        STA GETPTR+1
        LDA DEST
        STA PUTPTR
        LDA DEST+1
        STA PUTPTR+1
        RTS                Return to caller.
```

Move-Down: MOVEDN

Figure 10.3 shows an algorithm for moving a block of data down through memory.

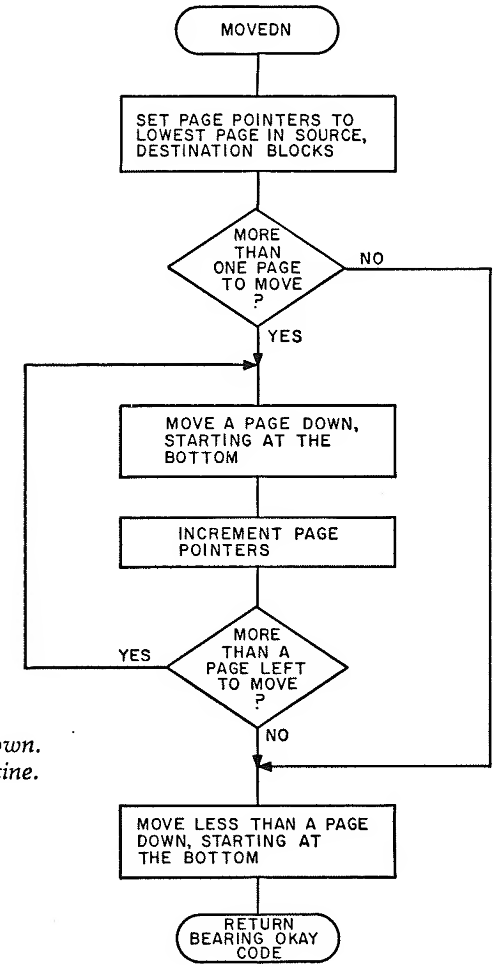

MOVEDN
SET PAGE POINTERS TO LOWEST PAGE IN SOURCE, DESTINATION BLOCKS
MORE THAN ONE PAGE TO MOVE ?
NO
YES
MOVE A PAGE DOWN, STARTING AT THE BOTTOM
INCREMENT PAGE POINTERS
YES
MORE THAN A PAGE LEFT TO MOVE ?
NO
MOVE LESS THAN A PAGE DOWN, STARTING AT THE BOTTOM
RETURN BEARING OKAY CODE

Figure 10.3: *Move a block down. Flowchart of the MOVEDN routine.*

Using figure 10.3 as a guide, we can write source code for the move-down routine:

```
MOVEDN   JSR LOPAGE         Set page pointers to bottom of origin
                            and destination blocks.
         LDY #0             Y must equal zero whether we move
                            more or less than a page.
         LDX NUM+1          More than one page to move?
         BEQ LESSDN         If not, move less than a page down.
                            Move a page down.
PAGEDN   LDA (GETPTR),Y     Get a byte from origin block
         STA (PUTPTR),Y     and put it in destination block.
         INY                Moved last byte in page?
```

```
        BNE PAGEDN
        INC GETPTR+1      Increment page pointers.
        INC PUTPTR+1
        DEX               Still more than a page to move?
        BNE PAGEDN        If so, move another page down.
        LDY #0            Move less than a page down starting at
                          the bottom.
LESSDN  LDA (GETPTR),Y    Get a byte from origin...
        STA (PUTPTR),Y    and put it in destination block.
        INY               Adjust index for next byte.
        SEC
        CPY NUM           Moved last byte yet?
        BCC LESSDN        If not, move another.
        JMP OK.RTN        If so, return to caller, bearing "OK"
                          code.
```

Speed

For large blocks of data, most bytes will be moved by the page-moving code: PAGE-UP and PAGE-DOWN. Since the processor spends most of its time in these loops, let's see how long they will take to move a byte. (Appendix A5, *Instruction Execution Times*, provides information on the number of cycles required for each 6502 operation.) Ordinarily I would not go into great detail concerning the speed of execution of a small block of code, but these two loops form the heart of the move utility, because they move most of the bytes in any large block. By making those two loops very efficient, we can make the move utility very fast. In fact, these loops will let us move blocks bigger than one page, at a rate approaching 16 cycles/byte moved. (By way of a benchmark, that's more than twice as fast as the time required to move large blocks with MOVIT, a smaller move program published in *The First Book of KIM.** MOVIT, made tiny [95 bytes] to use as little as possible of the KIM's limited programmable memory, requires at least 33 cycles/bytes moved.)

MOVE.EA and MOVNUM are move utilities because they have input configurations and performance suitable for many calling programs. But they are not very convenient to the human user who simply wants to move something. With the Visible Monitor and the move utility, you can move something from one place to

*Butterfield, et al, *The First Book of Kim*, Rochelle Park, NJ: Hayden Book Company, 1977.

another, but you have to know what addresses to set and you have to know the address of the move utility itself.

That's too much for me to remember. I want a *tool*, which will know the addresses and won't require me to remember them.

When I'm developing programs with the Visible Monitor and I want to move some data or code from one place to another, I'd like to be able to call up a move tool with a single keystroke — say "M." It's easier for me to remember " 'M' for Move" than it is to remember the address of the move utility and the addresses of its inputs.

Let's say I'm using the Visible Monitor and I press "M." This invokes the move tool. The first thing it should do is let me know that it's active. What if I hit the "M" key by mistake? The computer should let me know that I've invoked a new program.

It should put up a title: "MOVE TOOL." Then it should let me specify the start, end, and destination addresses of a given block in memory. When these addresses are set, the move tool can call MOV.EA, which will actually perform the move, based on the addresses set by the user.

The top level of the move tool is therefore quite simple. Figure 10.4 shows the flowchart for the following routine:

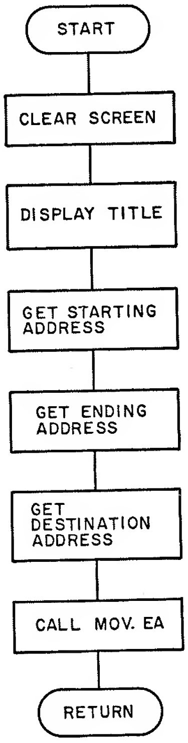


Figure 10.4: *A move tool. Flowchart of MOVER routine.*

MOVER

```
MOVER     JSR TVT.ON               Select screen as an output device.
          JSR PRINT:               Put a title on the screen.
          .BYTE TEX,CR
          .BYTE '   MOVE TOOL'
          .BYTE CR,LF,LF
          .BYTE ETX
          JSR SETADS               Get starting address,
                                   ending address, and
          JSR SET.DA               destination address from user.
          JSR MOV.EA               Move the block specified by those
                                   pointers.
          RTS                      Return to caller, with requested block
                                   moved and with zero page preserved.
```

Of course, MOVER can work only if we have a routine that lets the user set the destination address. Let's write such a routine, and we'll be all set to move whatever we like, to wherever we want it.

Set Destination Address: SET.DA

```
SET.DA    JSR TVT.ON               Select TVT as an output device. All
                                   other selected output devices will echo
                                   the screen output.
          JSR PRINT:               Put prompt on the screen:
          .BYTE TEX
          .BYTE CR,LF,LF
          .BYTE                    "SET DESTINATION ADDRESS   "
          .BYTE                    "AND PRESS Q."
          .BYTE ETX
          JSR VISMON               Call the Visible Monitor, so user can
                                   specify a given address.
DAHERE    LDA SELECT               Set destination address equal to
          STA DEST                 address set by the user.
          LDA SELECT+1
          STA DEST+1
          RTS                      Return to caller.
DEST      .WORD 0                  Pointer to destination of block to be
                                   moved.
```

See Chapter 12, *Extending the Visible Monitor,* to learn how to hook the move tool into the Visible Monitor by mapping it to a given key. Then to move anything in memory to anywhere else, you need only strike that key and the move tool will do the rest.

Chapter 11:

A Simple Text Editor

With the Visible Monitor you can enter ASCII text into memory by placing the arrow under field 2 and striking character keys. But you must strike two keys for every character in the message: first the character key, to enter the character into the displayed address, and then the space bar, to select the next address. Furthermore, if you want to enter an ASCII space or carriage return into memory, you'll have to place an arrow under field 1 and enter the hexadecimal representation of the desired character: $20 for a space; $0D for a carriage return. Then, of course, you'll have to hit the space bar to select the next address, and the "greater than" key to move the arrow back underneath field 2, so that you can enter the next character into memory.

If you only need to enter up to a dozen ASCII characters at a time, then the Visible Monitor should meet your needs. When you need to enter longer messages into memory, you'll find yourself wanting a more suitable tool — a simple text editor.

Text editors come in many different shapes, sizes and formats. A line-oriented editor, suitable for creating and editing program source files, requires that you enter and edit text a line at a time. Usually each line must be numbered when it is entered; then, in order to edit a line, you must first specify it by its line number.

On the other hand, a character-oriented editor allows you to overstrike, insert, or delete characters anywhere in a given string of characters. Character-oriented editors are frequently found in word processors for office applications, but don't get your hopes up; this chapter will not present software nearly as sophisticated as that available in even the humblest of word processors. However, it will present a very simple character-oriented editor that will enable you to enter and edit text strings, such as prompts, anywhere in memory.

Structure

The text editor will have the three-part structure shown in figure 11.1. From this we can write source code for the top level of the text editor:

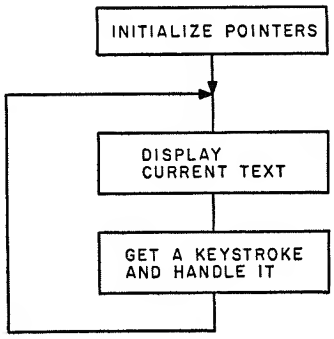


Figure 11.1: *Structure of simple text editor.*

```
EDITOR    JSR SETBUF       Initialize pointers and variables required
                           by the editor.
EDLOOP    JSR SHOWIT       Show the user a portion of the text
                           buffer.
          JSR EDITIT       Let the user edit the buffer or move
                           about within it.
          CLC
          BCC EDLOOP       Loop back to show the current text.
```

Look familiar? It should. This is essentially the same structure used in the Visible Monitor. It's a simple structure, well-suited to the needs of many interactive display programs.

SETBUF

The text editor will operate on text in a portion of memory called the *text buffer*. Because the editor must be able to change the contents of the text buffer, the buffer must occupy programmable memory and may not be used for any other purpose. This exemplifies a problem familiar to programmers: how to allocate memory in the most effective manner. Memory used to store a program cannot be used at the same time to store text; nor can memory allotted to the text buffer be used for storing programs or variables.

How do you get five pounds of tomatoes into a four-pound-capacity sack — without crushing the tomatoes or tearing the sack? You don't. If you want to store a lot of text in your computer's programmable memory, you might not have room for much of a text editor. On the other hand, an elaborate text editor, requiring a good deal of programmable memory for its own code, may not leave much room in your system for storing text.

Therefore, this text editor leaves the allocation of memory for the text buffer to the discretion of the user. A subroutine called SETBUF sets pointers to the starting and ending addresses of the text buffer. The rest of the editor then operates on the text buffer defined by those pointers.

SETBUF sets the starting and ending addresses of the edit buffer. If you always want to enter and edit text in the same buffer, then substitute your own subroutine to set the starting and ending addresses to the values you desire. Otherwise, use the following version of SETBUF, which lets the user define a new text buffer each time it is called.

For testing purposes, you might even want to set the text buffer completely inside screen memory. This allows you to *see* exactly what's happening inside the text buffer.

SETBUF

```
SETBUF    JSR TVT.ON                  Select TVT.
          JSR PRINT:                  Display "SET UP EDIT BUFFER."
          .BYTE TEX,CR,LF,LF
          .BYTE 'SET UP EDIT BUFFER'
          .BYTE CR,LF,LF,ETX
GETADS    JSR SETADS                  Let user set starting address and end ad-
                                      dress of edit buffer.
          JSR GOTOSA                  Now SELECT = starting address of edit
                                      buffer.
          RTS                         Return to caller.
```

This version of SETBUF allows the user to set the text buffer anywhere in memory, provided that the ending address is not lower in memory than the starting address. It returns with the SELECT pointer pointing at the starting address of the buffer.

SHOWIT

Now that SETBUF has set the pointers associated with the text buffer, let's figure out how to display part of that buffer.

Figure 11.2 shows the simple 3-line display to be used by the text editor. "X" marks the home position of the edit display. Everything in the edit display is relative to the home position. Thus, to move the edit display about on your screen (ie: from the top of the screen to the bottom of the screen), you need only change the home position, which is set by SHOWIT.

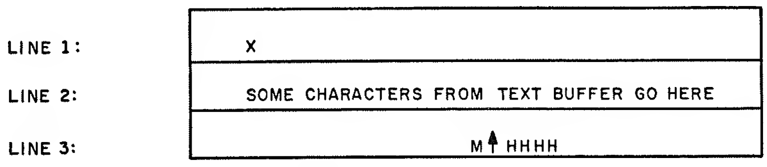


Figure 11.2: *Three-line display of simple text editor.*

Line 1 is entirely blank. Its only purpose is to separate the text displayed in line 2 from whatever you may have above it on your screen.

Line 2 displays a string of characters from the edit buffer. The central character in line 2 is the *current character*. The current character is indicated by an upward-pointing arrow as in line 3. The address of the current character is given by the four hexadecimal characters represented by "HHHH" in line 3.

The letter "M" in line 3 shows you where a graphic character will indicate the current mode of the editor.

Modes

This editor will have two modes: *overstrike mode* and *insert mode*. In overstrike mode you overstrike, or replace, the current character with the character from the keyboard. In insert mode, you insert the keyboard character into the text buffer just before the current character. How one sets these modes, a function for the subroutine EDITIT, will be discussed later. But SHOWIT must know the current mode in order to display the proper graphic in line 3 of the editor display.

Since we're going to have two modes, let's keep track of the current mode of the editor with a 1-byte variable called EDMODE. We'll assign the following values to EDMODE:

EDMODE = 0 when the editor is in overstrike mode.
EDMODE = 1 when the editor is in insert mode.

Any other value of EDMODE is undefined and therefore illegal. If SHOWIT should find that EDMODE has an illegal value, then it should set EDMODE to some legal default value — say, zero. That would make overstrike the default mode for the editor.

We'll also need two graphics characters, INSCHR and OVRCHR, to indicate insert and overstrike modes, respectively. In this chapter, the character to indicate a given edit mode will simply be the first initial of the mode name: "O" for overstrike mode, "I" for insert mode.

SHOWIT

```
SHOWIT    JSR TVPUSH        Save the zero-page bytes we'll use.
          JSR TVHOME        Set home position of the
                            edit display.
          LDX TVCOLS        Clear 3 rows for the
          LDY #3            edit display.
          JSR CLR.XY
          JSR TVHOME        Restore TV.PTR to home position of
                            edit display.
          JSR TVDOWN        Set TV.PTR to beginning of
          JSR TVPUSH        line 2 and save it.
          JSR LINE.2        Display text in line 2.
          JSR TV.POP        Set TV.PTR to beginning
          JSR TVDOWN        of line 3.
          JSR LINE.3        Display line 3.
          JSR TV.POP        Restore zero-page bytes used.
          RTS               Return to caller, with edit display on
                            screen, rest of screen unchanged, and
                            zero page preserved.
```

Of course, SHOWIT can work only if it can call a couple of routines (LINE.2 and LINE.3) to display lines 2 and 3 of the editor display, respectively. Let's write those routines.

Display Text Line

To display the text line, we simply need to copy a number of characters from the text buffer to the second line of the editor display. Since the screen is TVCOLS wide, we should display TVCOLS number of characters in such a way that the central character in the display is the currently selected character. We can do that if we decrement SELECT by TVCOLS/2 times, and then display TVCOLS number of characters:

LINE.2

```
LINE.2   JSR PUSHSL      Save SELECT pointer.
         LDA TVCOLS      Set X equal
         LSR A           to half the width
         TAX             of the screen.
         DEX
         DEX
LOOP.1   JSR DEC.SL      Decrement SELECT X times.
         DEX
         BPL LOOP.1
         LDA TVCOLS      Initialize COUNTR. (We're
         STA COUNTR      going to display TVCOLS characters.)
LOOP.2   JSR GET.SL      Get a character from buffer.
         JSR TV.PUT      Put it on screen.
         JSR TVSKIP      Go to next screen position.
         JSR INC.SL      Advance to next byte in buffer.
         DEC COUNTR      Done last character in row?
         BPL LOOP.2      If not, do next character.
         JSR POP.SL      Restore SELECT from stack.
         RTS             Return to caller.
```

Display Status Line

Line 3 of the editor display provides status information: identifying the current mode of the editor, pointing at the current character in line 2 of the edit display, and providing the address of the current character.

LINE.3

```
LINE.3    LDA TVCOLS
          LSR A               A = TVCOLS/2
          SBC #2              A = (TVCOLS/2) - 2
          JSR TVPLUS          Now TV.PTR is pointing 2 characters to
                              the left of center of line 3 of the edit
                              display.
          LDA EDMODE          What is current mode?
          CMP #1              Is it insert mode?
          BNE OVMODE          If not, it must be overstrike mode.
          LDA #INSCHR         If so, load A with the insert graphic.
          CLC
          BCC TVMODE
OVMODE    LDA #OVRCHR         Load A with the overstrike graphic.
TVMODE    JSR TV.PUT          Put mode graphic on screen.
          LDA #2
          JSR TVPLUS          Now TVPTR is pointing at the center of
                              line 3 of the edit display.
          LDA ARROW           Display an up-arrow here,
          JSR TV.PUT          pointing up at the current character.
          LDA #2
          JSR TVPLUS          Now TV.PTR is pointing at the position
                              reserved for the address of the current
                              character.
          LDA SELECT+1        Display address of current
          JSR VUBYTE          character.
          LDA SELECT
          JSR VUBYTE
          RTS                 Return to caller.
```

We've chosen to define the editor's current character as the character pointed to by SELECT. We've already developed some subroutines that operate on the SELECT pointer and on the currently selected byte, so we won't have to write many new editor utilities; instead, we can use many of the SELECT utilities presented in earlier chapters.

Edit Update

Now we can display the three lines of the edit display. What else must the editor do? Oh, yes: it must let us edit. Here's a reasonably useful, if small, set of editor functions:

- Allow the user to move forward through the message.
- Allow the user to move backward through the message.
- Allow the user to overstrike the current character.
- Allow the user to delete the current character.
- Allow the user to delete the entire message.
- Allow the user to insert a new character at the current character position.
- Allow the user to change modes from insert to overstrike and back again.
- Print the message.
- Allow the user to terminate editing, thus causing the editor to return to its caller.

What keys will perform these functions? I'll leave that up to you by treating the editor function keys as variables and keeping them in a table called EDKEYS (see Appendix C11). To assign a given function to a given key, store the character code generated by that key in the appropriate place in the table:

EDITIT

```
EDITIT   JSR GETKEY     Get a keystroke from the user.
         CMP QUITKY     Is it the "quit" key?
         BNE DO.KEY     If not, do what the key requires.
         PHA            Save the key on the stack. If the user
                        gives us 2 "quit" keys in a row, we
                        should exit the editor. So let's see if
                        another QUITKY follows:
         JSR GETKEY
         CMP QUITKY     Is this key a "quit" key?
         BNE NOTEND     If not, then this is not the end of the
                        edit session, so we'd better handle both
                        of those keys, and in their original
                        order.
                        End the edit session:
ENDEDT   PLA            Pop first "quit" key from stack.
         PLA            Pop from stack the return address to
         PLA            the editor's top level.
         RTS            Return to the editor's caller.
NOTEND   STA TEMPCH     Save the key that followed the "quit"
                        key.
         PLA            Pop first "quit" key from stack.
         JSR DO.KEY     Handle it.
         LDA TEMPCH     Restore to the accumulator the key that
                        followed the "quit" key.
```

```
                                  "DO.KEY" does what the key in the ac-
                                  cumulator requires:
DO.KEY    CMP MODEKY              Is it the "change mode" key?
          BNE IFNEXT              If not, perform the next test.
          DEC EDMODE              If so, change the editor's mode...
          BPL DO.END
          LDA #1
          STA EDMODE
DO.END    RTS                     and return.
IFNEXT    CMP NEXTKY              Is it the "next" key?
          BNE IFPREV              If not, perform the next test.
          JSR NEXTCH              If so, advance the current position by
                                  one character...
          RTS                     and return.
IFPREV    CMP PREVKY              Is it the "previous" key?
          BNE IF.RUB              If not, perform the next test.
          JSR PREVCH              If so, back up the current position by
                                  one character...
          RTS                     and return.
IF.RUB    CMP RUBKEY              Is it the "delete" key?
          BNE IF.PRT              If not, perform the next test.
          JSR DELETE              If so, delete the current character...
          RTS                     and return.
IF.PRT    CMP PRTKEY              Is it the "print" key?
          BNE IFFLSH              If not, perform the next test.
          JSR PRTBUF              If so, print the buffer...
          RTS                     and return.
IFFLSH    CMP FLSHKY              Is it the "flush" key?
          BNE CHARKY              If not, perform the next test.
          JSR FLUSH               If so, flush all text in the edit buffer...
          RTS                     and return.
                                  OK. It's not an editor function key, so it
                                  must be a regular character key. There-
                                  fore, if we're in overstrike mode we'll
                                  overstrike the current character with the
                                  new character, and if we're in insert
                                  mode we'll insert the new character at
                                  the current character position.
CHARKY    LDX EDMODE              Are we in overstrike mode?
          BEQ STRIKE              If so, overstrike the character.
          JSR INSERT              If not, insert the character...
          RTS                     and return.
STRIKE    JSR PUT.SL              Put the character into the currently
                                  selected address, which is the address of
```

```
                                 the current character.
         JSR NEXTSL              Advance to the next character position,
         RTS                     and return to caller.
INSERT   PHA                     Save the character to be inserted, while
                                 we make space for it in the edit buffer...
         JSR PUSHSL              Push the address of the current character
                                 onto the stack.
         LDA SA+1                Push starting address of the buffer
         PHA                     onto stack.
         LDA SA
         PHA
         LDA EA+1                Push ending address of the buffer
         PHA                     onto stack.
         LDA EA
         PHA
         JSR SAHERE              Set SA = SELECT, so current character
                                 will be the start of the block we'll move.
         JSR NEXTSL              Advance to next character position in
                                 the text buffer.
         BMI ENDINS              If we're at the end of the buffer, we'll
                                 overstrike instead of inserting.
         JSR DAHERE              Set DEST = SELECT, so destination of
                                 block move will be 1 byte above block's
                                 start address (ie, we'll move a block up
                                 by 1 byte).
         LDA EA                  Decrement end address
         BNE NEXT                so we won't move text
         DEC EA+1                beyond the end of
NEXT     DEC EA                  the text buffer.
                                 Now the starting address is the current
                                 character, the destination address is the
                                 next character, and the ending address is
                                 one character shy of the last character in
                                 the buffer. We're ready now to move a
                                 block.
OPENUP   JSR MOV.EA              Open up 1 byte of space at the current
                                 character's location, by moving to DEST
                                 the block specified by SA and EA.
ENDINS   PLA                     Restore EA so it points to the last byte
         STA EA                  in the edit buffer.
         PLA
         STA EA+1
         PLA                     Restore SA so it points to the first byte
         STA SA                  in the edit buffer.
```

```
          PLA
          STA SA+1
          JSR POP.SL          Restore SELECT so it points to the cur-
                              rent character.
          PLA                 Reload the accumulator with the
                              character to be inserted. Since we've
                              created a 1-byte space for this character,
                              we need only overstrike it.
          JSR STRIKE
          RTS                 Return to caller.
```

EDITIT looks like it will do what we want it to do — provided that it may call the following (as yet unwritten) subroutines:

- NEXTCH — Select next character.
- PREVCH— Select previous character.
- FLUSH — Flush the buffer.
- PRTBUF — Print the buffer.

Let's write them.

Select Next Character

We want to be able to advance through the text buffer, but we don't want to be able to go beyond the end of the buffer or beyond the end of the message. The end of the message will be indicated by one or more ETX (end-of-text) characters. ETX characters will fill from the last character in the message to the end of the buffer. So if the current character is an ETX, we shouldn't be allowed to advance through memory. Or, if the current character is the last byte in the edit buffer, we shouldn't be allowed to advance through memory. But if we aren't at the end of our text for one reason or another, select the next character by calling the NEXTSL subroutine:

NEXTCH

```
NEXTCH    JSR GET.SL          Get currently selected character.
          CMP #ETX            Is it an ETX?
          BEQ AN.ETX          If so, return to caller, bearing a negative
                              return code.
```

```
            JSR NEXTSL         If not, select next byte in the buffer, and
            RTS                return positive if we incremented
                               SELECT; negative if SELECT already
                               equaled EA.
AN.ETX      LDA #$FF           Since we are on an ETX, we won't incre-
                               ment
            RTS                SELECT; we'll just return with a
                               negative return code.
```

Select Previous Character

The PREVCH (select-previous-character routine) should work in a manner similar to that used by NEXTCH. NEXTCH increments the SELECT pointer and returns *plus*, unless SELECT is greater than or equal to EA, in which case NEXTCH preserves SELECT and returns *minus*. Conversely, PREVCH should decrement SELECT and return *plus*, unless SELECT is less than or equal to SA, in which case it should preserve SELECT and return *minus*:

PREVCH

```
PREVCH      SEC                Prepare to compare.
            LDA SA+1           Is SELECT in a higher page than SA?
            CMP SELECT+1
            BCC SL.OK          If so, SELECT may be decremented.
            BNE NOT.OK         If SELECT is in a lower page than SA,
                               then it's not okay. We'll have to fix it.
                               SELECT is in the same page as SA.
            LDA SA             Is SELECT greater than SA?
            CMP SELECT
            BEQ NO.DEC         If SELECT = SA, don't decrement it.
            BNE NOT.OK         If SELECT is less than SA, it's not okay,
                               so we'll have to fix it.
SL.OK       JSR DEC.SL         SELECT is OK, because it's greater than
                               SA. Thus, we may decrement it and it
                               will remain in the edit buffer.
            LDA #0             Set a positive return code...
            RTS                and return.
NOT.OK      LDA SA             Since SELECT is less than SA, it is
            STA SELECT         not even in the edit buffer. So give
            LDA SA+1           SELECT a legal value, by setting
                               it = SA.
            STA SELECT+1
            LDA #0              Set a positive return code...
            RTS.                and return.
NO.DEC      LDA #$FF            SELECT = SA, so change nothing. Set
            RTS                 a negative return code and return.
```

Flush Buffer

To flush the buffer, we'll just fill the buffer with ETX characters:

FLUSH

```
FLUSH       JSR GOTOSA          Set SELECT to the first character posi-
                                tion in the buffer.
FLOOP       LDA #ETX            Load accumulator with an ETX
                                character...
            JSR PUT.SL          and put it into the buffer.
            JSR NEXTSL          Advance to next byte.
            BPL FLOOP           If we haven't reached the last byte in the
                                buffer, let's repeat the operation for this
                                byte.
            JSR GOTOSA          If we have reached the last byte in the
                                buffer, let's set SELECT to the beginning
                                of the buffer...
            JSR RTS             and return.
```

Print Buffer

To print the buffer, we must print the characters in the edit buffer up to, but not including, the first ETX. Even if there is no ETX in the buffer, we must not print characters from beyond the end of the buffer:

PRTBUF

```
PRTBUF      JSR GOTOSA          Set SELECT to the start of the buffer.
PRLOOP      JSR GET.SL          Get the currently selected character.
            CMP #ETX            Is it an ETX character?
            BEQ ENDPRT          If so, stop printing and return.
```

```
          JSR PR.CHR      If not, print it on all currently selected
                          devices.
          JSR NEXTCH      Advance SELECT by 1 byte within the
                          buffer.
          BPL PRLOOP      If we haven't reached the end of the buf-
                          fer, let's get the next character from the
                          buffer, and handle it.
ENDPRT    RTS             Since we reached the end of the buffer,
                          let's return.
                          When this routine returns, the current
                          character is at the end of the message.
```

Delete Current Character

To delete the current character, we'll take all the characters that follow it in the text buffer and move them to the left by 1 byte. Here's some code to implement such behavior:

```
DELETE    JSR PUSHSL      Save address of current character.
          LDA SA+1        Save buffer's start address.
          PHA
          LDA SA
          PHA
          JSR DAHERE      Set DEST = SELECT, because we'll
                          move a block of text down to here, to
                          close up the buffer at the current
                          character.
          JSR NEXTSL      Advance by 1 byte through text buffer,
                          if possible.
          JSR SAHERE      Set SA = SELECT, because the block
                          we'll move starts 1 byte above the cur-
                          rent character. (Note: the end address of
                          the block we'll move is the end address
                          of the text buffer.)
          JSR MOV.EA      Move block specified by SA, EA, and
                          DEST.
          PLA             Restore initial SA (which
          STA SA          is the start address of the
          PLA             text buffer, not of the block
          STA SA+1        we just moved).
```

JSR POP.SL	Restore SELECT = address of the current character.
RTS	Return to caller.

That's the last of the utilities we need. We now have enough code to comprise a simple text editor. Appendices C10 and C11 are listings of this text editor, showing key assignments that work on an Ohio Scientific C-IP. If you have a different system or prefer your editor functions mapped to different keys, simply change the values of the variables in the key table. If you don't want to have a given function, then for that function store a keycode of zero. You'll find this editor very handy for entering tables of ASCII characters into memory, and for entering, editing, and printing short text strings such as titles for your hexdumps and disassembler listings.

Chapter 12:

Extending the Visible Monitor

At this point you have the Visible Monitor, the print utilities, two hexdump tools, a table-driven disassembler, a move tool, and a simple text editor. Wouldn't it be nice if they were all combined into one interactive software package? Then you could call any tool or function with a single keystroke. Since the Visible Monitor already uses several keys (0 thru 9; A thru F; G; Space; Return; and Rubout or Clear-Screen), we'll have to map these new functions into unused keys.

Here's a list of keys and the functions they will have in the extended monitor:

H	Call a HEXDUMP tool (TVDUMP if the printer is not selected; PRDUMP if the printer is selected).
M	Call MOVER, the move tool.
P	Toggle the printer flag.
T	Call the text editor.
U	Toggle the user output flag.
?	Call the disassembler (TV.DIS if the printer is not selected; PR.DIS if the printer is selected).

With this assignment of keys to functions, we can select or deselect the *printer* at any time just by pressing "P," and likewise the *user*-driven output device just by pressing "U." We can print or display a *hexdump* just by pressing "H" and print or display a disassembly just by pressing "?" (which is almost mnemonic if we think of the disassembler as an answer to our question, "What's in the machine?"). We can move anything from anywhere to anywhere else by pressing "M" for *move*, and we can enter and edit text just by pressing "T" for *text editor*.

Here's some code to provide these features. Since we want to extend the monitor, this subroutine is called EXTEND:

EXTEND

```
                                  When EXTEND is called by the Visible
                                  Monitor's UPDATE routine, a character
                                  from the keyboard is in the ac-
                                  cumulator.
EXTEND    CMP #'P                 Is it the "P" key?
          BNE IF.U                If not, perform the next test.
          LDA PRINTR              If so, toggle the
          EOR #$FF                printer flag...
          STA PRINTR
          RTS                     and return to caller.
IF.U      CMP #U                  Is it the "U" key?
          BNE IF.H                If not, perform the next test.
          LDA USR.FN              If so,
          EOR #$FF                toggle the user-output
          STA USR.FN              flag...
          RTS                     and return.
IF.H      CMP #'H                 Is it the "H" key?
          BNE IF.M                If not, perform the next test.
          LDA PRINTR              Is the printer selected?
          BNE NEXT.1              If so, print a hexdump.
          JSR TVDUMP              If not, dump to screen...
          RTS                     and return.
NEXT.1    JSR PRDUMP              Print a hexdump...
          RTS                     and return.
IF.M      CMP #'M                 Is it the "M" key?
          BNE IF.DIS              If not, perform the next test.
          JSR MOVER               If so, call the move tool.
          RTS                     ...and return.
IF.DIS    CMP #'?                 Is it the "?" key?
          BNE IF.T                If not, perform the next test.
          LDA PRINTR              Is the printer selected?
          BNE NEXT.2              If so, print a disassembly.
          JSR TV.DIS              If not, dump to screen...
          RTS                     and return.
NEXT.2    JSR PR.DIS              Print a disassembly...
          RTS                     and return.
IF.T      CMP #'T                 Is it the "T" key?
          BNE EXIT                If not, return.
```

```
            JSR EDITOR          If so, call the text editor...
            RTS                 and return.
EXIT        RTS                 Extend this subroutine by adding more
                                test-and-branch code here.
```

The only remaining step is to modify the Visible Monitor's UPDATE routine so that it calls EXTEND, rather than DUMMY, before it returns. Currently, the Visible Monitor's UPDATE routine calls DUMMY just before it returns, with the bytes $20, $10, and $10 at addresses $13D1, $13D2, and $13D3, respectively. To make the Visible Monitor's UPDATE routine call EXTEND (instead of DUMMY), you must change $13D2 from $10 to $B0.

You can change this byte with the Visible Monitor itself, provided that you are very careful not to touch any key except the keys that are legal to the *un*extended Visible Monitor. Once you have changed $13D2, you may strike any key, but while you are changing $13D2, striking a key that is not legal within the unextended Visible Monitor will cause the Visible Monitor to crash. Be careful. Once you have changed $13D2, try out your new extensions of the Visible Monitor by pressing the now legal keys: "H," "M," "P," "U," "?," and "T."

Chapter 13: Entering the Software into Your System

Chapters 5 thru 12 present software that will do useful work for you, but only if you can get it into your computer's memory. How you do that will depend on the system you have.

If you have an Apple II, you have an extended machine-language monitor built into your system. If the monitor doesn't come up on RESET, you can invoke it from BASIC with the following BASIC command:

```
POKE 0,0:CALL 0 [RETURN]
```

(The string "[RETURN]" means press the carriage return key.)

This writes a 6502 BRK instruction into location $0000, and then executes a call to a machine-language subroutine at location $0000. The 6502, upon encountering the BRK instruction, will pass control to the Apple II ROM monitor. You'll know you're in the Apple II monitor because you'll see an asterisk (*) on the screen. Your Apple II documentation should tell you how to use this monitor to enter data into memory, dump memory, etc.

The Ohio Scientific C-IP has a much simpler monitor than the Apple II built into its ROM (read-only memory). Press BREAK on the Ohio Scientific C-IP and then press "M." You'll get the ROM monitor display and can use the ROM monitor to enter hexadecimal object code into memory. Unfortunately, although the Ohio Scientific ROM monitor lets you enter a machine-language program into memory by hand, or even from a cassette file in the proper format, it provides no facility for recording a machine-language program onto a cassette. So unless you plan to key the Visible Monitor into memory and then leave your computer on forever, you're out of luck. However, you can SAVE a BASIC program on cassette, and then LOAD it from cassette. And that's the key: we'll use the OSI C-1P's ROM BASIC interpreter to help get machine-language programs into memory.

And what if you have an Atari or a PET Computer? Each of these systems features a BASIC interpreter in ROM (read-only memory), but lacks a machine-language monitor. How can you enter hexadecimal object code into memory using only a BASIC interpreter? Perhaps more importantly, even if we manage to enter that object code into memory, how can we save that object code onto a cassette? If all we have is a BASIC interpreter, the simplest solution is to make our object code look like a BASIC program.

That's not so hard. A BASIC program may contain DATA statements, so a simple BASIC program can contain a number of DATA statements, where the DATA statements actually represent, in decimal, the values of successive bytes in the object code. Then the BASIC program can READ those DATA statements and POKE the values it finds into the appropriate section of memory.

Using BASIC to Load Machine Language

The software in this book can be entered into your computer by RUNning just such a series of BASIC programs. Each of these programs consists of an OBJECT CODE LOADER followed by some number of DATA statements. The first two DATA statements specify the range of DATA statements that follow. Each of the following DATA statements contains ten values: the first value is the start address at which object code from the line is to be loaded; the next eight values represent bytes to be loaded into memory, beginning at the specified address; and the tenth value is the checksum. The checksum is simply the total of the first nine values in the DATA statement. Of these ten values, the first and the tenth will always be greater than 4000, and the others will always be less than 256.

Appendices E1 through E11 contain this book's object code in the form of such DATA statements. You must type each of these DATA statements into your computer, but the BASIC OBJECT CODE LOADER is designed to let you know if you've made a mistake. It won't catch any error you might make while typing, but it will catch the most likely errors. How? The answer is in the checksum. If you make a mistake while typing in one of these DATA lines, the checksum will almost certainly fail to match the sum of the address and the 8 bytes in the line. Then, when the OBJECT CODE LOADER detects a checksum error, it will identify the offending data statement by printing its line number as well as the address specified by the offending line.

The object code loader will use the following variables:

A	The address specified by a data line. Object code from that data line is to be loaded into memory beginning at that address.
BYTE	An array of DIMension 8, containing the values of 8 consecutive bytes of object code as specified by a data line.
CHECK	The checksum specified by a data line.
FIRST	The number of the first DATA statement containing object code.
LAST	The number of the last DATA statement containing object code.
LINE	A line counter, tracking the number of data lines of object code already loaded into memory.
SUM	The calculated sum of the 8 bytes of object code and the address specified by a given data line. If SUM equals the checksum specified by that data line, then the data is probably correct.
TEMP	A temporary variable.

Here is the object code loader:

```
100 REM                          OBJECT CODE LOADER by Ken Skier
110 REM
120 DIM BYTE(8)                  :REM Initialize BYTE array.
130 READ FIRST                   :REM Get the line number of the first
140 REM                          DATA statement containing object code.
150 READ LAST                    :REM Get the line number of the last
160 REM                          DATA statement containing object code.
170 FOR LINE=FIRST TO LAST       :REM Read the specified DATA lines.
180 GOSUB 300                    :REM Load next data line into memory.
190 NEXT LINE                    :REM If not done, read next DATA line.
200 PRINT "LOADED LINES",FIRST,"THROUGH",LAST,"SUCCESSFULLY."
210 END                          :REM If done, say so.
220 REM
230 REM                          Subroutine at 300 handles one
240 REM                          DATA statement.
300 READ A                       :REM Get address for object code.
310 SUM=A                        :REM Initialize calculated sum of data.
320 FOR J=1 TO 8                 :REM Get 8 bytes of object code from
321 REM                          data.
330 READ TEMP: BYTE(J)=TEMP      :REM Put them in the byte array, and
340 SUM=SUM+BYTE(J)              :REM add them to the calculated sum of
341 REM                          data.
350 NEXT J                       :REM Now we have the 8 bytes, and we
360 REM                          have calculated the sum of the data.
370 READ CHECK                   :REM Get checksum from data line.
380 IF SUM <>CHECK THEN 500      :REM If checksum error, handle it.
```

```
390 FOR J=1 TO 8                      :REM Since there is no checksum error,
400 POKE A+J−1,BYTE(J)                :REM poke the data into the specified
410 NEXT J                            :REM portion of memory,
420 RETURN                            :REM and return to caller.
430 REM
440 REM                               Checksum error-handling code follows.
500 PRINT "CHECKSUM ERROR IN DATA LINE",LINE
510 PRINT "START ADDRESS GIVEN IN BAD DATA LINE IS", A
520 END
530 REM                               The next two DATA statements specify
540 REM                               the range of DATA statements that
550 REM                               contain object code.
570 REM
600 DATA ????                         :REM This should be the number of the
610 REM                               first DATA statement containing object
611 REM                               code.
612 REM
620 DATA ????                         :REM This should be the number of the
630 REM                               last DATA statement containing object
631 REM                               code.
```

Once you've entered the BASIC OBJECT CODE LOADER into your computer's memory, SAVE it on a cassette. Remember that by itself the BASIC OBJECT CODE LOADER can do nothing; it needs DATA statements in the proper form to be a complete, useful program. When you're ready to create such a program, LOAD the BASIC OBJECT CODE LOADER from cassette back into memory. Now you're ready to append to it DATA statements from one of the E Appendices — for example, from Appendix E1. Do not append DATA statements from more than one appendix to the same BASIC program. Append as many DATA lines as you can, without using memory above $0FFF (decimal 4095). You can insure that you don't run over this limit by setting 4095 as the top of memory available to your system's BASIC interpreter. How do you set the top of memory available to the BASIC interpreter? That varies from system to system, so consult the B Appendix for your system.

Before you can append to the OBJECT CODE LOADER all the DATA statements from Appendix E1, your BASIC interpreter may give you an OUT OF MEMORY error (MEMORY FULL). When that happens, delete the last DATA line you appended to the OBJECT CODE LOADER. Let's say you've appended DATA lines 1000 thru 1022 when you get an OUT OF MEMORY error. Delete DATA line 1022. Now enter the line numbers of the first and last of the object code DATA statements into DATA lines 600 and 620, like this:

```
600    DATA    1000
620    DATA    1021
```

DATA lines 600 and 620, the very first DATA lines in your program, tell the BASIC OBJECT CODE LOADER how many DATA lines of object code follow. Now the OBJECT CODE LOADER can "know" how many DATA lines to read, without reading too few or too many. In this case, DATA lines 600 and 620 tell the OBJECT CODE LOADER that the object code may be found in DATA lines 1000 thru 1021.

Note that DATA lines 600 and 620 each contain one value, whereas the remaining DATA lines each contain ten values.

Now you are ready to RUN the OBJECT CODE LOADER. Unless you're a better typist than I am, you probably made some mistakes while typing in the DATA lines from Appendix E1. Don't worry; the incorrect data will not be blindly loaded into memory. If the BASIC OBJECT CODE LOADER detects a checksum error, it will tell you so, like this:

```
CHECKSUM ERROR IN DATA STATEMENT            1012
START ADDRESS GIVEN IN BAD DATA LINE IS     4442
```

This means that data statement 1012 has a checksum error: ie, bad data. To help you double check, the second line of the error message specifies the start address given by the bad data line: this is the first number in the offending data line. These two items of information should make it easy for you to find the bad data line—just look for the DATA statement whose line number is 1012 and whose first value is 4442. That's the DATA statement you entered incorrectly. Now you need only eyeball the ten numbers in that line, comparing them to the corresponding DATA statement in Appendix E1, and you should quickly find the number or numbers you entered incorrectly. Fix that DATA statement, and RUN the LOADER again.

When you have entered all of the DATA statements correctly, RUNning the LOADER will load the object code they specify into memory. The OBJECT CODE LOADER will then print:

```
LOADED LINES aaaa THROUGH bbbb SUCCESSFULLY
```

where 'aaaa' is the number of the first DATA line of object code, and 'bbbb' is the number of the last DATA line of object code in the program. This message tells you that the BASIC OBJECT CODE LOADER has read and POKE'd the indicated range of DATA statements into memory.

When you see this message, you have verified the program, so SAVE it on a cassette. Then make up a new BASIC program, containing the OBJECT CODE LOADER and the next group of DATA statements from an E Appendix. (Remember not to append DATA lines from more than one E Appendix to the same BASIC program.) Store in lines 600 and 620 the line numbers of the first and last DATA statements you copied from the E Appendix. Verify and SAVE this program as well, and then continue in this manner until you have entered, verified, and SAVE'd BASIC programs containing all of the DATA statements in Appendices E1 thru E10, as well as the DATA statements in the E Appendix containing system data for your computer (one of the Appendices E11 thru E14). RUNning all of those BASIC programs will then enter all of the software presented in this book into your computer's memory.

At this point, you should be ready to transfer control from your computer's BASIC interpreter to the VISIBLE MONITOR.

Activating the Visible Monitor

Once you have entered the object code for the Screen Utilities, the Visible Monitor, and the System Data Block into your system, you can activate the Visible Monitor by causing the 6502 in your computer to execute a JSR (jump to subroutine) to $1207.

Using the Ohio Scientific C-IP ROM monitor, you can activate the Visible Monitor simply by typing:

```
1207G
```

Using the Apple II ROM monitor, you can call the Visible Monitor with the command:

```
G1207 [RETURN]
```

Using the Atari 400 or 800 with its BASIC cartridge plugged in, you can invoke the Visible Monitor with the BASIC command:

```
X=USR(4615) [RETURN]
```

In Atari BASIC, you can call a machine-language subroutine by passing the address of that subroutine as a parameter to the USR function. Since $1207 is 4615 in decimal, the command X=USR(4615) causes Atari BASIC to call the subroutine at $1207. (The value returned by that subroutine will then be stored in the BASIC variable X — not in the 6502's X register. But that doesn't concern us because the Visible Monitor isn't designed to return a value to its caller.)

Using the PET 2001, you can invoke the Visible Monitor from BASIC in the immediate mode with the following BASIC command:

```
SYS (4615)
```

When you press (RETURN), you'll see the Visible Monitor display, because SYS (4615) causes BASIC to call the subroutine at address 4615 decimal, which is $1207—the entry point for the Visible Monitor.

If and when you press "Q" to quit the Visible Monitor, the Visible Monitor will return to its caller — PET BASIC. (The Visible Monitor doesn't leave much room for a PET BASIC program, since your BASIC program and its arrays, variables, etc cannot require memory beyond $0FFF, but the Visible Monitor should work very well with a small PET BASIC program. In any case, it's reassuring to have a new program such as the Visible Monitor return to a familiar one such as the PET BASIC interpreter.)

Once you have activated the Visible Monitor, you should see its display on the screen. If you don't see such a display, then the Visible Monitor has not been entered properly into your system's memory; perhaps you failed to enter the display code properly.

If you do see the Visible Monitor display on the screen, press the space bar. The display should change — specifically, the displayed address should increment, and fields 1 and 2, immediately to the right of the displayed address, may also change.

If nothing changes when you press the space bar, then the display code probably works fine, but you failed to enter the UPDATE code properly.

If the space bar does change the display, then test out the other functions of the Visible Monitor: press RETURN to decrement the selected address; press hexadecimal keys to select a different address; then select an address somewhere in screen memory and place new data into that address. If you picked a place in display memory that is not cleared by the Visible Monitor (ie: a place not in the top five rows of the screen), then you should be able to place arbitrary characters on the screen just by using the Visible Monitor to store arbitrary values in the selected address.

If your Visible Monitor fails to perform properly, you may have entered it into memory incorrectly. Compare the DATA statements you appended to the OBJECT

CODE LOADER with the DATA statements in the E Appendices. Remember: if even 1 byte is entered incorrectly, then in all likelihood the Visible Monitor will fail to function.

To extend the Visible Monitor as described in Chapter 12, store a $BO in address $13D2. To disable the features described in Chapter 12, store a $10 in address $13D2. Now you're really getting your hands on the machine, reaching into memory and operating on the bytes, and with that kind of control, you can do almost anything.

NOTE:

The author intends to provide the software in this book for sale on cassettes compatible with the Apple II, Atari, Ohio Scientific, and PET computers. If you prefer to load your software from cassette, rather than enter it in by hand, contact the author through BYTE Books.

Appendices

Appendix A1:

Hexadecimal Conversion Table

HEX	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	00	000
0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0	0
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	256	4096
2	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	512	8192
3	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	768	12288
4	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	1024	16384
5	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	1280	20480
6	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	1536	24576
7	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	1792	28672
8	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	2048	32768
9	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	158	2304	36864
A	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	2560	40960
B	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	2816	45056
C	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	3072	49152
D	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	3328	53248
E	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	3584	57344
F	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	3840	61440

Appendix A2:

ASCII Character Codes

Code	Char	Code	Char	Code	Char	Code	Char
00	NUL	20	SP	40	@	60	`
01	SOH	21	!	41	A	61	a
02	STX	22	"	42	B	62	b
03	ETX	23	#	43	C	63	c
04	EOT	24	$	44	D	64	d
05	ENQ	25	%	45	E	65	e
06	ACK	26	&	46	F	66	f
07	BEL	27	'	47	G	67	g
08	BS	28	(	48	H	68	h
09	HT	29	)	49	I	69	i
0A	LF	2A	*	4A	J	6A	j
0B	VT	2B	+	4B	K	6B	k
0C	FF	2C	,	4C	L	6C	l
0D	CR	2D	–	4D	M	6D	m
0E	SO	2E	.	4E	N	6E	n
0F	SI	2F	/	4F	O	6F	o
10	DLE	30	0	50	P	70	p
11	DC1	31	1	51	Q	71	q
12	DC2	32	2	52	R	72	r
13	DC3	33	3	53	S	73	s
14	DC4	34	4	54	T	74	t
15	NAK	35	5	55	U	75	u
16	SYN	36	6	56	V	76	v
17	ETB	37	7	57	W	77	w
18	CAN	38	8	58	X	78	x
19	EM	39	9	59	Y	79	y
1A	SUB	3A	:	5A	Z	7A	z
1B	ESC	3B	;	5B	[	7B	{
1C	FS	3C	<	5C	\	7C	¦
1D	GS	3D	=	5D	]	7D	}
1E	RS	3E	>	5E	^	7E	~
1F	US	3F	?	5F	___	7F	DEL

Appendix A3:

6502 Instruction Set — Mnemonic List

ADC	Add Memory to Accumulator with Carry
AND	"AND" Memory with Accumulator
ASL	Shift Left One Bit (Memory or Accumulator)
BCC	Branch on Carry Clear
BCS	Branch on Carry Set
BEQ	Branch on Result Zero
BIT	Test Bits in Memory with Accumulator
BMI	Branch on Result Minus
BML	Branch on Result not Zero
BPL	Branch on Result Plus
BRK	Force Break
BVC	Branch on Overflow Clear
BVS	Branch on Overflow Set
CLC	Clear Carry Flag
CLD	Clear Decimal Mode
CLI	Clear Interrupt Disable Bit
CLV	Clear Overflow Flag
CMP	Compare Memory and Accumulator
CPX	Compare Memory and Register X
CPY	Compare Memory and Register Y
DEC	Decrement Memory
DEX	Decrement Register X
DEY	Decrement Register Y
EOR	"Exclusive Or" Memory with Accumulator
INC	Increment Memory
INX	Increment Register X
INY	Increment Register Y

JMP	Jump to New Location
JSR	Jump to New Location Saving Return Address
LDA	Load Accumulator with Memory
LDX	Load Register X with Memory
LDY	Load Register Y with Memory
LSR	Shift Right One Bit (Memory or Accumulator)
NOP	No Operation
ORA	"OR" Memory with Accumulator
PHA	Push Accumulator on Stack
PHP	Push Processor Status on Stack
PLA	Pull Accumulator from Stack
PLP	Pull Processor Status from Stack
ROL	Rotate One Bit Left (Memory or Accumulator)
ROR	Rotate One Bit Right (Memory or Accumulator)
RTI	Return from Interrupt
RTS	Return from Subroutine
SBC	Subtract Memory from Accumulator with Borrow
SEC	Set Carry Flag
SED	Set Decimal Mode
SEI	Set Interrupt Disable Status
STA	Store Accumulator in Memory
STX	Store Register X in Memory
STY	Store Register Y in Memory
TAX	Transfer Accumulator to Register X
TAY	Transfer Accumulator to Register Y
TSX	Transfer Stack Pointer to Register X
TXA	Transfer Register X to Accumulator
TXS	Transfer Register X to Stack Pointer
TYA	Transfer Register Y to Accumulator

Appendix A4:

6502 Instruction Set — Opcode List

00 — BRK
01 — ORA — (Indirect,X)
02 — Future Expansion
03 — Future Expansion
04 — Future Expansion
05 — ORA — Zero Page
06 — ASL — Zero Page
07 — Future Expansion
08 — PHP
09 — ORA — Immediate
0A — ASL — Accumulator
0B — Future Expansion
0C — Future Expansion
0D — ORA — Absolute
0E — ASL — Absolute
0F — Future Expansion

10 — BPL
11 — ORA — (Indirect),Y
12 — Future Expansion
13 — Future Expansion
14 — Future Expansion
15 — ORA — Zero Page,X
16 — ASL — Zero Page,X
17 — Future Expansion
18 — CLC
19 — ORA — Absolute,Y
1A — Future Expansion
1B — Future Expansion
1C — Future Expansion
1D — ORA — Absolute, X
1E — Future Expansion
1F — Future Expansion

20 — JSR
21 — AND — (Indirect,X)
22 — Future Expansion
23 — Future Expansion
24 — Bit — Zero Page
25 — AND — Zero Page
26 — ROL — Zero Page
27 — Future Expansion
28 — PLP
29 — AND — Immediate
2A — ROL — Accumulator
2B — Future Expansion
2C — BIT — Absolute
2D — AND — Absolute
2E — ROL — Absolute
2F — Future Expansion

30 — BMI
31 — AND — (Indirect),Y
32 — Future Expansion
33 — Future Expansion
34 — Future Expansion
35 — AND — Zero Page,X
36 — ROL — Zero Page,X
37 — Future Expansion
38 — SEC
39 — AND — Absolute,Y
3A — Future Expansion
3B — Future Expansion
3C — Future Expansion
3D — AND — Absolute,X
3F — Future Expansion

40 — RTI
41 — EOR — (Indirect,X)
42 — Future Expansion
43 — Future Expansion
44 — Future Expansion
45 — EOR — Zero Page
46 — LSR — Zero Page
47 — Future Expansion
48 — PHA
49 — EOR — Immediate
4A — LSR — Accumulator
4B — Future Expansion
4C — JMP — Absolute
4D — EOR — Absolute
4E — LSR — Absolute
4F — Future Expansion

50 — BVC
51 — EOR — (Indirect),Y
52 — Future Expansion
53 — Future Expansion
54 — Future Expansion
55 — EOR — Zero Page,X
56 — Zero Page,X
57 — Future Expansion
58 — CLI
59 — EOR — Absolute,Y
5A — Future Expansion
5B — Future Expansion
5C — Future Expansion
5D — EOR — Absolute,X
5E — LSR — Absolute,X
5F — Future Expansion

60 — RTS
61 — ADC — (Indirect,X)
62 — Future Expansion
63 — Future Expansion
64 — Future Expansion
65 — ADC — Zero Page
66 — ROR — Zero Page
57 — Future Expansion
68 — PLA
69 — ADC — Immediate
6A — ROR — Accumulator
6B — Future Expansion
6C — JMP — Indirect
6D — ADC — Absolute
6E — ROR — Absolute
6F — Future Expansion

70 — BVS
71 — ADC — (Indirect),Y
72 — Future Expansion
73 — Future Expansion
74 — Future Expansion
75 — ADC — Zero Page,X
76 — ROR — Zero Page,X
77 — Future Expansion
78 — SEI
79 — ADC Absolute,Y
7A — Future Expansion
7B — Future Expansion
7C — Future Expansion
7D — ADC — Absolute,X
7E — ROR — Absolute,X
7F — Future Expansion

80 — Future Expansion
81 — STA — (Indirect,X)
82 — Future Expansion
83 — Future Expansion
84 — STY — Zero Page
85 — STA — Zero Page
86 — STX — Zero Page
87 — Future Expansion
88 — DEY
89 — Future Expansion
8A — TXA
8B — Future Expansion
8C — STY — Absolute
8D — STA — Absolute
8E — STX — Absolute
8F — Future Expansion

90 — BCC
91 — STA — (Indirect),Y
92 — Future Expansion
93 — Future Expansion
94 — STY — Zero Page,X
95 — STA — Zero Page,X
96 — STX — Zero Page,Y
97 — Future Expansion
98 — TYA
99 — STA — Absolute,Y
9A — TXS
9B — Future Expansion
9C — Future Expansion
9D — STA — Absolute,X
9E — Future Expansion
9F — Future Expansion

A0 — LDY — Immediate
A1 — LDA — (Indirect,X)
A2 — LDX — Immediate
A3 — Future Expansion
A4 — LDY — Zero Page
A5 — LDA — Zero Page
A6 — LDX — Zero Page
A7 — Future Expansion
A8 — TAY
A9 — LDA — Immediate
AA — TAX
AB — Future Expansion
AC — LDY — Absolute
AD — LDA — Absolute
AE — LDX — Absolute
AF — Future Expansion

B0 — BCS
B1 — LDA — (Indirect),Y
B2 — Future Expansion
B3 — Future Expansion
B4 — LDY — Zero Page,X
B5 — LDA — Zero Page,X
B6 — LDX — Zero Page,Y
B7 — Future Expansion
B8 — CLV
B9 — LDA — Absolute,Y
BA — TSX
BB — Future Expansion
BC — LDY — Absolute,X
BD — LDA — Absolute,X
BE — LDX — Absolute,Y
BF — Future Expansion

C0 — CPY — Immediate
C1 — CMP — (Indirect,X)
C2 — Future Expansion
C3 — Future Expansion
C4 — CPY — Zero Page
C5 — CMP — Zero Page
C6 — DEC — Zero Page
C7 — Future Expansion
C8 — INY
C9 — CMP — Immediate
CA — DEX
CB — Future Expansion
CC — CPY — Absolute
CD — CMP — Absolute
CE — DEC — Absolute
CF — Future Expansion

D0 — BNE
D1 — CMP — (Indirect),Y
D2 — Future Expansion
D3 — Future Expansion
D4 — Future Expansion
D5 — CMP — Zero Page,X
D6 — DEC — Zero Page,X
D7 — Future Expansion
D8 — CLD
D9 — CMP — Absolute,Y
DA — Future Expansion
DB — Future Expansion
DC — Future Expansion
DD — CMP — Absolute,X
DE — DEC — Absolute,X
DF — Future Expansion

E0 — CPX — Immediate
E1 — SEC — (Indirect,X)
E2 — Future Expansion
E3 — Future Expansion
E4 — CPX — Zero Page
E5 — SBC — Zero Page
E6 — Zero Page
E7 — Future Expansion
E8 — INX
E9 — SBC — Immediate
EA — NOP
EB — Future Expansion
EC — CPX — Absolute
ED — SBC — Absolute
EE — INC — Absolute
EF — Future Expansion

F0 — BEQ
F1 — SBC — (Indirect),Y
F2 — Future Expansion
F3 — Future Expansion
F4 — Future Expansion
F5 — SBC — Zero Page,X
F6 — INC — Zero Page,X
F7 — Future Expansion
F8 — SED
F9 — SBC — Absolute,Y
FA — Future Expansion
FB — Future Expansion
FC — Future Expansion
FD — SBC — Absolute,X
FE — INC — Absolute,X
FF — Future Expansion

Appendix A5:

Instruction Execution Times (in clock cycles)

	Accumulator	Immediate	Zero Page	Zero Page, X	Zero Page, Y	Absolute	Absolute, X	Absolute, Y	Implied	Relative	(Indirect), X	(Indirect), Y	Absolute Indirect
ADC	.	2	3	4	.	4	4*	4*	.	.	6	5*	.
AND	.	2	3	4	.	4	4*	4*	.	.	6	5*	.
ASL	2	.	5	6	.	6	7	.	.	.	.	.	.
BCC	.	.	.	.	.	.	.	.	.	2**	.	.	.
BCS	.	.	.	.	.	.	.	.	.	2**	.	.	.
BEQ	.	.	.	.	.	.	.	.	.	2**	.	.	.
BIT	.	.	3	.	.	4	.	.	.	.	.	.	.
BMI	.	.	.	.	.	.	.	.	.	2**	.	.	.
BNE	.	.	.	.	.	.	.	.	.	2**	.	.	.
BPL	.	.	.	.	.	.	.	.	.	2**	.	.	.
BRK	.	.	.	.	.	.	.	.	.	.	.	.	.
BVC	.	.	.	.	.	.	.	.	.	2**	.	.	.
BVS	.	.	.	.	.	.	.	.	.	2**	.	.	.
CLC	.	.	.	.	.	.	.	.	2	.	.	.	.
CLD	.	.	.	.	.	.	.	.	2	.	.	.	.
CLI	.	.	.	.	.	.	.	.	2	.	.	.	.
CLV	.	.	.	.	.	.	.	.	2	.	.	.	.
CMP	.	2	3	4	.	4	4*	4*	.	.	6	5*	.
CPX	.	2	3	.	.	4	.	.	.	.	.	.	.
CPY	.	2	3	.	.	4	.	.	.	.	.	.	.
DEC	.	.	5	6	.	6	7	.	.	.	.	.	.
DEX	.	.	.	.	.	.	.	.	2	.	.	.	.
DEY	.	.	.	.	.	.	.	.	2	.	.	.	.
EOR	.	2	3	4	.	4	4*	4*	.	.	6	5	.

	Accumulator	Immediate	Zero Page	Zero Page, X	Zero Page, Y	Absolute	Absolute, X	Absolute, Y	Implied	Relative	(Indirect), X	(Indirect), Y	Absolute Indirect
INC	.	.	5	6	.	6	7	.	.	.	.	.	.
INX	.	.	.	.	.	.	.	.	2	.	.	.	.
INY	.	.	.	.	.	.	.	.	2	.	.	.	.
JMP	.	.	.	.	.	3	.	.	.	.	.	.	5
JSR	.	.	.	.	.	6	.	.	.	.	.	.	.
LDA	.	2	3	4	.	4	4*	4*	.	.	6	5*	.
LDX	.	2	3	.	4	4	.	4*	.	.	.	.	.
LDY	.	2	3	4	.	4	4*	.	.	.	.	.	.
LSR	2	.	5	6	.	6	7	.	.	.	.	.	.
NOP	.	.	.	.	.	.	.	.	2	.	.	.	.
ORA	.	2	3	4	.	4	4*	4*	.	.	6	5*	.
PHA	.	.	.	.	.	.	.	.	3	.	.	.	.
PHP	.	.	.	.	.	.	.	.	3	.	.	.	.
PLA	.	.	.	.	.	.	.	.	4	.	.	.	.
PLP	.	.	.	.	.	.	.	.	4	.	.	.	.
ROL	2	.	5	6	.	6	7	.	.	.	.	.	.
ROR	2	.	5	6	.	6	7	.	.	.	.	.	.
RTI	.	.	.	.	.	.	.	.	6	.	.	.	.
RTS	.	.	.	.	.	.	.	.	6	.	.	.	.
SBC	.	2	3	4	.	4	4*	4*	.	.	6	5*	.
SEC	.	.	.	.	.	.	.	.	2	.	.	.	.
SED	.	.	.	.	.	.	.	.	2	.	.	.	.
SEI	.	.	.	.	.	.	.	.	.	.	.	.	.
STA	.	.	3	4	.	4	5	5	.	.	6	6	.
STX*	.	.	3	.	4	4	.	.	.	.	.	.	.
STY**	.	.	3	4	.	4	.	.	.	.	.	.	.
TAX	.	.	.	.	.	.	.	.	2	.	.	.	.
TAY	.	.	.	.	.	.	.	.	2	.	.	.	.
TSX	.	.	.	.	.	.	.	.	2	.	.	.	.
TXA	.	.	.	.	.	.	.	.	2	.	.	.	.
TXS	.	.	.	.	.	.	.	.	2	.	.	.	.
TYA	.	.	.	.	.	.	.	.	2	.	.	.	.

* Add one cycle if indexing across page boundary

** Add one cycle if branch is taken, Add one additional if branching operation crosses page boundary

Appendix A6:

6502 Opcodes by Mnemonic and Addressing Mode

	Addressing Modes												
	ABSOLUTE	ABSOLUTE,X	ABSOLUTE,Y	ACCUMULATOR	IMMEDIATE	IMPLIED	INDIRECT	INDIRECT,X	INDIRECT,Y	RELATIVE	ZERO PAGE	ZERO PAGE,X	ZERO PAGE,Y
Mnemonics													
ADC	6D	7D	79	.	69	.	.	61	71	.	65	75	.
AND	2D	3D	39	.	29	.	.	21	31	.	25	35	.
ASL	0E	1E	.	0A	.	.	.	.	.	.	06	16	.
BCC	.	.	.	.	.	.	.	.	.	90	.	.	.
BCS	.	.	.	.	.	.	.	.	.	B0	.	.	.
BEQ	.	.	.	.	.	.	.	.	.	F0	.	.	.
BIT	2C	.	.	.	.	.	.	.	.	.	24	.	.
BMI	.	.	.	.	.	.	.	.	.	30	.	.	.
BNE	.	.	.	.	.	.	.	.	.	D0	.	.	.
BPL	.	.	.	.	.	.	.	.	.	10	.	.	.
BRK	.	.	.	.	.	00	.	.	.	.	.	.	.
BVC	.	.	.	.	.	.	.	.	.	50	.	.	.
BVS	.	.	.	.	.	.	.	.	.	70	.	.	.
CLC	.	.	.	.	.	18	.	.	.	.	.	.	.
CLD	.	.	.	.	.	D8	.	.	.	.	.	.	.
CLI	.	.	.	.	.	58	.	.	.	.	.	.	.

	Addressing Modes												
Mnemonics	ABSOLUTE	ABSOLUTE,X	ABSOLUTE,Y	ACCUMULATOR	IMMEDIATE	IMPLIED	INDIRECT	INDIRECT,X	INDIRECT,Y	RELATIVE	ZERO PAGE	ZERO PAGE,X	ZERO PAGE,Y
CLV	.	.	.	.	.	B8	.	.	.	.	.	.	.
CMP	CD	DD	D9	.	C9	.	.	C1	D1	.	C5	D5	.
CPX	EC	.	.	.	E0	.	.	.	.	.	E4	.	.
CPY	CC	.	.	.	C0	.	.	.	.	.	C4	.	.
DEC	CE	DE	.	.	.	.	.	.	.	.	C6	D6	.
DEX	.	.	.	.	.	CA	.	.	.	.	.	.	.
DEY	.	.	.	.	.	88	.	.	.	.	.	.	.
EOR	4D	5D	59	.	49	.	.	41	51	.	45	55	.
INC	EE	FE	.	.	.	.	.	.	.	.	E6	F6	.
INX	.	.	.	.	.	E8	.	.	.	.	.	.	.
INY	.	.	.	.	.	C8	.	.	.	.	.	.	.
JMP	4C	.	.	.	.	.	6C	.	.	.	.	.	.
JSR	20	.	.	.	.	.	.	.	.	.	.	.	.
LDA	AD	BD	B9	.	A9	.	.	A1	B1	.	A5	B5	.
LDX	AE	.	BE	.	A2	.	.	.	.	.	A6	.	.
LDY	AC	BC	.	.	A0	.	.	.	.	.	A4	B4	.
LSR	4E	5E	.	4A	.	.	.	.	.	.	46	56	.
NOP	.	.	.	.	.	EA	.	.	.	.	.	.	.
ORA	0D	1D	19	.	09	.	.	01	11	.	05	15	.
PHA	.	.	.	.	.	48	.	.	.	.	.	.	.
PHP	.	.	.	.	.	08	.	.	.	.	.	.	.
PLA	.	.	.	.	.	68	.	.	.	.	.	.	.
PLP	.	.	.	.	.	28	.	.	.	.	.	.	.
ROL	2E	3E	.	2A	.	.	.	.	.	.	26	36	.
ROR	6E	7E	.	6A	.	.	.	.	.	.	66	76	.
RTI	.	.	.	.	.	40	.	.	.	.	.	.	.

Mnemonics	ABSOLUTE	ABSOLUTE,X	ABSOLUTE,Y	ACCUMULATOR	IMMEDIATE	IMPLIED	INDIRECT	INDIRECT,X	INDIRECT,Y	RELATIVE	ZERO PAGE	ZERO PAGE,X	ZERO PAGE,Y
RTS	.	.	.	.	.	60	.	.	.	.	.	.	.
SBC	ED	FD	F9	.	E9	.	.	E1	F1	.	E5	F5	.
SEC	.	.	.	.	.	38	.	.	.	.	.	.	.
SED	.	.	.	.	.	F8	.	.	.	.	.	.	.
SEI	.	.	.	.	.	78	.	.	.	.	.	.	.
STA	8D	9D	99	.	.	.	.	81	91	.	85	95	.
STX	8E	.	.	.	.	.	.	.	.	.	86	.	.
STY	8C	.	.	.	.	.	.	.	.	.	84	94	.
TAX	.	.	.	.	.	AA	.	.	.	.	.	.	.
TAY	.	.	.	.	.	A8	.	.	.	.	.	.	.
TSX	.	.	.	.	.	BA	.	.	.	.	.	.	.
TXA	.	.	.	.	.	8A	.	.	.	.	.	.	.
TXS	.	.	.	.	.	9A	.	.	.	.	.	.	.
TYA	.	.	.	.	.	98	.	.	.	.	.	.	.

Appendix B1:
The Ohio Scientific Challenger I-P

The Ohio Scientific Challenger I-P is the simplest of the systems considered in this book. Its screen is mapped in the manner described in Chapter 5: the lowest screen address is in the upper left corner, and the screen addresses increase uniformly as you move to the right and down the screen. Any ASCII character stored in screen memory will be displayed properly on the video screen; it is not necessary to replace the ASCII character with a system-specific display code. Therefore, the system data block may be initialized as shown in Appendices C13 and E12.

Incidentally, the OSI C-IP's screen TVT subroutine at $BF2D stores the relative location of the cursor in $0200. Modify $0200 and you change the next location at which a character will be printed to the screen.

If you have an Ohio Scientific BASIC-in-ROM system other than the Challenger I-P, it may have different character input/output routines. If so, examine the following locations:

BASIN	$FFEB	General character-input routine for OSI BASIC-in-ROM.
BASOUT	$FFEE	General character-output routine for OSI BASIC-in-ROM.

For example, in the OSI C-IP you can get a character from the keyboard by calling $FEED, or you may call OSI's general character-input routine at $FFEB. This routine gets a character from the keyboard unless the SAVE flag is set, in which case it gets a character from the cassette input port. Similarly, in the OSI C-IP you can print a character to the screen by calling $BF2D, or send a character to the cassette output port by calling $FCB1. Or, you can simply call OSI's general character-output routine at $FFEE, which outputs the accumulator to the screen and, if the SAVE flag is set, echoes to the serial port as well.

Thus, even if you don't know the addresses of your OSI system's specific I/O routines, you can set ROMKEY=$FFEB and ROMTVT=$FFEE. When you RESET your system, the Ohio Scientific Operating System will automatically "hook" those routines to your keyboard for input and to your screen for output.

Setting the Top of Memory

If you wish to load object code using the BASIC OBJECT CODE LOADER (see Chapter 13) you must first set the top of memory available to your BASIC interpreter to $0FFF. Do this as part of cold-starting BASIC. To cold-start BASIC, turn on your OSI computer, press the (BREAK) key, and then press 'C'. The screen will prompt, "Memory Size?" Type "4095" and then press (RETURN). Now BASIC will use the lowest 4K of RAM, leaving memory from $1000 and up available to machine-language programs.

With the top of memory set to $0FFF, you may enter and RUN the BASIC programs that load object code into your computer's memory.

Calling Machine-Language Code from BASIC

To call a machine-language subroutine from BASIC, first set the pointer at $000B, 000C so it points to the subroutine, and then call that subroutine with BASIC's USR function, either in the immediate mode or from within a BASIC program. For example, let's say you wish to call the Visible Monitor from BASIC. The Visible Monitor's entry point is at $1207, so we must make $000B,000C point to $1207. This means storing 07 in $000B, and storing $12 (decimal 18) in $000C. The following line will do that for us:

```
POKE 11,7:POKE 12,18
```

Now we may invoke the Visible Monitor with the line:

```
X = USR(X)
```

or with any other line that uses the USR function.

Note that the USR function does not set a BASIC variable equal to the contents of some register in the 6502; in fact, the line X = USR(X) will not change the value of the BASIC variable X at all. Thus, the USR function lets you activate any desired machine-language subroutine, but it doesn't let you capture a value returned by such a subroutine. If you want a machine-language subroutine to return some value which you can then use in a BASIC program, you'll have to make the machine-language subroutine store its value or values somewhere in memory, and then have the BASIC program PEEK that memory location after it has called the machine-language subroutine via the USR function.

Appendix B2:

The PET 2001

Display Memory

The PET screen is mapped conventionally, with the HOME address at $8000 (32,768 decimal). It has 25 rows, each consisting of 40 characters. The address of each screen location is 40 ($28) greater than the address of the screen location directly above it. Thus, the screen parameters for the PET 2001 are:

```
HOME      .WORD $8000,
ROWINC    .BYTE $28
TVCOLS    .BYTE 39              (We count columns from zero.)
TVROWS    .BYTE 24              (We count rows from zero.)
```

PET Character Set

However, although the PET screen buffer is mapped conventionally, you cannot simply store an ASCII character in screen memory if you wish to see that ASCII character on the screen. The PET character generator introduces a few wrinkles and you must compensate carefully if you are to display ASCII characters properly on the screen.

For example, if you store $31 (the code for an ASCII "1") in the PET's display memory, then you will see a "1" displayed on the screen. So far, so good. The same is true for all ASCII digits and for some ASCII punctuation marks. But if you store $45 (ASCII code for an upper case "E") in screen memory, then you won't see an "E" on the screen: you'll see either a lowercase "e" or else a horizontal line segment much longer than a hyphen. What's happening?

The PET 2001 features a memory location, $E84C (59468) which has a special effect on the video-display circuitry. The value stored in that address selects for the video display one character set or another.

To see how the choice of character set affects the display, enter the following BASIC program into your PET:

```
100  REM      DISPLAY PET CHARACTER SET
110  REM      IN 16 BY 16 MATRIX
120  REM
130  HOME=32768
140  CHAR=0
150  FOR ROW=0 TO 15
160  FOR COL=0 TO 15
170  POKE (HOME+COL)+(40*ROW),CHAR
180  CHAR=CHAR+1
190  NEXT COL
200  NEXT ROW
210  END
```

Before running this program, clear the screen by holding down the PET's SHIFT key at the same time that you depress the CLR/HOME key. When the screen is clear, use the CRSR SOUTH key to move the cursor down seventeen rows. Then type RUN and press RETURN. You'll see one PET character set appear in a 16 by 16 matrix in the upper left portion of your PET's screen.

What you'll see on your screen will look like table B2.1 (without the labeled axes).

Table B2.1: *The PET character set.*

	RIGHT NYBBLE OF CHARACTER															
LEFT NYBBLE OF CHARACTER	−0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−A	−B	−C	−D	−E	−F
0−	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1−	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	↑	←
2−		!	"	#	$	%	&	'	(	)	*	+	'	−	.	/
3−	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4−	−	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
5−	p	q	r	s	t	u	v	w	x	y	z	—	—	—	—	—
6−	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7−	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8−	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
9−	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	↑	←
A−		!	"	#	$	%	&	'	(	)	*	+	'	−	.	/
B−	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
C−	−	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
D−	p	q	r	s	t	u	v	w	x	y	z	—	—	—	—	—
E−	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
F−	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

In this chart, special graphic characters are indicated by an underline. Look at your PET screen to see those special graphics in all their glorious detail.

Note that the characters for $80 thru $FF are the same as for $00 thru $7F, but in reverse intensity. The low 128 characters ($00 thru $7F) are "normal" — that is, white characters on a dark background; whereas the high 128 characters ($80 thru $FF) are in reverse video — dark characters in a white background. An "A" in normal intensity may be displayed by storing an $01 somewhere in the screen memory; a reverse intensity "A" may be displayed by storing an $81 somewhere in screen memory. From this pattern we can derive a handy corollary: to reverse the intensity of any character on the screen, simply reverse its bit 7. You don't even have to know what the character represents; just toggle bit 7 and you change its intensity.

The chart in figure B2.1 (and on your PET screen) shows one complete character set because the BASIC program stores every 8-bit value, from $00 thru $FF, into the screen buffer. But I mentioned two character sets. What must you do to see the second character set?

If the cursor is within three rows of the bottom of the screen, move it up so that it is at least three rows above the bottom of the screen. This will insure that you don't scroll part of the character set up off the screen when you execute the following BASIC command in the immediate mode:

```
POKE 59468,12
```

Did that change the display? If not, then execute the following BASIC command in the immediate mode (again being sure that the cursor is at least three rows from the bottom of the screen):

```
POKE 59468,14
```

Depending on the value stored in 59468 ($E84C), one or another character set will be displayed. The values of the bytes stored in screen memory will not change when you change the contents of $E84C, but in some cases the displayed characters will change. In the ranges 00 thru $3F and $80 thru $BF, the two character sets are identical. But in the ranges $40 thru $7F and $C0 thru $FF, they differ.

Both character sets include numbers, uppercase letters, and certain punctuation marks; but only one character set includes lowercase letters and the remaining punctuation marks. The second character set lacks lowercase letters and these punctuation marks, offering instead a set of special graphics characters, including playing-card suits. POKE 59468,14 to select the former character set (thereby making possible the display of all printable ASCII characters); POKE 59468,12 to select the latter character set (thereby making possible the display of the gaming graphics).

FIXCHR

Note that neither character set corresponds directly to ASCII. If you have an ASCII character in the accumulator and you want to display the appropriate graphic character on the screen, you must first call FIXCHR (as TV.PUT does, in Chapter 5). When an ASCII character is passed in the accumulator, FIXCHR must return in the accumulator the proper PET display code for that character. FIXCHR's caller may then store this display code in memory, thereby placing on the screen an appropriate image of the original ASCII character.

How will FIXCHR work? By examining the PET character set and comparing it to Appendix A2, ASCII codes, we can see a solution in the form of the following algorithm:

- If a character is in the range $40 thru $5F, subtract $40 and return.
- If a character is in the range $20 thru $3F, return.
- If a character is in the range $60 thru $7A, store a decimal 14 in 59468 to select the character set that has lower case letters; and return.
- All other input characters are either ASCII control codes, for which there are no agreed-upon graphics, or else PET special graphics characters, so just return.

Examine the tables yourself to see if this algorithm will work.

FIXCHR

```
FIXCHR    AND #$7F          Clear bit 7, so the character will be in
                            the legal ASCII range.
          SEC               Prepare to compare.
          CMP #$40          If it's less than $40, return.
          BCC FIXEND
                            Okay. The character is greater than $40.
          CMP #$60          Is it greater than $5F?
          BCS LOWERC        If so, handle it as lowercase.
                            Okay. The character is in the range
                            $40-$5F.
          SBC #$40          Subtract $40 for proper display code.
          RTS
LOWERC    LDX #14           Since we have a lowercase letter, let's
                            select the character set that
          STX 59468         has lowercase letters.
FIXEND    RTS               Return, bearing PET display code for
                            character originally in accumulator.
```

Call FIXCHR with an ASCII character in the accumulator. FIXCHR will return with the corresponding PET display code in the accumulator. When it returns, its caller may store the accumulator anywhere in screen memory, thus displaying an image of the original ASCII character.

PET Keyboard Input Routine

To get an ASCII character from the PET keyboard, call the following subroutine:

```
PETKEY    JSR $FFE4        Call PET ROM key scan routine.
          CMP #0           Zero means no key.
          BEQ PETKEY       If no key, scan again.
                           A new key is in the accumulator. If the
                           shift key was down, bit 7 is set.
          AND #$7F         So clear bit 7, just to be sure we've got
                           a legal ASCII character.
          RTS              Return with ASCII character in the ac-
                           cumulator.
```

This subroutine yields the uppercase ASCII code for any letter key that you depress, and the proper ASCII code for any digit key or punctuation key.

PET TVT Routine

To print an ASCII character to the screen, call $FFD2, a PET ROM routine I will refer to as PETTVT.

Any printable ASCII character passed to $FFD2 (or, apparently, to $E3EA or $F230) will be printed properly to the screen at the PET's current TVT screen location. You may change the PET's current TVT screen location (which is *not* the same as the current location used by the screen utilities in Chapter 5) by calling PETTVT with the accumulator holding any of the control codes from Table B2.1.

Table B2.1: *Control codes that affect the next character to be printed by PETTVT.*

Character Name	Code	Function
CURSOR NORTH	$91	Move current location up by one row.
CURSOR EAST	$1D	Move current location one column to the right.
CURSOR SOUTH	$11	Move current location down by one row.
CURSOR WEST	$9D	Move current location left by one column.
INSERT	$94	Move current character, and all characters to its right, one column to the right.
DELETE	$14	Move current character, and all characters to its right, one column to the left.
HOME	$13	Set current location to upper left of screen.
CLEAR	$93	Set current location to the upper left corner and clear the screen.
REVERSE	$12	Select reverse video for following characters.
REVERSE-OFF	$92	Select normal video mode for following characters.

These control codes may be passed directly to PETTVT, or they may be included within a string of characters to be printed by "PRINT:" or "PR.MSG." For example, if you wish to clear the screen before printing a message, just put the CLEAR character ($93) at the beginning of your message string, immediately following the STX. The message-printing subroutine will get the CLEAR character and pass it to PR.CHR, which, in turn, will pass it through the ROMTVT vector on to the PETTVT routine. The PETTVT routine will then clear the screen and set the current location to the upper left corner of the screen.

The next character in the string will then be printed in the upper left corner of a clear screen. If, instead of printing your message at the top row of a clear screen, you'd prefer to print it in the fifth row of a clear screen, just follow the CLEAR character with four CURSOR-SOUTH characters ($11, $11, $11, $11), and follow the four cursor-south characters with the text of your message. Following the text of your message, of course, you must include an ETX ($FF).

You might never use the PETTVT control codes, but it's good to know they're available, should you ever want your PET's display screen to perform as something more than a glass teletype.

System Data Block

To run on a PET 2001, the software in this book requires the system data block shown in Appendices C14 and E13.

Setting the Top of Memory

Before you can use the BASIC OBJECT CODE LOADER (presented in Chapter 12) to load object code into your PET's memory, you must insure that your PET's BASIC interpreter leaves undisturbed all memory above $0FFF (4095 decimal). The PET BASIC interpreter will do as we wish if we set its top-of-memory pointer appropriately. The top-of-memory pointer specifies the highest address that may be used for the storage of BASIC program lines, variables, and strings. Memory above that address is off-limits to BASIC.

As you may know, there is more than one version of the PET 2001 by Commodore. Some PET's have software in "old" ROMS (REV 2 ROMS), and others have software in "new" ROMS (REV 3 ROMS). As far as the software in this book is concerned, old ROM PETS and new ROM PETS are the same, since the ROM routines we care about are accessible from the same addresses in both old and new ROM PETS. Therefore, until now I haven't even mentioned that the PET 2001 comes in two flavors. But now you must discover whether you have an old ROM or a new ROM PET, because otherwise you won't be able to set the top of memory.

Old ROM and new ROM PETS each contain a machine-language subroutine to clear the screen, but in new ROM PETS that subroutine is at $E229 (57897 decimal), and in old ROM PETS that subroutine is as $E236 (57910 decimal). To see what ROMS are in your PET, use the PET's screen editor to place some characters on the screen, and then type:

```
SYS (57897)
```

and press (RETURN). Does the screen clear? If so, you've got a new ROM PET. If not, turn off your PET, turn it on, place some characters on the screen, and then type:

```
SYS (57910)
```

and press (RETURN). Does the screen clear? If so, you've got an old ROM PET. If not, then your PET contains neither Rev 2 ROMS nor Rev 3 ROMS, and you'll have to consult your system's documentation carefully to discover the address of the top-of-memory pointer.

On old ROM PETS, the top-of-memory pointer is at 134 and 135 ($86,87). On new ROM PETS, the top-of-memory pointer is at 52 and 53 ($34,35). Regardless of the location of the top-of-memory pointer, we want to set the low byte of that pointer equal to $FF (255 decimal), and the high byte of that pointer equal to $0F (15 decimal), so that the pointer itself points to $0FFF. That will leave memory from

$1000 and up available to machine-language programs.

Thus, we set the top of memory on an old ROM PET with:

```
POKE 134,255:POKE 135,15
```

Similarly, we set the top of memory on a new ROM PET with:

```
POKE 34,255:POKE 35,15
```

Once you have set the top of memory available to your PET's BASIC interpreter, you may enter the BASIC OBJECT CODE LOADER and the DATA statements from Appendices E1 thru E11, and from Appendix E13. Remember to set the top of memory not only when typing in these DATA statements, but when RUNning the OBJECT CODE LOADER, as well.

Appendix B3:

The Apple II

Apple Display

The display memory of the Apple II is mapped in a manner that is much more complex than the Ohio Scientific or PET computers. On each of these other systems, only one portion of memory is mapped to the screen. The screen cannot display the contents of any other bank of memory (unless, of course, you copy the contents of another bank of memory into the display memory). But the Apple II may display the contents of any of four banks of memory: Low-Resolution Graphics and Text Page 1, Low-Resolution Graphics and Text Page 2, High-Resolution Graphics Page 1, and High-Resolution Graphics Page 2. Table B3.1 summarizes the locations of these pages in memory.

Table B3.1: *Banks of display memory in the Apple II.*

	Hexadecimal	**Decimal**
Low-Resolution Graphics and Text Page 1:	\$0400-\$07FF	1024-2043
Low-Resolution Graphics and Text Page 2:	\$0800-\$0BFF	2048-3071
Hi-Resolution Graphics Page 1:	\$2000-\$3FFF	8192-16383
Hi-Resolution Graphics Page 2:	\$4000-\$5FFF	16384-24575

Note that each of these display pages takes up much more than one hexadecimal page (256 bytes). A display page is simply an area of any size memory, whose contents may be displayed on the screen. Each low-res display page occupies four hexadecimal pages, and each hi-res display page occupies 32 hexadecimal pages. Why are the hi-res display pages bigger than the low-res display pages? Hi-res means high-resolution, and higher resolution requires more information.

How do you make the video screen show the contents of a given display page? You need only store a zero in a particular address. Certain addresses in the Apple II signal the video-display circuitry whenever data are written to them. The video-display circuitry responds to these signals by displaying the contents of a given bank of memory. These special addresses, or *display selectors*, are given in Table B3.2.

Table B3.2: *Addresses that affect the APPLE II Display.*

Hexadecimal	Decimal	Label	Purpose of Address
$C050	−16304	TXTCLR	Store a 0 here to set graphics mode.
$C051	−16303	TXTSET	Store a 0 here to set text mode.
$C052	−16302	MIXCLR	Store a 0 here to set bottom four lines to graphics.
$C053	−16301	MIXSET	Store a 0 here to select text/graphics mix (bottom four lines text).
$C055	−16299	HISCR	Store a 0 here to select Page 2.
$C056	−16298	LORES	Store a 0 here to select low-resolution graphics and text page.
$C057	−16297	HIRES	Store a 0 here to select high-resolution graphics.

Space limitations prohibit a discussion in this book of the power of high-resolution graphics. The Apple II documentation, however, provides an excellent step-by-step guide to the design, display, saving, and loading of high-resolution images. I must stress, however, that the software in this book expects the host system to have low-resolution graphics, so you'd better tell your Apple II to have low-resolution graphics. The software in this book uses the Apple's low-resolution graphics with text page 1 as the screen memory. To select this display page, simply press the RESET button on your Apple. If, on the other hand, you wish to select this display page under software control, you can do it by calling the subroutine LORES1:

```
LORES1   PHP                 Save processor flags.
         PHA                 Save accumulator.
         LDA # 0             Store a 0 in
         STA LOWSCR          LOWSCR to select Page 1,
         STA LORES           and in LORES to select low-resolution
                             graphics.
         PLA                 Restore accumulator.
         PLP                 Restore processor flags.
         RTS                 Return to caller.
```

This subroutine will select low-resolution graphics and text page 1. It preserves all flags and registers, and is completely relocatable.

Even when you've configured your Apple II to low-resolution graphics, your job isn't done. The low-res display of the Apple II is mapped in an unusual manner. For any other system you can assume that the address of a given location on the screen is simply the address of the location above it, plus some row increment. On the Apple II this is not always true. See Table B3.3, Apple II low-res display memory map.

Table B3.3: *Apple II low-resolution display.*

Page 1

Row Number	**Address of Leftmost Column**	**Address of Rightmost Column**
$00	$400	$427
$01	$480	$4A7
$02	$500	$527
$03	$580	$5A7
$04	$600	$627
$05	$680	$6A7
$06	$700	$727
$07	$780	$7A7
$08	$428	$44F
$09	$4A8	$4CF
$0A	$528	$54F
$0B	$5A8	$5CF
$0C	$628	$64F
$0D	$6A8	$6CF
$0E	$728	$74F
$0F	$7A8	$7CF
$10	$450	$477
$11	$4D0	$4F7
$12	$550	$577
$13	$5D0	$5F7
$14	$650	$677
$15	$6D0	$6F7
$16	$750	$777
$17	$7D0	$7F7

Page 2

Row Number	Address of Leftmost Column	Address of Rightmost Column
$00	$800	$827
$01	$880	$8A7
$02	$900	$927
$03	$980	$9A7
$04	$A00	$A27
$05	$A80	$AA7
$06	$B00	$B27
$07	$B80	$BA7
$08	$828	$84F
$09	$8A8	$8CF
$0A	$928	$94F
$0B	$9A8	$9CF
$0C	$A28	$A4F
$0D	$AA8	$ACF
$0E	$B28	$B4F
$0F	$BA8	$BCF
$10	$850	$877
$11	$8D0	$8F7
$12	$950	$977
$13	$9D0	$9F7
$14	$A50	$A77
$15	$AD0	$AF7
$16	$B50	$B77
$17	$BD0	$BF7

Note that the display addresses do not increase uniformly as we move down, row-by-row, through low-res display page 1 or 2. The addresses increase uniformly from row 0 thru row 7, but from row 7 to row 8 the display addresses do not increase; they decrease! Then they increase uniformly through line $0F (15 decimal), but from line $0F to line $10 (15 to 16 decimal), the display address plummets again. Then from row $10 to row $17 (16 thru 23) the display addresses again increase uniformly.

If you'd like to take a visual tour of the Apple II's low-res display memory, run the BASIC program in listing B3.1. This program will simply poke a blank into each address in low-res display page 1, starting at the lowest address and moving to the highest address. You'll see that the screen does not fill with blanks in a contiguous manner, but follows a pattern of three interleaved parts.

Listing B3.1: *APPLE II low-resolution display, memory-mapper program.*

```
100   REM APPLE II LOW-RESOLUTION DISPLAY, MEMORY-MAPPER
105   REM
108   REM BY KEN SKIER
110   REM
120   FIRST=1024: REM START OF LOW-RESOLUTION PAGE 1.
130   LAST=2043: REM  END OF LOW-RESOLUTION PAGE 1.
140   CHAR=32: REM    CHARACTER TO BE POKED INTO SCREEN
150   REM             WILL BE A WHITE BLANK.
160   REM
170   FOR X=FIRST TO LAST
175   REM   FOR EACH ADDRESS IN LOW-RESOLUTION PAGE 1.
180   POKE X,CHAR
185   REM             POKE A WHITE BLANK. THEN,
190   GOSUB 1000: REM WAIT A MOMENT...
200   NEXT X: REM     BEFORE POKING NEXT ADDRESS.
210   END
220   REM
230   REM
1000  FOR WAIT=0 TO 100
1005  REM             THIS IS A WAIT SUBROUTINE.
1010  NEXT WAIT: REM IT SLOWS DOWN PROGRAM SO YOU
1020  RETURN: REM     CAN FOLLOW THE ACTION.
```

Must we now write a whole new set of display procedures to accommodate the unusual mapping of the Apple II low-res display pages? We could. But the screen utilities presented in Chapter 5 will work for the Apple II if we think of the Apple low-res screen as three separate screens: the top eight rows are one screen, the middle eight rows are another screen, and the bottom eight rows are a third screen. Each of these "screens" has a set of screen parameters.

The sceen utilities in this book will work fine if you limit their scope to a given third of the screen. Use TVTOXY only to set a relative screen position within the third of the screen that you have selected. Use the screen utilities only for the top third of the screen. The middle and bottom thirds of the screen may still be used by the PRINT utilities.

To limit the screen utilities to the top third of low-res display page 1, initialize the screen parameters as follows:

```
SCREEN    .WORD $0400
TVCOLS    .BYTE $27
TVROWS    .BYTE $07
ROWINC    .BYTE $80
```

If you want to keep text from scrolling into the upper third of the screen, store $08 in address $0022. (In BASIC you may do this with the command POKE 34,8.)

There's one more quirk to the Apple display. If you store an ASCII character in display memory, then you will display a blinking or inverse version of the character. Setting bit 7 in an ASCII character code will cause that character to be displayed in normal mode (a white character on a black background), rather than as a black character on a white background or as a blinking character.

You may experiment with this feature of the Apple II by using the Apple II monitor to store $41 (an ASCII "A") in a location in low-res display page 1. You'll see a blinking "A." Now store $C1 in a location in low-res display page 1. You'll see a normal "A." Why? Because $C1 is $41 with bit 7 set. To understand what's happening here, look at the Apple II's character set given in Table B3.4.

Table B3.4: *The Apple II character set.*

	RIGHT NYBBLE OF CHARACTER															
LEFT NYBBLE OF CHARACTER	—0	—1	—2	—3	—4	—5	—6	—7	—8	—9	—A	—B	—C	—D	—E	—F
0—	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1—	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]		--
2—		!	"	#	$	%	'	(	)	*	+	,	—	.	/	
3—	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4—	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5—	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]		--
6—		!	"	#	$	%	'	(	)	*	+	,	—	.	/	
7—	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
8—	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
9—	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]		--
A—		!	"	#	$	%	'	(	)	*	+	,	—	.	/	
B—	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
C—	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
D—	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]		--
E—		!	"	#	$	%	'	(	)	*	+	,	—	.	/	
F—	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?

The Apple II really has only 64 characters in its character set, but it has four ways of displaying each character. Thus, the table shows a set of characters at $00 thru $3F; the same characters, in the same sequence, appear again at $40 thru $7F, at $80 thru $BF, and at $C0 thru $FF. These represent what I call the first, the second, the third, and the fourth quadrants of the character set.

Character codes in this first quadrant ($00 thru $3F) will be displayed in reverse video: as black characters on a white background. Character codes in the second quadrant ($40 thru $7F) will be displayed in a blinking mode. Character codes in the third and fourth quadrants ($80 thru $BF and $C0 thru $FF) will be displayed in normal mode: as white characters on black background.

Before we store any ASCII character in screen memory, we must first call FIXCHR, to convert, if necessary, the ASCII character to the host system's corresponding display code. In the Apple II, FIXCHR is very simple:

```
FIXCHR    ORA #$80              Set bit 7, so character will be displayed
                                in normal mode.
RTS                             Return appropriate display code to
                                caller.
```

I/O Vectors

The Apple II has a subroutine in read-only memory to get a character from the keyboard, and another subroutine to print a character on the screen. However, the key-in routine at $FD35 does not return an ASCII code when you press the key for an ASCII character; instead, it returns the appropriate ASCII code with bit 7 set. Similarly, the screen-printing routine at $FBFD will print an ASCII character to the screen, but the character will be in reverse video or blinking. In order to print an ASCII character to the screen, you must first set bit 7 and then call $FBFD. Conversely, to get an ASCII character from the keyboard, you must first call $FD35 and then clear bit 7. Therefore, the following patches are offered:

Subroutine to Print an ASCII Character to Apple II Screen

```
APLTVT    ORA #$80              Set bit 7 in the ASCII code.
          JSR $FBFD             Call the ROM screen printer.
          RTS                   Return to caller, now that ASCII
                                character originally in accumulator has
                                been printed to screen in normal mode.
```

Subroutine to Get an ASCII Character from Apple II Keyboard

```
APLKEY    JSR $FD0C             Get ASCII character from keyboard
                                with bit 7 set. (Note: you may call
                                $FD35 instead of calling $FD0C.)
```

ORA #$80	Clear bit 7, leaving the accumulator holding a conventional ASCII code.
RTS	Return to caller, bearing ASCII character code for depressed key.

Apple II System Data Block

The I/O vectors ROMTVT and ROMKEY should be initialized to point to APLTVT and APLKEY, respectively. This has been done in the Apple II system data block. You *must enter* the Apple II system data block into your system's memory if any of the software in this book is to run on your Apple II. See Appendices C15 and E14.

Appendix B4:
The Atari 800

Screen

The Atari 800 microcomputer has the most flexible — and, perhaps the most confusing — video-display hardware of any system discussed in this book. Unlike the other systems, almost any portion of the Atari computer's memory may be mapped to the screen. Furthermore, there are many different screen-display modes. When the Atari computer is powered-up, the screen is in text mode zero. That's comparable to the Apple II's low-resolution graphics and text display, which is comparable to the only video-display mode available on the Ohio Scientific or PET computers.

The Atari computer makes other screen modes available to the programmer, but the software in this book assumes a low-resolution text display, so you'd better leave your Atari in screen mode zero if you expect to see any of the displays driven by the software in this book. In other words, if you change the screen mode, the Visible Monitor may well become invisible.

I mentioned that the screen buffer may be almost anywhere in memory. If that's true (and it is), how can you determine the HOME address upon which all the displays in this book are based? It's easy. A pointer at $58,$59 (88,89 decimal) points to the lowest address in screen memory: the address we refer to as HOME. Before running any of the software in this book, you must set HOME properly for your system. Simply set HOME equal to the value of that pointer. HIPAGE, the value of the highest page in screen memory, is equal to (the high byte of HOME) plus three.

Once we've set HOME and HIPAGE properly, we're home free. The other screen parameters are fixed:

```
ROWINC   .BYTE 40
TVCOLS   .BYTE 39
TVROWS   .BYTE 23
SPACE    .BYTE $20
ARROW    .BYTE $7B
```

Note that the top of screen memory is always at the top of programmable memory, so if you add more programmable memory to your Atari 800, you'll move the screen memory up higher in the address space.

Proper Display of ASCII Characters

Like the PET, and to a lesser extent the APPLE II, the Atari screen requires that we perform a conversion before we can properly display an ASCII character on the screen. To determine the nature of this conversion, let us first look at the ATARI character set in Table B4.1.

Table B4.1: *The Atari character set ATASCI.*

	−0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−A	−B	−C	−D	−E	−F
0−	*space*	!	"	#	$	%	&	'	(	)	*	+	,	−	.	/
1−	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
2−	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
3−	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]		←
4−	*special graphics characters*															
5−	*special graphics characters*															
6−		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7−	p	q	r	s	t	u	v	w	x	y	z	*graphics*				

A quick examination shows that ASCII characters $20 thru $5F are ATASCI (Atari's character set) characters $00 thru $3F. Thus, if an ASCII character is in the range of $20 thru $5F, we can convert it to the appropriate ATASCI character simply by subtracting $20.

Further inspection reveals that ASCII characters $61 thru $7A correspond to ATASCI characters $61 through $7A. Thus, if an ASCII character is in the range of $61 thru $7A, it needs no conversion to ATASCI; it already *is* the corresponding ATASCI character.

Finally, if an ASCII character is not in the range $20 thru $5F or $61 thru $7A, it's not a printable character and has no agreed-upon graphic representation. For those cases we'll just leave them alone.

Figure B4.1 flow-charts this algorithm.

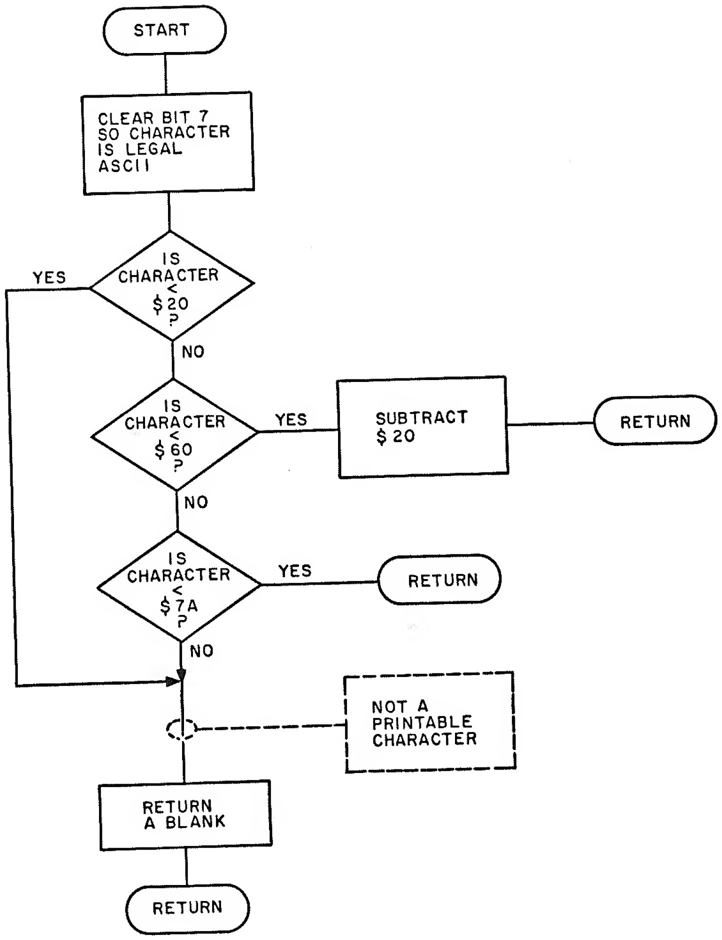


Figure B4.1: *Flowchart of routine to convert an ASCII character for display on Atari screen.*

Using the flowchart in figure B4.1 as a guide, we can write source code for FIXCHR, which takes an ASCII character as input and returns an Atari display code so that the character may be properly displayed on the video screen.

FIXCHR

```
FIXCHR      AND #$7F          Clear bit 7 so character is a legitimate
                              ASCII character.
            SEC               Prepare to compare.
            CMP #$20          Character less than $20?
```

```
              BCC BADCHR           If so, it's not a printable ASCII
                                   character, so return a blank.
              CMP #$60             Character less than $60?
              BCC SUB$20           If so, subtract $20 and return.
              CMP #$7B             Character less than $7B?
              BCC EXIT             If so, return with the character.
                                   If not less than $7B,
BADCHR        LDA BLANK            the character is not a printable ASCII
                                   character, so return a blank.
EXIT          RTS
SUB$20        SBC #$20             Subtract $20 and
              RTS                  return.
```

Keyboard Input

If no key has been pressed, then address $02FC (764 decimal) contains $FF. But whenever you depress a key on the Atari keyboard — even if a program is not scanning the keys — an electronic circuit will sense that a key has closed and will store the hardware code for that key in address $02FC. However, the code in $02FC will be a hardware code, not obviously related to ASCII or ATASCI.

Table B4.2: *Atari Hardware Key-Codes.*

Hex	Decimal	Key	Hex	Decimal	Key
$00	0	L	$20	32	,
1	1	J	1	33	SPACE
2	2	;	2	34	.
3	3		3	35	N
4	4		4	36	
5	5	K	5	37	M
6	6	+	6	38	/
7	7	*	7	39	ATARI
8	8	0	8	40	R
9	9		9	41	
A	10	P	A	42	E
B	11	U	B	43	Y
C	12	RETURN	C	44	TAB
D	13	I	D	45	T
E	14	−	E	46	W
F	15	=	F	47	Q

$10	16	V	$30	48	9
1	17		1	49	
2	18	C	2	50	Ø
3	19		3	51	7
4	20		4	52	BACK S
5	21	B	5	53	8
6	22	X	6	54	<
7	23	Z	7	55	>
8	24	4	8	56	F
9	25		9	57	H
A	26	3	A	58	D
B	27	6	B	59	
C	28	ESC	C	60	LOWR
D	29	5	D	61	G
E	30	2	E	62	S
F	31	1	F	63	A

The Hex and Decimal Columns give the low 6 bits of the hardware key-code stored in address $02FC (764 decimal) when the given keys are pressed. Either SHIFT key sets bit 6. CTRL key sets bit 7.

In order to convert that hardware code to ASCII, we need to understand its nature. The six low-order bits of the hardware key-code uniquely identify the key. (See Table B4.2.) Bits 6 and 7 identify its shift state. Bit 6 is set if the key is typewriter-shifted; bit 7 is set if the key is control-shifted. The key is typewriter-shifted if either SHIFT key is down; the CAPS/LOWR key has no effect on the typewriter-shift state as reflected in the hardware key-code. The keyboard is control-shifted if the CTRL key is down.

If you don't care about the keyboard's shift state, but merely want to determine which physical key has been pressed, then you can clear the two high-order bits in the hardware key-code and you'll be left with a number from 0 to 63 decimal (00 to $3F) uniquely identifying the key most recently depressed. If you care about the keyboard's typewriter-shift state but are indifferent to its control-shift state, then you can clear bit 7 in the hardware key-code and you'll be left with a number from 0 to 127 decimal (00 to $7F), which means the keyboard can generate twice as many characters as it has physical keys. To enable control-shifting, simply preserve the hardware key-code, and you double once again the number of characters that the keyboard (and hence the user) may generate.

Since the simple text editor presented in Chapter 11 assigns certain functions to control-shifted keys, and since you never know when you might need some additional character codes from your keyboard, Appendix C16 presents a key-handling subroutine for the Atari. This subroutine is capable of generating different characters in each of the four different shift-states (unshifted, typewriter-shifted, control-shifted, typewriter- and control-shifted).

It's a simple matter to use the eight-bit hardware keycode as an index into a keyboard definition table. For any given hardware key-code, we may assign any character we like. The keyboard definition table presented in Appendix C16 assigns standard ASCII characters to all letter, number, and punctuation keys, in both the unshifted and typewriter-shifted states. Other keys are assigned values consistent with their expected use by the software in this book (eg: Control-P generates a $10, thus making it a PRINT key in the eyes of the simple text editor). All keys and shift states that have no special meaning to this software have been assigned character codes of zero; feel free to change these character codes to any values you desire.

Assuming that we have in memory a keyboard definition table called ATRKYS, we can get an ASCII character from the Atari keyboard with the following subroutine, ATRKEY:

```
ATRKEY   LDA $02FC        Has a key been depressed?
         CMP #$FF         $FF means no key.
         BEQ ATRKEY       If not, look again. A key has gone down
                          and the accumulator holds its hardware
                          key-code.
         TAY              Prepare to use that code as an index.
         LDA ATRKYS,Y     Look up character for that key and shift
                          state.
         RTS              Return with ASCII character
                          corresponding to that key and shift
                          state.
```

Print a Character to the Screen

The Atari 400 and 800 computers each provide a powerful I/O (input/output) routine which allows the programmer to get characters from virtually any source, and to send characters to virtually any device — the screen, the printer, the cassette recorder, and the disk. But, as in the case of Atari's varied screen modes, power breeds complexity. I have found it easier to substitute my own simple routine to print a character on the TV screen, bypassing the Atari I/O routines entirely.

Incidentally, this routine will work with any 6502-based computer that has a low-resolution memory-mapped display. If you need a simple TVT simulator for your home-brew 6502-based system with a video display, TVTSIM might meet your needs. In any event, it prints characters to the screen, and avoids the necessity of plumbing the depths of the many modes and data structures associated with Atari's central I/O routine.

With your system data block initialized as shown in Appendices C16 and E15 (which includes the TVT simulator as the subroutine to print characters to the screen), you are almost ready to run the software in this book on your own system.

Setting the Top Of Memory

Address $2E6 (742 decimal) holds the number of pages of RAM available to the BASIC interpreter. Store a $0D (13 decimal) in that location and BASIC will use memory up to $0DFF, but will not use $0E00 and up.

NOTE: On the Atari, the software in this book uses memory from $0E80 to $1FFF, which is the address space required by the ATARI DOS (Disk Operating System) and the ATARI RS-232 serial interface, so you may *not* use DOS or RS-232 if you expect to use the software in this book. However, there should be no conflict between software in this book and the cassette-based Atari 800.

Thus, we may set the top of memory with the following BASIC command:

```
POKE 742,13
```

When you have used the OBJECT CODE LOADER to READ and POKE object code from all the appropriate E appendices into your Atari computer, run the following BASIC program. It will initialize screen parameters and the top of memory, and then pass control to the Visible Monitor.

```
100 REM                 Visible Monitor Start-Up Program for the Atari.
110 REM
120 REM                 First, set the screen parameters.
130 REM
140 REM                 A pointer at 88,89 points to lowest screen address.
150 LO=PEEK(88):        REM Set LO to the low byte of HOME.
160 HI=PEEK(89):        REM Set HI to the high byte of HOME.
165 IF HI < 32 THEN PRINT "ON AN 8 K ATARI YOU MAY NOT USE EDITOR
    OR DISASSEMBLER"
170 POKE 4096,LO:       REM Set Low byte of HOME.
180 POKE 4097, HI:      REM Set High byte of HOME.
190 POKE 4101,HI+3:     REM Set HIPAGE = Highest page in screen memory.
200 REM
210 REM                 Now set the top of memory available to BASIC.
220 POKE 742,13:        Tell BASIC to use only memory up to $0DFF.
230 REM
240 REM                 Now call the Visible Monitor.
250 X=USR(4615):        REM Call the Visible Monitor as a subroutine.
260 END
```

Appendix C1:

Screen Utilities

```
              ;     APPENDIX C1: ASSEMBLER LISTING OF
              ;                  SCREEN UTILITIES
              ;
              ;
              ;
              ;       SEE CHAPTER 5 OF BEYOND GAMES: SYSTEMS
              ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
              ;
              ;
              ;                      BY KEN SKIER
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ; ********************************************
              ;
              ;          ZERO PAGE BYTES
              ;
              ; ******************************************
              ;
              ;
              ;
              ;
              ;
0000=               TV.PTR=0       THIS POINTER HOLDS THE
              ;                    ADDRESS OF THE CURRENT
              ;                    SCREEN LOCATION.
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ; ********************************************
              ;
              ;          SCREEN PARAMETERS
              ;
              ; ********************************************
              ;
              ;
              ;
1000=               PARAMS=$1000   THE FOLLOWING ADDRESSES
              ;                    MUST BE INITIALIZED TO HOLD
              ;                    DATA DESCRIBING THE SCREEN
              ;                    ON YOUR SYSTEM.
              ;
              ;
              ;
              ;
1000=               HOME=PARAMS    HOME IS A POINTER TO CHARACTER
```

```
                  ;                     POSITION IN UPPER LEFT CORNER.
                  ;
     1002=              ROWINC=PARAMS+2
                  ;                     ROWINC IS A BYTE GIVING
                  ;                     ADDRESS DIFFERENCE FROM ONE
                  ;                     ROW TO THE NEXT.
                  ;
     1003=              TVCOLS=PARAMS+3
                  ;                     TVCOLS IS A BYTE GIVING
                  ;                     NUMBER OF COLUMNS ON SCREEN.
                  ;                     (COUNTING FROM ZERO.)
                  ;
     1004=              TVROWS=PARAMS+4
                  ;                     TVROWS IS A BYTE GIVING
                  ;                     NUMBER OF ROWS ON SCREEN,
                  ;                     (COUNTING FROM ZERO.)
                  ;
     1005=              HIPAGE=PARAMS+5
                  ;                     HIPAGE IS THE HIGH BYTE OF
                  ;                     THE HIGHEST ADDRESS ON SCREEN.
                  ;
                  ;
     1006=              BLANK=PARAMS+6  YOUR SYSTEM'S CHARACTER
                  ;                     CODE FOR A BLANK.
                  ;
     1007=              ARROW=PARAMS+7  YOUR SYSTEM'S CHARACTER
                  ;                     FOR AN UP-ARROW.
                  ;
     1011=              FIXCHR=PARAMS+$11
                  ;                     FIXCHR IS A SUBROUTINE THAT
                  ;                     RETURNS YOUR SYSTEM'S
                  ;                     DISPLAY CODE FOR ASCII.
                  ;                     CODE.
                  ;
                  ;
                  ;
                  ;
                  ;
     1100               *=$1100
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ; *********************************************
                  ;
                  ;          CLEAR SCREEN
                  ;
                  ; *********************************************
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
```

```
1170                ;       CLEAR SCREEN, PRESERVING THE ZERO PAGE.
1180                ;
1190                ;
1200                ;
1210                ;
1220 1100 20C411 CLR.TV JSR TVPUSH     SAVE ZERO PAGE BYTES THAT
1230                ;                  WILL BE CHANGED.
1240 1103 202B11        JSR TVHOME     SET SCREEN LOCATION TO UPPER
1250                ;                  LEFT CORNER OF THE SCREEN.
1260 1106 AE0310        LDX TVCOLS     LOAD X,Y REGISTERS WITH
1270 1109 AC0410        LDY TVROWS     X,Y DIMENSIONS OF SCREEN.
1280 110C 201311        JSR CLR.XY     CLEAR X COLUMNS, Y ROWS
1290                ;                  FROM CURRENT SCREEN LOCATION.
1300 110F 20D311        JSR TV.POP     RESTORE ZERO PAGE BYTES THAT
1310                ;                  WERE CHANGED.
1320 1112 60            RTS            RETURN TO CALLER, WITH ZERO
1330                ;                  PAGE PRESERVED.
1340                ;
1350                ;
1360                ;
1370                ;
1380                ;
1390                ;
1400                ;
1410                ;
1420                ;
1430                ;
1440                ;
1450                ; ******************************************
1460                ;
1470                ;       CLEAR PORTION OF SCREEN
1480                ;
1490                ; ******************************************
1500                ;
1510                ;
1520                ;
1530                ;
1540                ;                  CLEAR X COLUMNS, Y ROWS
1550                ;                  FROM CURRENT SCREEN LOCATION.
1560                ;                  MOVES TV.PTR DOWN BY Y ROWS.
1570                ;
1580                ;
1590                ;
1600 1113 8E2A11 CLR.XY STX COLS       SET THE NUMBER OF COLUMNS
1610                ;                  TO BE CLEARED.
1620 1116 98            TYA
1630 1117 AA            TAX            NOW X HOLDS NUMBER OF ROWS
1640                ;                  TO BE CLEARED.
1650                ;
1660 1118 AD0610 CLRROW LDA BLANK      WE'LL CLEAR THEM BY
1670                ;                  WRITING BLANKS TO THE
1680                ;                  SCREEN.
1690 111B AC2A11        LDY COLS       LOAD Y WITH NUMBER OF
1700                ;                  COLUMNS TO BE CLEARED.
1710 111E 9100   CLRPOS STA (TV.PTR),Y CLEAR A POSITION BY
1720                ;                  WRITING A BLANK INTO IT.
1730                ;
1740 1120 88            DEY            ADJUST INDEX FOR NEXT
```

```
             ;                    POSITION ON THE ROW.
             ;
1121 10FB          BPL CLRPOS     IF NOT DONE WITH ROW,
             ;                    CLEAR NEXT POSITION...
             ;
1123 207611        JSR TVDOWN     IF DONE WITH ROW, MOVE
             ;                    CURRENT SCREEN LOCATION
             ;                    DOWN BY ONE ROW.
             ;
1126 CA            DEX            DONE LAST ROW YET?
1127 10EF          BPL CLRROW     IF NOT, CLEAR NEXT ROW...
1129 60            RTS            IF SO, RETURN TO CALLER.
             ;
112A 00     COLS   .BYTE 0        DATA CELL: HOLDS NUMBER OF
             ;                    COLUMNS TO BE CLEARED.
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;        TVHOME
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
112B A200   TVHOME LDX #0         SET TV.PTR TO UPPER LEFT
112D A000          LDY #0         CORNER OF SCREEN, BY
             ;                    ZEROING X AND Y AND THEN
112F 18            CLC            GOING TO X,Y COORDINATES:
1130 900A          BCC TVTOXY
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;        CENTER
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;                    SET TV.PTR TO SCREEN'S
             ;                    CENTER:
             ;
             ;
             ;
```

```
2330                ;
2340 1132 AD0410 CENTER LDA TVROWS     LOAD A WITH TOTAL ROWS.
2350 1135 4A            LSR A          DIVIDE IT BY TWO.
2360 1136 A8            TAY            Y NOW HOLDS THE NUMBER OF
2370                ;                  THE SCREEN'S CENTRAL ROW.
2380                ;
2390 1137 AD0310        LDA TVCOLS     LOAD A WITH TOTAL COLUMNS.
2400 113A 4A            LSR A          DIVIDE IT BY TWO.
2410 113B AA            TAX            X NOW HOLDS THE NUMBER OF
2420                ;                  THE SCREEN'S CENTRAL COLUMN.
2430                ;
2440                ;
2450                ;                  X AND Y REGISTERS NOW HOLD
2460                ;                  X,Y COORDINATES OF CENTER
2470                ;                  OF SCREEN.
2480                ;
2490                ;                  SO NOW LET'S SET THE SCREEN
2500                ;                  LOCATION TO THOSE X,Y
2510                ;                  COORDINATES:
2520                ;
2530                ;
2540                ;
2550                ;
2560                ;
2570                ;
2580                ;
2590                ;
2600                ;
2610                ; *********************************************
2620                ;
2630                ;         TVTOXY
2640                ;
2650                ; *********************************************
2660                ;
2670                ;
2680                ;
2690                ;
2700                ;
2710 113C 38     TVTOXY SEC            SET CURRENT SCREEN LOCATION
2720                ;                  TO COORDINATES GIVEN BY
2730                ;                  THE X AND Y REGISTERS.
2740                ;
2750 113D EC0310        CPX TVCOLS     IS X OUT OF RANGE?
2760 1140 9003          BCC X.OK       IF NOT, LEAVE IT ALONE.
2770                ;                  IF X IS OUT OF RANGE, GIVE
2780 1142 AE0310        LDX TVCOLS     IT ITS HIGHEST LEGAL VALUE.
2790                ;                  NOW X IS LEGAL.
2800                ;
2810 1145 38     X.OK   SEC            IS Y OUT OF RANGE?
2820 1146 CC0410        CPY TVROWS
2830 1149 9003          BCC Y.OK       IF NOT, LEAVE IT ALONE.
2840                ;
2850                ;                  IF Y IS OUT OF RANGE, GIVE
2860 114B AC0410        LDY TVROWS     Y ITS HIGHEST LEGAL VALUE.
2870                ;                  NOW Y IS LEGAL.
2880                ;
2890                ;
2900 114E AD0010 Y.OK   LDA HOME       SET TV.PTR = LOWEST SCREEN
```

```
1151 8500            STA TV.PTR     ADDRESS.
1153 AD0110          LDA HOME+1
1156 8501            STA TV.PTR+1
                ;
1158 08              PHP            SAVE CALLER'S DECIMAL FLAG.
1159 D8              CLD            CLEAR DECIMAL FOR BINARY
                ;                   ADDITION.
                ;
115A 8A              TXA            ADD X TO TV.PTR
115B 18              CLC
115C 6500            ADC TV.PTR
115E 9003            BCC COLSET
1160 E601            INC TV.PTR+1
1162 18              CLC
                ;
                ;
1163 C000    COLSET  CPY #0         ADD Y*ROWINC TO TV.PTR:
1165 F00B            BEQ TV.SET
1167 18      ADDROW  CLC
1168 6D0210          ADC ROWINC
116B 9002            BCC *+4
116D E601            INC TV.PTR+1
116F 88              DEY
1170 D0F5            BNE ADDROW
                ;
                ;
1172 8500    TV.SET  STA TV.PTR
1174 28              PLP            RESTORE CALLER'S DECIMAL FLAG
1175 60              RTS            RETURN TO CALLER
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ; ********************************************
                ;
                ;           TVDOWN, TVSKIP, and TVPLUS
                ;
                ; ********************************************
                ;
                ;
                ;
                ;
                ;
1176 AD0210  TVDOWN  LDA ROWINC     MOVE TV.PTR DOWN BY ONE ROW.
1179 18              CLC
117A 9005            BCC TVPLUS
                ;
117C 209B11  VUCHAR  JSR TV.PUT     PUT CHARACTER ON SCREEN
                ;                   AND THEN
                ;
117F A901    TVSKIP  LDA #1         SKIP ONE SCREEN LOCATION
                ;                   BY INCREMENTING TV.PTR
```

```
3490                 ;
3500                 ;
3510 1181 08     TVPLUS PHP             TVPLUS ADDS ACCUMULATOR
3520 1182 D8            CLD             TO TV.PTR, KEEPING TV.PTR
3530 1183 18            CLC             WITHIN SCREEN MEMORY.
3540 1184 6500          ADC TV.PTR
3550 1185 9002          BCC *+4
3560 1188 E601          INC TV.PTR+1
3570 118A 8500          STA TV.PTR
3580 118C 38            SEC             IS CURRENT SCREEN LOCATION
3590 118D AD0510        LDA HIPAGE      OUTSIDE OF SCREEN MEMORY?
3600 1190 C501          CMP TV.PTR+1
3610 1192 B005          BCS TV.OK
3620                 ;
3630 1194 AD0110        LDA HOME+1      IF SO, WRAP AROUND FROM
3640 1197 8501          STA TV.PTR+1    BOTTOM TO TOP OF SCREEN.
3650                 ;
3660 1199 28     TV.OK  PLP             RESTORE ORIGINAL DECIMAL
3670 119A 60            RTS             FLAG AND RETURN TO CALLER.
3680                 ;
3690                 ;
3700                 ;
3710                 ;
3720                 ;
3730                 ;
3740                 ;
3750                 ;
3760                 ;
3770                 ;
3780                 ; *********************************************
3790                 ;
3800                 ;         TV.PUT
3810                 ;
3820                 ; *********************************************
3830                 ;
3840                 ;
3850                 ;
3860                 ;
3870                 ;
3880                 ;
3890 119B 201110 TV.PUT JSR FIXCHR      CONVERT ASCII CHARACTER
3900                 ;                  TO YOUR SYSTEM'S DISPLAY
3910                 ;                  CODE.
3920                 ;
3930 119E A000          LDY #0          PUT CHARACTER AT CURRENT
3940 11A0 9100          STA (TV.PTR),Y  SCREEN LOCATION.
3950 11A2 60            RTS             THEN RETURN.
3960                 ;
3970                 ;
3980                 ;
3990                 ;
4000                 ;
4010                 ;
4020                 ;
4030                 ;
4040                 ;
4050                 ; *********************************************
4060                 ;
```

```
4070                ;          DISPLAY A BYTE IN HEX FORMAT
4080                ;
4090                ; *********************************************
4100                ;
4110                ;
4120                ;
4130                ;
4140                ;
4150 11A3 48       VUBYTE PHA             SAVE BYTE TO BE DISPLAYED.
4160 11A4 4A              LSR A           MOVE 4 MOST SIGNIFICANT
4170 11A5 4A              LSR A           BITS INTO POSITIONS
4180 11A6 4A              LSR A           FORMERLY OCCUPIED BY 4
4190 11A7 4A              LSR A           LEAST SIGNIFICANT BITS.
4200                ;
4210 11A8 20B611          JSR ASCII       DETERMINE ASCII CHAR FOR
4220                ;                     HEX DIGIT IN A'S 4 LSB.
4230                ;
4240 11AB 207C11          JSR VUCHAR      DISPLAY THAT ASCII CHAR ON
4250                ;                     SCREN AND ADVANCE TO NEXT
4260                ;                     SCREEN LOCATION.
4270                ;
4280 11AE 68              PLA             RESTORE ORIGINAL BYTE TO A.
4290 11AF 20B611          JSR ASCII       DETERMINE ASCII CHAR FOR
4300                ;                     A'S 4 LSB.
4310                ;
4320 11B2 207C11          JSR VUCHAR      STORE THIS ASCII CHAR JUST
4330                ;                     TO THE RIGHT OF THE OTHER
4340                ;                     ASCII CHAR, AND ADVANCE TO
4350                ;                     NEXT SCREEN POSITION.
4360                ;
4370                ;
4380 11B5 60              RTS             RETURN TO CALLER.
4390                ;
4400                ;
4410                ;
4420                ;
4430                ;
4440                ;
4450                ;
4460                ;
4470                ;
4480                ;
4490                ; *********************************************
4500                ;
4510                ;          HEX-TO-ASCII
4520                ;
4530                ; *********************************************
4540                ;
4550                ;
4560                ;
4570                ;
4580                ;
4590 11B6 08       ASCII  PHP             THIS ROUTINE RETURNS ASCII
4600 11B7 D8              CLD             FOR 4 LSB IN ACCUMULATOR.
4610 11B8 290F            AND #$0F        CLEAR HIGH 4 BITS IN A.
4620 11BA C90A            CMP #$0A        IS ACCUMULATOR GREATER
4630                ;                     THAN 9?
4640 11BC 3002            BMI DECIML      IF NOT, IT MUST BE 0-9.
```

```
                ;
11BE 6906               ADC #6          IF SO, IT MUST BE A-F.
                ;                       ADD 36 HEX TO CONVERT IT.
                ;                       TO CORRESPONDING ASCII CHAR.
11C0 6930       DECIML  ADC #$30        IF A IS 0-9, ADD 30 HEX
                ;                       TO CONVERT IT TO
                ;                       CORRESPONDING ASCII CHAR.
                ;
11C2 28                 PLP             RESTORE ORIGINAL DECIMAL
                ;                       FLAG, AND
11C3 60                 RTS             RETURN TO CALLER
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ; ********************************************
                ;
                ;          TVPUSH
                ;
                ; ********************************************
                ;
                ;
                ;                       SAVE CURRENT SCREEN LOCATION
                ;                       ON STACK, FOR CALLER.
                ;
                ;
                ;
                ;
                ;
                ;
11C4 68         TVPUSH  PLA             PULL RETURN ADDRESS FROM
11C5 AA                 TAX             STACK AND SAVE IT IN X AND
11C6 68                 PLA             Y REGISTERS.
11C7 A8                 TAY
                ;
                ;
11C8 A501               LDA TV.PTR+1    GET TV.PTR AND
11CA 48                 PHA
11CB A500               LDA TV.PTR      PUSH IT ONTO THE STACK.
11CD 48                 PHA
                ;
                ;
11CE 98                 TYA             PLACE RETURN ADDRESS
11CF 48                 PHA
11D0 8A                 TXA             BACK ON STACK.
11D1 48                 PHA
                ;
                ;
11D2 60                 RTS             THEN RETURN TO CALLER.
```

```
             ;                    CALLER WILL FIND TV.PTR ON
             ;                    STACK, LOW BYTE ON TOP.
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;      TV.POP
             ;
             ; ********************************************
             ;
             ;
             ;
             ;                    RESTORE SCREEN LOCATION
             ;                    PREVIOUSLY SAVED ON STACK.
             ;
             ;
             ;
11D3 68     TV.POP PLA            PULL RETURN ADDRESS FROM
11D4 AA            TAX            STACK, SAVING IT IN X...
11D5 68            PLA
11D6 A8            TAY            ...AND IN Y
             ;
             ;
11D7 68            PLA            RESTORE...
11D8 8500          STA TV.PTR     ...TV.PTR
11DA 68            PLA               ...FROM
11DB 8501          STA TV.PTR+1         ...STACK.
             ;
             ;
11DD 98            TYA            PLACE RETURN ADDRESS
11DE 48            PHA            BACK ...
11DF 8A            TXA
11E0 48            PHA            ...ON STACK.
             ;
             ;
11E1 60            RTS            RETURN TO CALLER.
```

Appendix C2:

Visible Monitor (Top Level and Display Subroutines)

```
          ;     APPENDIX C2: ASSEMBLER LISTING OF
          ;                 THE VISIBLE MONITOR
          ;
          ;          TOP LEVEL AND DISPLAY SUBROUTINES
          ;
          ;
          ;
          ;
          ;
          ;      SEE CHAPTER 6 OF BEYOND GAMES: SYSTEMS
          ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
          ;
          ;                      BY KEN SKIER
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ; ********************************************
          ;
          ;          EQUATES
          ;
          ; ******************************************
          ;
          ;
          ;
          ;
0000=           TV.PTR = 0
          ;
0002=           GETPTR = 2
          ;
          ;
1000=           PARAMS = $1000 ADDRESS OF SYSTEM DATA
          ;                    BLOCK.
          ;
          ;
1007=           ARROW = PARAMS+7
          ;                    THIS DATA BYTE HOLDS YOUR
          ;                    SYSTEM'S CHARACTER CODE
          ;                    FOR AN UP-ARROW.
          ;
1008=           ROMKEY = PARAMS+8
          ;                    ROMKEY IS A POINTER TO
          ;                    YOUR SYSTEM'S SUBROUTINE
          ;                    TO GET AN ASCII CHARACTER
          ;                    FROM THE KEYBOARD.
          ;
0020=           SPACE = $20
```

```
               ;
007F=                 RUBOUT = $7F
               ;
000D=                 CR = $0D       ASCII FOR CARRIAGE RETURN.
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ; ***********************************************
               ;
               ;          REQUIRED SUBROUTINES
               ;
               ; ***********************************************
               ;
               ;
               ;
1100=                 TVSUBS = $1100
1100=                 CLR.TV = TVSUBS
1113=                 CLR.XY = TVSUBS+$13
112B=                 TVHOME = TVSUBS+$2B
113C=                 TVTOXY = TVSUBS+$3C
1176=                 TVDOWN = TVSUBS+$76
117C=                 VUCHAR = TVSUBS+$7C
117F=                 TVSKIP = TVSUBS+$7F
1181=                 TVPLUS = TVSUBS+$81
11A3=                 VUBYTE = TVSUBS+$A3
11B6=                 ASCII  = TVSUBS+$B6
11C4=                 TVPUSH = TVSUBS+$C4
11D3=                 TV.POP = TVSUBS+$D3
               ;
               ;
               ;
1200                  * = $1200
               ;
               ;
               ;
12E3=                 UPDATE = *+$E3
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
```

```
                ; *********************************************
                ;
                ;          USER-MODIFIABLE DATA
                ;
                ; *********************************************
                ;
                ;
                ;
                ;
                ;
1200 00        FIELD  .BYTE 0          NUMBER OF CURRENT FIELD.
                ;                      (MUST BE 0-6.)
                ;
1201 00        REG.A  .BYTE 0          IMAGE OF ACCUMULATOR.
                ;
1202 00        REG.X  .BYTE 0          IMAGE OF X-REGISTER.
                ;
1203 00        REG.Y  .BYTE 0          IMAGE OF Y-REGISTER.
                ;
1204 00        REG.P  .BYTE 0          IMAGE OF PROCESSOR STATUS
                ;                      REGISTER.
                ;
1201=                 REGS = REG.A
                ;
1205 0000      SELECT .WORD 0          POINTER TO CURRENTLY-
                ;                      SELECTED ADDRESS.
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ; *********************************************
                ;
                ;          THE VISIBLE MONITOR
                ;
                ; *********************************************
                ;
                ;
                ;
                ;
1207 08        VISMON PHP              SAVE CALLER'S STATUS FLAGS.
1208 D8               CLD              CLEAR DECIMAL MODE, SINCE
                ;                      ARITHMETIC OPERATIONS IN THIS
                ;                      BOOK ARE ALWAYS BINARY.
                ;
1209 201212           JSR DSPLAY       PUT MONITOR DISPLAY ON
                ;                      SCREEN.
                ;
120C 20E312           JSR UPDATE       GET USER REQUEST AND
                ;                      HANDLE IT.
120F 18               CLC
1210 90F6             BCC VISMON+1     LOOP BACK TO DISPLAY...
                ;
                ;
                ;
```

```
            ;
            ;
            ;
            ;
            ;
            ;
            ; *********************************************
            ;
            ;         MONITOR-DISPLAY
            ;
            ; *********************************************
            ;
            ;
            ;
            ;
            ;
1212 20C411 DSPLAY JSR TVPUSH     SAVE ZERO PAGE BYTES THAT
            ;                     WILL BE MODIFIED.
            ;
1215 202512        JSR CLRMON     CLEAR A PORTION OF SCREEN.
1218 203412        JSR LINE.1     DISPLAY LABEL LINE.
121B 205C12        JSR LINE.2     DISPLAY DATA LINE.
121E 20AF12        JSR LINE.3     DISPLAY ARROW LINE.
            ;
1221 20D311        JSR TV.POP     RESTORE ZERO PAGE BYTES
            ;                     THAT WERE SAVED ABOVE.
            ;
1224 60            RTS            RETURN TO CALLER.
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ; *********************************************
            ;
            ;         CLEAR PORTION OF SCREEN
            ;
            ; *********************************************
            ;
            ;
            ;
            ;
            ;
1225 A202   CLRMON LDX #2         SET TV.PTR TO COLUMN 2,
1227 A002          LDY #2         ROW 2.
1229 203C11        JSR TVTOXY
            ;
122C A219          LDX #25        LOAD X WITH NUMBER OF
            ;                     COLUMNS (25) TO BE CLEARED.
            ;
122E A003          LDY #3         LOAD Y WITH NUMBER OF
            ;                     ROWS (3) TO BE CLEARED.
            ;
```

```
2330 1230 201311        JSR CLR.XY     CLEAR X COLUMNS, Y ROWS.
2340                 ;
2350 1233 60            RTS            RETURN TO CALLER.
2360                 ;
2370                 ;
2380                 ;
2390                 ;
2400                 ;
2410                 ;
2420                 ;
2430                 ;
2440                 ;
2450                 ;
2460                 ; ********************************************
2470                 ;
2480                 ;        DISPLAY LABEL LINE
2490                 ;
2500                 ; ********************************************
2510                 ;
2520                 ;
2530                 ;
2540                 ;
2550                 ;
2560 1234 A20D   LINE.1 LDX #13        X-COORDINATE OF LABEL "A".
2570 1236 A002          LDY #2         Y-COORDINATE OF LABEL "A".
2580 1238 203C11        JSR TVTOXY     SET TV.PTR TO POINT TO
2590                 ;                 SCREEN LOCATION OF LABEL "A
2600                 ;
2610 123B A000          LDY #0         PUT LABELS ON SCREEN:
2620 123D 8C5112        STY LBLCOL     INITIALIZE LABEL COLUMN
2630                 ;                 COUNTER.
2640                 ;
2650 1240 B95212 LBLOOP LDA LABELS,Y   GET A CHARACTER AND
2660 1243 207C11        JSR VUCHAR     PUT IT ON THE SCREEN.
2670 1246 EE5112        INC LBLCOL     PREPARE FOR NEXT CHARACTER.
2680 1249 AC5112        LDY LBLCOL     DONE LAST CHARACTER?
2690 124C C00A          CPY #10
2700 124E D0F0          BNE LBLOOP     IF NOT, DO NEXT CHARACTER.
2710                 ;
2720 1250 60            RTS            RETURN TO CALLER.
2730 1251 00     LBLCOL .BYTE 0        DATA CELL: HOLDS COLUMN
2740                 ;                 OF CHARACTER TO BE COPIED.
2750                 ;
2760                 ;
2770                 ;
2780                 ;
2790 1252 41     LABELS .BYTE 'A  X  Y  P'
2790 1253 20
2790 1254 20
2790 1255 58
2790 1256 20
2790 1257 20
2790 1258 59
2790 1259 20
2790 125A 20
2790 125B 50
2800                 ;
2810                 ;
```

```
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ; ********************************************
                ;
                ;          DISPLAY DATA LINE
                ;
                ; ********************************************
                ;
                ;
                ;
                ;
                ;
125C A202      LINE.2 LDX #2          LOAD X WITH STARTING
                ;                     COLUMN OF DATA LINE.
                ;
125E A003             LDY #3          LOAD Y WITH ROW NUMBER
                ;                     OF DATA LINE.
                ;
1260 203C11           JSR TVTOXY      SET TV.PTR TO POINT TO
                ;                     THE START OF THE DATA LINE.
                ;
1263 AD0612           LDA SELECT+1    DISPLAY HIGH BYTE OF
1266 20A311           JSR VUBYTE      CURRENTLY-SELECTED ADDRESS.
1269 AD0512           LDA SELECT      DISPLAY LOW BYTE OF
126C 20A311           JSR VUBYTE      CURRENTLY-SELECTED ADDRESS.
                ;
126F 207F11           JSR TVSKIP      SKIP ONE SPACE AFTER
                ;                     ADDRESS FIELD.
                ;
1272 209412           JSR GET.SL      GET CURRENTLY-SELECTED
                ;                     BYTE.
                ;
1275 48               PHA             SAVE IT.
                ;
1276 20A311           JSR VUBYTE      DISPLAY IT, IN HEX FORMAT,
                ;                     IN FIELD 1.
                ;
1279 207F11           JSR TVSKIP      SKIP ONE SPACE AFTER FIELD
                ;                     1.
                ;
127C 68               PLA             RESTORE CURRENTLY-SELECTED
                ;                     BYTE TO ACCUMULATOR.
                ;
127D 207C11           JSR VUCHAR      DISPLAY IT IN CHARACTER
                ;                     FORMAT, IN FIELD 2.
                ;
1280 207F11           JSR TVSKIP      SKIP ONE SPACE AFTER FIELD 2.
                ;
                ;
                ;                     DISPLAY 6502 REGISTER
                ;                     IMAGES IN FIELDS 3-6:
                ;
```

```
3400 1283 A200          LDX #0         START WITH ACCUMULATOR
3410                 ;                 IMAGE.
3420 1285 BD0112 VUREGS LDA REGS,X     LOOK UP THE REGISTER IMAGE.
3430 1288 20A311        JSR VUBYTE     DISPLAY IT IN HEX FORMAT.
3440 128B 207F11        JSR TVSKIP     SKIP ONE SPACE AFTER HEX
3450                 ;                 FIELD.
3460                 ;
3470 128E E8            INX            GET READY FOR NEXT REGISTER...
3480 128F E004          CPX #4         DONE FOUR REGISTERS YET?
3490 1291 D0F2          BNE VUREGS     IF NOT, DO NEXT ONE...
3500                 ;
3510 1293 60            RTS            IF ALL REGISTERS DISPLAYED,
3520                 ;                 RETURN.
3530                 ;
3540                 ;
3550                 ;
3560                 ;
3570                 ;
3580                 ;
3590                 ;
3600                 ;
3610                 ;
3620                 ;
3630                 ;
3640                 ; ********************************************
3650                 ;
3660                 ;          GET SELECTED BYTE
3670                 ;
3680                 ; ********************************************
3690                 ;
3700                 ;
3710                 ;
3720                 ;
3730                 ;
3740                 ;
3750 1294 A502   GET.SL LDA GETPTR     GET BYTE POINTED TO BY
3760 1296 48            PHA            THE SELECT POINTER
3770 1297 A603          LDX GETPTR+1   (PRESERVING THE ZERO PAGE).
3780                 ;
3790 1299 AD0512        LDA SELECT
3800 129C 8502          STA GETPTR
3810 129E AD0612        LDA SELECT+1
3820 12A1 8503          STA GETPTR+1
3830                 ;
3840 12A3 A000          LDY #0
3850 12A5 B102          LDA (GETPTR),Y
3860 12A7 A8            TAY
3870 12A8 68            PLA
3880 12A9 8502          STA GETPTR
3890 12AB 8603          STX GETPTR+1
3900 12AD 98            TYA
3910 12AE 60            RTS            RETURN TO CALLER.
3920                 ;
3930                 ;
3940                 ;
3950                 ;
3960                 ;
3970                 ;
```

```
                   ;
                   ;
                   ;
                   ;
                   ; ********************************************
                   ;
                   ;          DISPLAY ARROW LINE
                   ;
                   ; ********************************************
                   ;
                   ;
                   ;
                   ;
                   ;
12AF A202   LINE.3 LDX #2          LOAD X WITH STARTING COLUMN.
12B1 A004          LDY #4          LOAD Y WITH ROW NUMBER.
12B3 203C11        JSR TVTOXY      SET TV.PTR TO BEGINNING
                   ;               OF ARROW LINE.
                   ;
12B6 AC0012        LDY FIELD       LOOK UP CURRENT FIELD.
12B9 38            SEC
12BA C007          CPY #7
12BC 9005          BCC FLD.OK
12BE A000          LDY #0
12C0 8C0012        STY FIELD
12C3 B9CD12 FLD.OK LDA FIELDS,Y    LOOK UP COLUMN NUMBER FOR
                   ;               CURRENT FIELD.
                   ;
12C6 A8            TAY             USE THAT COLUMN NUMBER AS
                   ;               AN INDEX INTO THE ROW.
                   ;
12C7 AD0710        LDA ARROW       PLACE AN UP-ARROW IN
12CA 9100          STA (TV.PTR),Y COLUMN OF THE ARROW LINE.
12CC 60            RTS             RETURN TO CALLER.
                   ;
                   ;
12CD 03     FIELDS .BYTE 3,6,8     THIS DATA AREA SHOWS WHICH
12CE 06
12CF 08
12D0 0B            .BYTE $0B,$0E   COLUMN SHOULD GET AN UP-
12D1 0E
12D2 11            .BYTE $11,$14   ARROW TO INDICATE ANY ONE
12D3 14
                   ;               OF FIELDS 0-6.  CHANGING
                   ;               ONE OF THESE VALUES WILL
                   ;               CAUSE THE UP-ARROW TO APPEAR
                   ;               IN A DIFFERENT COLUMN WHEN
                   ;               INDICATING A GIVEN FIELD.
                   ;
                   ;
```

Appendix C3:

Visible Monitor (Update Subroutine)

```
                ;     APPENDIX C3: ASSEMBLER LISTING OF
                ;                  THE VISIBLE MONITOR
                ;
                ;
                ;                   UPDATE SUBROUTINE
                ;
                ;
                ;
                ;     SEE CHAPTER 6 OF BEYOND GAMES: SYSTEMS
                ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
                ;
                ;                      BY KEN SKIER
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ; ********************************************
                ;
                ;          EQUATES
                ;
                ; ******************************************
                ;
                ;
                ;
                ;
                ;
                ;
                ;
0000=                 TV.PTP = 0
                ;
0002=                 GETPTR = 2
                ;
                ;
1000=                 PARAMS = $1000 ADDRESS OF SYSTEM DATA
                ;                     BLOCK.
                ;
                ;
1007=                 ARROW = PARAMS+7
                ;                     THIS DATA BYTE HOLDS YOUR
                ;                     SYSTEM'S CHARACTER CODE
                ;                     FOR AN UP-ARROW.
                ;
1008=                 ROMKEY = PARAMS+8
                ;                     ROMKEY IS A POINTER TO
                ;                     YOUR SYSTEM'S SUBROUTINE
                ;                     TO GET AN ASCII CHARACTER
                ;                     FROM THE KEYBOARD.
                ;
1010=                 DUMMY = PARAMS+$10
                ;                     DUMMY RETURNS WITHOUT DOING
                ;                     ANYTHING.
```

```
 580                ;
 590                ;
 600 0020=                SPACE = $20
 610                ;
 620 007F=                RUBOUT = $7F
 630                ;
 640 000D=                CR = $0D          ASCII FOR CARRIAGE RETURN.
 650                ;
 660                ;
 670                ;
 680                ;
 690                ;
 700                ;
 710                ;
 720                ;
 730                ;
 740                ;
 750                ;
 760                ;
 770                ; ********************************************
 780                ;
 790                ;          REQUIRED SUBROUTINES
 800                ;
 810                ; ********************************************
 820                ;
 830                ;
 840                ;
 850                ;
 860                ;
 870 1100=                TVSUBS = $1100
 880 1100=                CLR.TV = TVSUBS CLR.TV CLEARS THE SCREEN.
 890                ;
 900                ;
 910 1200=                VMSUBS = $1200 STARTING PAGE OF VISIBLE
 920                ;                        MONITOR CODE.
 930                ;
 940 1294=                GET.SL = VMSUBS+$94
 950                ;                        GET.SL GETS THE CURRENTLY-
 960                ;                        SELECTED BYTE.
 970                ;
 980                ;
 990                ;
1000                ;
1010                ;
1020                ;
1030                ;
1040                ;
1050                ;
1060                ;
1070                ;
1080                ;
1090                ;
1100                ; ********************************************
1110                ;
1120                ;          USER-MODIFIABLE DATA
1130                ;
1140                ; ********************************************
1150                ;
```

```
              ;
              ;
              ;
              ;
1200                 * = VMSUBS
              ;
              ;
              ;
              ;
1200 00       FIELD  .BYTE 0          NUMBER OF CURRENT FIELD.
              ;                       (MUST BE 0-6.)
              ;
1201 00       REG.A  .BYTE 0          IMAGE OF ACCUMULATOR.
              ;
1202 00       REG.X  .BYTE 0          IMAGE OF X-REGISTER.
              ;
1203 00       REG.Y  .BYTE 0          IMAGE OF Y-REGISTER.
              ;
1204 00       REG.P  .BYTE 0          IMAGE OF PROCESSOR STATUS
              ;                       REGISTER.
              ;
1201=                REGS = REG.A
              ;
1205 0000     SELECT .WORD 0          POINTER TO CURRENTLY-
              ;                       SELECTED ADDRESS.
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ; ********************************************
              ;
              ;          KEYBOARD INPUT ROUTINE
              ;
              ; ********************************************
              ;
              ;
12E0                 * = VMSUBS+$E0
              ;
              ;
12E0 6C0810   GETKEY JMP (ROMKEY)     JSR GETKEY CALLS YOUR
              ;                       SYSTEM'S KEYBOARD INPUT
              ;                       ROUTINE INDIRECTLY.
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
              ;
```

```
                     ;
                     ; ********************************************
                     ;
                     ;              MONITOR-UPDATE
                     ;
                     ; ********************************************
                     ;
                     ;
                     ;
                     ;
                     ;
1 2E3 20E012 UPDATE JSR GETKEY       GET A CHARACTER FROM THE
                     ;               KEYBOARD.
                     ;
12E6 C93E           CMP #'>          IS IT THE '>' KEY?
12E8 D010           BNE IF.LSR       IF NOT, PERFORM NEXT TEST.
                     ;
12EA EE0012 NEXT.F  INC FIELD        IF SO, SELECT NEXT FIELD.
12ED AD0012         LDA FIELD
12F0 C907           CMP #7           IF ARROW WAS UNDER RIGHT-
12F2 D005           BNE UP.EX1       MOST FIELD, PLACE IT UNDER
12F4 A900           LDA #0           LEFT-MOST FIELD.
12F6 8D0012         STA FIELD
12F9 60      UP.EX1 RTS              THEN RETURN TO CALLER.
                     ;
                     ;
12FA C93C    IF.LSR  CMP #'<         IS IT THE '<' KEY?
12FC D00B           BNE IF.SP        IF NOT, PERFORM NEXT TEST.
                     ;
12FE CE0012 PREV.F  DEC FIELD        IF SO, SELECT PREVIOUS
1301 1005           BPL UP.EX2       FIELD: THE FIELD TO THE
1303 A906           LDA #6           LEFT OF THE CURRENT FIELD.
1305 8D0012         STA FIELD
1308 60      UP.EX2 RTS              THEN RETURN
                     ;
                     ;
1309 C920    IF.SP  CMP #SPACE       IS IT THE SPACE BAR?
130B D009           BNE IF.CR        IF NOT, PERFORM NEXT TEST.
                     ;
130D EE0512 INC.SL  INC SELECT       IF SO, STEP FORWARD THROUGH
1310 D003           BNE *+5          MEMORY BY INCREMENTING
1312 EE0612         INC SELECT+1     THE POINTER THAT SELECTS
                     ;               THE ADDRESS TO BE DISPLAYED.
1315 60             RTS              THEN RETURN TO CALLER.
                     ;
                     ;
1316 C90D    IF.CR  CMP #CR          IS IT THE CARRIAGE RETURN?
1318 D00C           BNE IFCHAR       IF NOT, PERFORM NEXT TEST.
                     ;
131A AD0512 DEC.SL  LDA SELECT       IF SO, STEP BACKWARD THROUGH
131D D003           BNE *+5          MEMORY BY DECREMENTING THE
131F CE0612         DEC SELECT+1     POINTER THAT SELECTS THE
1322 CE0512         DEC SELECT       ADDRESS TO BE DISPLAYED.
1325 60             RTS              THEN RETURN.
                     ;
                     ;
1326 AE0012 IFCHAR  LDX FIELD        IS ARROW UNDER CHARACTER
1329 E002           CPX #2           FIELD (FIELD 2)?
```

```
132B D01B          BNE IF.GO       IF NOT, PERFORM NEXT TEST.
                ;                  IF SO,
132D A8      PUT.SL TAY            STORE THE
132E A500          LDA TV.PTR      CHARACTER IN THE CURRENTLY-
1330 48            PHA             SELECTED ADDRESS.
1331 A601          LDX TV.PTR+1    (PRESERVING THE ZERO PAGE.)
1333 AD0512        LDA SELECT
1336 8500          STA TV.PTR
1338 AD0612        LDA SELECT+1
133B 8501          STA TV.PTR+1
133D 98            TYA
133E A000          LDY #0
1340 9100          STA (TV.PTR),Y
1342 8601          STX TV.PTR+1
1344 68            PLA
1345 8500          STA TV.PTR
1347 60            RTS             THEN RETURN.
                ;
                ;
1348 C947    IF.GO CMP #'G         IS IT 'G' FOR GO?
134A D023          BNE IF.HEX      IF NOT, PERFORM NEXT TEST.
                ;
134C AC0312 GO     LDY REG.Y       IF SO, LOAD REGISTERS
134F AE0212        LDX REG.X       FROM REGISTER IMAGES...
1352 AD0412        LDA REG.P
1355 48            PHA
1356 AD0112        LDA REG.A
1359 28            PLP
135A 206C13        JSR CALLIT      AND CALL SELECTED ADDRESS.
135D 08            PHP             WHEN THE SUBROUTINE RETURNS,
135E 8D0112        STA REG.A       SAVE REGISTER VALUES IN
1361 8E0212        STX REG.X       REGISTER IMAGES.
1364 8C0312        STY REG.Y
1367 68            PLA
1368 8D0412        STA REG.P
136B 60            RTS             THEN RETURN TO CALLER.
                ;
                ;
136C 6C0512 CALLIT JMP (SELECT)    JSR CALLIT CALLS THE
                ;                  CURRENTLY-SELECTED ADDRESS,
                ;                  INDIRECTLY.
                ;
                ;
136F 48     IF.HEX PHA             SAVE KEYBOARD CHARACTER.
1370 20D513        JSR BINARY      IS IT ASCII CHAR FOR 0-9 OR
                ;                  A-F?  IF SO, CONVERT TO BINARY.
                ;
                ;
1373 304B          BMI IF.CLR      IF KEYBOARD CHAR WAS N
                ;                  0-9 OR A-F, PERFORM NEXT
                ;                  TEST.
                ;
1375 A8            TAY             PULL KEYBOARD CHARACTER
1376 68            PLA             FROM STACK, WHILE SAVING
1377 98            TYA             BINARY EQUIVALENT IN A AND Y.
                ;
1378 AE0012        LDX FIELD       IS ARROW UNDER ADDRESS
137B D014          BNE NOTADR      FIELD (FIELD 0)?
```

```
                   ;
137D A203    ADRFLD LDX #3         SINCE ARROW IS UNDER ADDRESS
137F 18      ADLOOP CLC            FIELD, ROLL HEX DIGIT INTO
1380 0E0512         ASL SELECT     ADDRESS FIELD BY ROLLING IT
1383 2E0612         ROL SELECT+1   IT INTO THE POINTER THAT
1386 CA             DEX            SELECTS THE DISPLAYED
1387 10F6           BPL ADLOOP     ADDRESS.
1389 98             TYA
138A 0D0512         ORA SELECT
138D 8D0512         STA SELECT
1390 60             RTS            THEN RETURN.
                   ;
                   ;
1391 E001    NOTADR CPX #1         IS ARROW UNDER FIELD 1?
1393 D018           BNE REGFLD     IF NOT, IT MUST BE UNDER
                   ;               A REGISTER FIELD.
                   ;
1395 290F    ROL.SL AND #$0F       ROLL 4 LSB IN A INTO
1397 48             PHA            CURRENTLY-SELECTED BYTE.
1398 209412         JSR GET.SL     GET THE CURRENTLY-SELECTED
139B 0A             ASL A          BYTE AND SHIFT LEFT 4 TIMES...
139C 0A             ASL A
139D 0A             ASL A
139E 0A             ASL A
139F 29F0           AND #$F0
13A1 8DAC13         STA TEMP
13A4 68             PLA
13A5 0DAC13         ORA TEMP
13A8 202D13         JSR PUT.SL     PUT IT IN CURRENTLY-SELECTED
13AB 60             RTS            ADDRESS AND RETURN.
                   ;
13AC 00      TEMP   .BYTE 0
                   ;
                   ;
                   ;
13AD CA      REGFLD DEX            THE ARROW MUST BE UNDER A
13AE CA             DEX            REGISTER IMAGE: FIELD 3,
13AF CA             DEX            4, 5, OR 6.
13B0 A003           LDY #3
                   ;
13B2 18      RGLOOP CLC            ROLL HEX DIGIT INTO
13B3 1E0112         ASL REGS,X     APPROPRIATE REGISTER IMAGE.
13B6 88             DEY
13B7 10F9           BPL RGLOOP
13B9 1D0112         ORA REGS,X
13BC 9D0112         STA REGS,X
13BF 60             RTS
                   ;
                   ;
13C0 68      IF.CLR PLA            RESTORE KEYBOARD CHARACTER.
13C1 C97F           CMP #RUBOUT    IS IT RUBOUT?  (IF YOUR
                   ;               SYSTEM DOESN'T HAVE A
                   ;               RUBOUT KEY, SUBSTITUTE THE
                   ;               CODE FOR THE KEY YOU'LL USE
                   ;               TO CLEAR THE SCREEN.)
                   ;
13C3 D004           BNE NOTCLR     IF IT ISN'T THE 'CLEAR
                   ;               SCREEN' KEY, PERFORM NEXT
```

```
3480                ;                       TEST.
3490                ;
3500 13C5 200011          JSR CLR.TV        IF IT IS, THEN CLEAR THE
3510 13C8 60              RTS               SCREEN AND RETURN.
3520                ;
3530                ;
3540 13C9 C951     NOTCLR CMP #'Q           IS IT 'Q' FOR QUIT?
3550 13CB D004            BNE OTHER         IF NOT, PERFORM NEXT TEST.
3560                ;
3570                ;                       IT IS 'Q' FOR QUIT.  THE
3580                ;                       USER WANTS TO RETURN TO THE
3590                ;                       CALLER OF THE VISIBLE
3600                ;                       MONITOR.  SO LET'S DO THAT:
3610 13CD 68              PLA               POP UPDATE'S RETURN ADDRESS.
3620 13CE 68              PLA
3630                ;
3640 13CF 28              PLP               RESTORE INITIAL 6502 FLAGS.
3650                ;                       VISMON'S RETURN ADDRESS IS
3660                ;                       NOW ON THE STACK.
3670 13D0 60              RTS               SO RETURN TO CALLER OF
3680                ;                       VISMON.  IN THIS WAY,
3690                ;                       VISMON CAN BE USED BY ANY
3700                ;                       CALLER TO GET AN ADDRESS
3710                ;
3720                ;                       FROM THE USER.
3730                ;
3740 13D1 201010 OTHER    JSR DUMMY         REPLACE THIS CALL TO
3750                ;                       DUMMY WITH A CALL TO ANY
3760                ;                       SUBROUTINE THAT EXTENDS
3770                ;                       FUNCTIONALITY OF THE
3780                ;                       VISIBLE MONITOR.
3790 13D4 60              RTS               THEN RETURN.
3800                ;
3810                ;
3820                ;
3830                ;
3840                ;
3850                ;
3860                ;
3870                ;
3880                ;
3890                ;
3900                ;
3910                ;
3920                ; *********************************************
3930                ;
3940                ;         ASCII TO BINARY
3950                ;
3960                ; *********************************************
3970                ;
3980                ;
3990                ;
4000                ;                       IF ACCUMULATOR HOLDS ASCII
4010                ;                       0-9 OR A-F, THIS ROUTINE
4020                ;                       RETURNS BINARY EQUIVALENT--
4030                ;                       OTHERWISE, IT RETURNS $FF.
4040                ;
4050                ;
```

```
4060 13D5 38       BINARY SEC
4070 13D6 E930            SBC #$30
4080 13D8 900F            BCC BAD
4090 13DA C90A            CMP #$0A
4100 13DC 900E            BCC GOOD
4110 13DE E907            SBC #7
4120 13E0 C910            CMP #$10
4130 13E2 B005            BCS BAD
4140 13E4 38              SEC
4150 13E5 C90A            CMP #$0A
4160 13E7 B003            BCS GOOD
4170 13E9 A9FF     BAD    LDA #$FF
4180 13EB 60              RTS
4190                ;
4200 13EC A200     GOOD   LDX #0
4210 13EE 60              RTS
```

Appendix C4:

Print Utilities

```
10             ;      APPENDIX C4: ASSEMBLER LISTING OF
20             ;              PRINT UTILITIES
30             ;
40             ;
50             ;
60             ;
70             ;      SEE CHAPTER 7 OF BEYOND GAMES: SYSTEMS
80             ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
90             ;
100            ;
110            ;
120            ;
130            ;
140            ;
150            ;
160            ;
170            ;
180            ;
190            ;
200            ;
210            ; ********************************************
220            ;
230            ;         CONSTANTS
240            ;
250            ; ********************************************
260            ;
270            ;
280            ;
290            ;
300            ;
310 000D=          CR = $0D        CARRIAGE RETURN.
320            ;
330 00FF=          ETX = $FF       THIS CHARACTER MUST
340            ;                   TERMINATE ANY MESSAGE STRING.
350            ;
360 000A=          LF = $0A        LINE FEED.
370            ;
380 0000=          OFF = 0
390            ;
400 00FF=          ON = $FF
410            ;
420            ;
430            ;
440            ;
450            ;
460            ;
470            ;
480            ;
490            ;
500            ;
510            ; ********************************************
520            ;
530            ;         EXTERNAL ADDRESSES
540            ;
550            ; ********************************************
560            ;
570            ;
580            ;
```

```
590                ;
600                ;
610                ;
620                ;
630                ;
640                ;
650                ;
660  1000=                PARAMS = $1000 ADDRESS OF SYSTEM DATA BLOCK.
670                ;
680                ;
690                ;
700  100C=                ROMPRT = PARAMS+$0C
710                ;                      POINTER TO ROM ROUTINE THAT
720                ;                      SENDS CHAR TO SERIAL OUTPUT.
730                ;
740                ;
750                ;
760  100A=                ROMTVT = PARAMS+$0A
770                ;                      POINTER TO ROM ROUTINE THAT
780                ;                      PRINTS A CHAR TO THE SCREEN.
790                ;
800                ;
810                ;
820  100E=                USROUT = PARAMS+$0E
830                ;                      POINTER TO USER-WRITTEN
840                ;                      CHARACTER OUTPUT ROUTINE.
850                ;
860                ;
870                ;
880                ;
890  1100=                TVSUBS = $1100
900  11B6=                ASCII  = TVSUBS+$B6
910                ;
920                ;
930                ;
940                ;
950  1200=                VMPAGE = $1200 VISIBLE MONITOR STARTING
960                ;                      PAGE
970                ;
980  1205=                SELECT = VMPAGE+5
990  1294=                GET.SL = VMPAGE+$94
1000 130D=                INC.SL = VMPAGE+$10D
1010               ;
1020               ;
1030               ;
1040               ;
1050               ;
1060               ;
1070               ;
1080               ; ********************************************
1090               ;
1100               ;         VARIABLES
1110               ;
1120               ; ********************************************
1130               ;
1140               ;
1150               ;
1160               ;
```

```
             ;
1400                 * = $1400
             ;
1400 00      PRINTR .BYTE OFF        PRINTER OUTPUT FLAG.
             ;
1401 FF      TVT    .BYTE ON         TVT OUTPUT FLAG.
             ;
             ;
1402 00      USER   .BYTE OFF        OUTPUT FLAG FOR USER-
             ;                       PROVIDED OUTPUT SUBROUTINE.
             ;
1403 00      CHAR   .BYTE 0          CHARACTER MOST RECENTLY
             ;                       PRINTED BY PR.CHR.
             ;                       CHAR=00 MEANS PR.CHR HAS
             ;                       NEVER PRINTED A CHARACTER.
             ;
             ;
1404 00      REPEAT .BYTE 0          THIS BYTE IS USED AS A
             ;                       COUNTER BY SPACES, CHARS,
             ;                       AND CR.LFS.
             ;
             ;
1405 00      TEMP.X .BYTE 0          DATA CELL: USED BY PR.MSG.
             ;
             ;
1406 0000    RETURN .WORD 0          THIS POINTER IS USED BY
             ;                       PUSHSL AND POP.SL.
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;         DEVICE SELECT SUBROUTINES
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
             ;
             ;
1408 A9FF    TVT.ON LDA #ON          SELECT SCREEN FOR OUTPUT
140A 8D0114         STA TVT          BY SETTING ITS DEVICE FLAG.
140D 60             RTS
             ;
             ;
             ;
             ;
             ;
             ;
140E A900    TVTOFF LDA #OFF         DE-SELECT SCREEN FOR
1410 8D0114         STA TVT          OUTPUT BY CLEARING ITS
1413 60             RTS              DEVICE FLAG.
```

```
                ;
                ;
                ;
                ;
                ;
1414 A9FF    PR.ON  LDA #ON       SELECT PRINTER FOR OUTPUT
1416 8D0014         STA PRINTR    BY SETTING ITS DEVICE FLAG.
1419 60             RTS
                ;
                ;
                ;
                ;
                ;
141A A900    PR.OFF LDA #OFF      DE-SELECT PRINTER FOR OUTPUT
141C 8D0014         STA PRINTR    BY CLEARING ITS DEVICE FLAG.
141F 60             RTS
                ;
                ;
                ;
                ;
                ;
1420 A9FF    USR.ON LDA #ON       SELECT USER-WRITTEN
1422 8D0214         STA USER      SUBROUTINE BY SETTING
1425 60             RTS           USER'S DEVICE FLAG.
                ;
                ;
                ;
                ;
                ;
1426 A900    USROFF LDA #OFF      DE-SELECT USER-WRITTEN
1428 8D0214         STA USER      OUTPUT SUBROUTINE BY
142B 60             RTS           CLEARING ITS DEVICE FLAG.
                ;
                ;
                ;
                ;
                ;
142C 200814 ALL.ON JSR TVT.ON     SELECT ALL OUTPUT DEVICES
142F 201414        JSR PR.ON      BY SELECTING EACH OUTPUT
1432 202014        JSR USR.ON     DEVICE INDIVIDUALLY.
1435 60            RTS
                ;
                ;
                ;
                ;
                ;
1436 200E14 ALLOFF JSR TVTOFF     DE-SELECT ALL OUTPUT DEVICES
1439 201A14        JSR PR.OFF     BY DE-SELECTING EACH ONE
143C 202614        JSR USROFF     INDIVIDUALLY.
143F 60            RTS
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
```

```
             ;
             ;
             ; ********************************************
             ;
             ;         A GENERAL CHARACTER PRINT ROUTINE
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
             ;     PRINT CHARACTER IN ACCUMULATOR
             ;
             ;  ON ALL CURRENTLY-SELECTED OUTPUT DEVICES.
             ;
             ;
             ;
1440 C900   PR.CHR CMP #0        TEST CHARACTER.
1442 F024          BEQ EXIT      IF IT'S A NULL, RETURN
             ;                   WITHOUT PRINTING IT.
1444 8D0314        STA CHAR      SAVE CHARACTER.
             ;
1447 AD0114        LDA TVT       IS SCREEN SELECTED?
144A F006          BEQ IF.PR     IF NOT, TEST NEXT DEVICE.
             ;
144C AD0314        LDA CHAR      IF SO, SEND CHARACTER
144F 206914        JSR SEND.1    INDIRECTLY TO SYSTEM'S
             ;                   TVT OUTPUT ROUTINE.
             ;
             ;
1452 AD0014 IF.PR  LDA PRINTR    IS PRINTER SELECTED?
1455 F006          BEQ IF.USR    IF NOT, TEST NEXT DEVICE.
             ;
1457 AD0314        LDA CHAR      IF SO, SEND CHARACTER
145A 206C14        JSR SEND.2    INDIRECTLY TO SYSTEM'S
             ;                   PRINTER DRIVER.
             ;
             ;
145D AD0214 IF.USR LDA USER      IS USER-WRITTEN OUTPUT
             ;                   SUBROUTINE SELECTED?
1460 F006          BEQ EXIT      IF NOT, RETURN.
             ;
1462 AD0314        LDA CHAR      IF SO, SEND CHARACTER
1465 206F14        JSR SEND.3    INDIRECTLY TO USER-WRITTEN
             ;                   SUBROUTINE.
             ;
1468 60     EXIT   RTS           RETURN TO CALLER.
             ;
             ;
             ;
             ;             VECTORED SUBROUTINE CALLS
             ;
             ;
             ;
1469 6C0A10 SEND.1 JMP (RONTVT)
             ;
146C 6C0C10 SEND.2 JMP (ROMPRT)
```

```
             ;
146F 6C0E10 SEND.3 JMP (USROUT)
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;     SPECIALIZED CHARACTER OUTPUT ROUTINES
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
             ;          PRINT A CARRIAGE RETURN-LINE FEED
             ;
             ;
1472 A90D   CR.LF  LDA #CR          SEND A CARRIAGE RETURN
1474 204014        JSR PR.CHR
1477 A90A          LDA #LF          AND A LINE-FEED TO ALL
1479 204014        JSR PR.CHR       CURRENTLY-SELECTED DEVICES.
147C 60            RTS              THEN RETURN.
             ;
             ;
             ;
             ;
             ;
             ;       PRINT A SPACE:
             ;
             ;
             ;
147D A920   SPACE  LDA #$20         LOAD ACCUMULATOR WITH AN
147F 204014        JSR PR.CHR       ASCII SPACE AND PRINT IT.
1482 60            RTS              THEN RETURN.
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;       PRINT BYTE
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
```

```
3490                 ;
3500                 ;
3510                 ;       PR.BYT OUTPUTS THE ACCUMULATOR, IN HEX,
3520                 ;    TO ALL CURRENTLY-SELECTED DEVICES.
3530                 ;
3540                 ;
3550                 ;
3560 1483 48         PR.BYT PHA             SAVE BYTE.
3570 1484 4A                LSR A           DETERMINE ASCII FOR 4 MSB...
3580 1485 4A                LSR A
3590 1486 4A                LSR A
3600 1487 4A                LSR A
3610 1488 20B611            JSR ASCII       ...IN THE BYTE.
3620 148B 204014            JSR PR.CHR      PRINT THAT ASCII CHAR TO
3630                 ;                      CURRENT DEVICE(S).
3640 148E 68                PLA             DETERMINE ASCII FOR 4 LSB
3650 148F 20B611            JSR ASCII       IN THE ORIGINAL BYTE.
3660 1492 204014            JSR PR.CHR      PRINT THAT CHARACTER.
3670 1495 60                RTS             RETURN TO CALLER.
3680                 ;
3690                 ;
3700                 ;
3710                 ;
3720                 ;
3730                 ;
3740                 ;
3750                 ; *********************************************
3760                 ;
3770                 ;       REPETITIVE CHARACTER OUTPUT
3780                 ;
3790                 ; *********************************************
3800                 ;
3810                 ;
3820                 ;
3830                 ;      PRINT X SPACES:
3840                 ;
3850                 ;
3860 1496 A920       SPACES LDA #$20        LOAD A WITH ASCII SPACE.
3870                 ;
3880                 ;                      PRINT IT X TIMES:
3890                 ;
3900                 ;
3910                 ;
3920                 ;
3930                 ;      PRINT X CHARACTERS:
3940                 ;
3950                 ;
3960                 ;
3970 1498 8E0414 CHARS  STX REPEAT      PRINT CHAR IN A X TIMES.
3980 149B 48     RPLOOP PHA             SAVE CHAR TO BE REPEATED.
3990 149C AE0414        LDX REPEAT      REPEAT COUNTER TIMED OUT?
4000 149F F00A          BEQ RPTEND      IF SO, EXIT.  IF NOT,
4010 14A1 CE0414        DEC REPEAT      DECREMENT REPEAT COUNTER.
4020 14A4 204014        JSR PR.CHR      PRINT CHARACTER.
4030                 ;
4040 14A7 68            PLA             RESTORE CHARACTER TO A.
4050 14A8 18            CLC             LOOP BACK TO PRINT IT
4060 14A9 90F0          BCC RPLOOP      AGAIN IF NECESSARY.
```

```
4070                  ;
4080 14AB 68     RPTEND PLA            CLEAN UP STACK AND
4090 14AC 60            RTS            RETURN TO CALLER.
4100                  ;
4110                  ;
4120                  ;
4130                  ;     PRINT X NEWLINES
4140                  ;
4150                  ;
4160 14AD 8E0414 CR.LFS STX REPEAT     INITIALIZE REPEAT COUNTER.
4170 14B0 AE0414 CRLOOP LDX REPEAT     EXIT IF REPEAT COUNTER
4180 14B3 F009          BEQ END.CR     HAS TIMED OUT.
4190 14B5 CE0414        DEC REPEAT     DECREMENT REPEAT COUNTER.
4200 14B8 207214        JSR CR.LF      PRINT A CARRIAGE RETURN
4210                  ;                AND A LINE FEED.
4220 14BB 18            CLC            LOOP BACK TO SEE IF DONE
4230 14BC 90F2          BCC CRLOOP     YET.
4240                  ;
4250 14BE 60     END.CR RTS            RETURN TO CALLER.
4260                  ;
4270                  ;
4280                  ;
4290                  ;
4300                  ;
4310                  ;
4320                  ;
4330                  ;
4340                  ;
4350                  ; ********************************************
4360                  ;
4370                  ;       PRINT A MESSAGE
4380                  ;
4390                  ; ********************************************
4400                  ;
4410                  ;
4420                  ;
4430                  ;
4440                  ;      Xth POINTER IN ZERO PAGE
4450                  ;       POINTS TO THE MESSAGE.
4460                  ;
4470                  ;
4480 14BF 8E0514 PR.MSG STX TEMP.X     SAVE X REGISTER, WHICH
4490                  ;                SPECIFIES MESSAGE POINTER.
4500                  ;
4510 14C2 B501          LDA 1,X        SAVE MESSAGE POINTER.
4520 14C4 48            PHA
4530 14C5 B500          LDA 0,X
4540 14C7 48            PHA
4550                  ;
4560 14C8 AE0514 LOOP   LDX TEMP.X     RESTORE ORIGINAL X, SO IT
4570                  ;                SPECIFIES MESSAGE POINTER.
4580 14CB A100          LDA (0,X)      GET NEXT CHARACTER FROM
4590 14CD C9FF          CMP #ETX       MESSAGE.  IS MESSAGE OVER?
4600 14CF F00C          BEQ MSGEND     IF SO, HANDLE END OF MESSAGE.
4610                  ;
4620 14D1 F600          INC 0,X        IF NOT, INCREMENT POINTER.
4630 14D3 D002          BNE NEXT       SO IT POINTS TO NEXT
4640 14D5 F601          INC 1,X        CHARACTER IN MESSAGE.
```

```
4650 14D7 204014 NEXT    JSR FR.CHR      PRINT THE CHARACTER.
4660 14DA 18             CLC             LOOP BACK FOR NEXT
4670 14DB 90EB           BCC LOOP        CHARACTER...
4680                  ;
4690                  ;
4700 14DD 68      MSGEND PLA             RESTORE ORIGINAL MESSAGE
4710 14DE 9500           STA 0,X         POINTER.
4720 14E0 68             PLA
4730 14E1 9501           STA 1,X
4740 14E3 60             RTS             RETURN TO CALLER, WITH
4750                  ;                  MESSAGE POINTER PRESERVED.
4760                  ;
4770                  ;
4780                  ;
4790                  ;
4800                  ;
4810                  ;
4820                  ;
4830                  ;
4840                  ;
4850                  ; *********************************************
4860                  ;
4870                  ;       PRINT THE FOLLOWING TEXT
4880                  ;
4890                  ; *********************************************
4900                  ;
4910                  ;
4920                  ;
4930                  ;
4940                  ;
4950 14E4 68      PRINT: PLA             PULL RETURN ADDRESS FROM
4960 14E5 AA             TAX             STACK AND SAVE IT IN X AND
4970 14E6 68             PLA             Y REGISTERS.
4980 14E7 A8             TAY
4990                  ;
5000 14E8 201215         JSR PUSHSL      SAVE THE SELECT POINTER.
5010 14EB 8E0512         STX SELECT      SET SELECT=RETURN ADDRESS.
5020 14EE 8C0612         STY SELECT+1
5030                  ;
5040                  ;
5050 14F1 200D13         JSR INC.SL      ADVANCE SELECT TO STX.
5060                  ;
5070 14F4 200D13 NEXTCH JSR INC.SL       SELECT NEXT CHARACTER.
5080 14F7 209412         JSR GET.SL      GET IT.
5090 14FA C9FF           CMP #ETX        IS IT END OF MESSAGE?
5100 14FC F006           BEQ ENDIT       IF SO, RETURN.
5110 14FE 204014         JSR PR.CHR      IF NOT, PRINT CHARACTER.
5120 1501 18             CLC             LOOP BACK FOR NEXT
5130 1502 90F0           BCC NEXTCH      CHARACTER...
5140                  ;
5150                  ;
5160 1504 AE0512 ENDIT  LDX SELECT
5170 1507 AC0612         LDY SELECT+1
5180 150A 202B15         JSR POP.SL      RESTORE SELECT POINTER.
5190 150D 98             TYA             PUSH ADDRESS OF ETX ONTO
5200 150E 48             PHA
5210 150F 8A             TXA             ...THE STACK.
5220 1510 48             PHA
```

```
5230 1511 60            RTS              RETURN (TO BYTE IMMEDIATELY
5240                ;                    FOLLOWING THE ETX.)
5250                ;
5260                ;
5270                ;
5280                ;
5290                ;
5300                ;
5310                ;
5320                ;
5330                ;
5340                ;
5350                ; ********************************************
5360                ;
5370                ;         SAVE, RESTORE SELECT POINTER
5380                ;
5390                ; ********************************************
5400                ;
5410                ;
5420                ;
5430                ;
5440                ;
5450 1512 68      PUSHSL PLA             PULL RETURN ADDRESS FROM
5460 1513 8D0614         STA RETURN      STACK AND SAVE IT IN RETURN.
5470 1516 68             PLA
5480 1517 8D0714         STA RETURN+1
5490                ;
5500                ;
5510 151A AD0612         LDA SELECT+1    PUSH SELECT POINTER ONTO
5520 151D 48             PHA             THE STACK.
5530 151E AD0512         LDA SELECT
5540 1521 48             PHA
5550                ;
5560                ;
5570 1522 AD0714         LDA RETURN+1    PUSH RETURN ADDRESS BACK
5580 1525 48             PHA             ON THE STACK.
5590 1526 AD0614         LDA RETURN
5600 1529 48             PHA
5610                ;
5620                ;
5630 152A 60             RTS             RETURN TO CALLER.  CALLER
5640                ;                    WILL FIND SELECT ON STACK.
5650                ;
5660                ;
5670                ;
5680                ;
5690                ;
5700                ;
5710                ;
5720                ;
5730 152B 68      POP.SL PLA             SAVE RETURN ADDRESS.
5740 152C 8D0614         STA RETURN
5750 152F 68             PLA
5760 1530 8D0714         STA RETURN+1
5770                ;
5780                ;
5790 1533 68             PLA             LOAD SELECT FROM STACK
5800 1534 8D0512         STA SELECT
```

```
5810 1537 68              PLA
5820 1538 8D0612          STA SELECT+1
5830                 ;
5840                 ;
5850 153B AD0714          LDA RETURN+1   PLACE RETURN ADDRESS BACK
5860 153E 48              PHA            ON STACK.
5870 153F AD0614          LDA RETURN
5880 1542 48              PHA
5890                 ;
5900                 ;
5910 1543 60              RTS            RETURN TO CALLER.
5920                 ;
```

Appendix C5:

Two Hexdump Tools

```
                ;       APPENDIX C5: ASSEMBLER LISTING OF
                ;               TWO HEXDUMP TOOLS
                ;
                ;
                ;
                ;       SEE CHAPTER 8 OF BEYOND GAMES: SYSTEMS
                ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
                ;
                ;
                ;                BY KEN SKIER
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ; ********************************************
                ;
                ;          CONSTANTS
                ;
                ; ********************************************
                ;
                ;
                ;
                ;
                ;
000D=               CR = $0D        CARRIAGE RETURN.
                ;
000A=               LF = $0A        LINE FEED.
                ;
                ;
007F=               TEX = $7F       THIS CHARACTER MUST START
                ;                   ANY MESSAGE.
                ;
00FF=               ETX = $FF       THIS CHARACTER MUST END
                ;                   ANY MESSAGE.
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
```

```
580                 ;
590                 ; ********************************************
600                 ;
610                 ;         EXTERNAL ADDRESSES
620                 ;
630                 ; ********************************************
640                 ;
650                 ;
660                 ;
670                 ;
680                 ;
690                 ;
700                 ;
710                 ;
720                 ;
730                 ;
740 1100=               TVSUBS=$1100   STARTING PAGE OF DISPLAY
750                 ;                  CODE.
760 1100=               CLR.TV=TVSUBS
770 11B6=               ASCII =TVSUBS+$B6
780                 ;
790                 ;
800 1200=               VMPAGE=$1200   STARTING PAGE OF VISIBLE
810                 ;                  MONITOR CODE.
820 1205=               SELECT=VMPAGE+5
830 1207=               VISMON=VMPAGE+7
840 1294=               GET.SL=VMPAGE+$94
850 130D=               INC.SL=VMPAGE+$10D
860                 ;
870                 ;
880 1400=               PRPAGE=$1400   STARTING PAGE OF PRINT
890                 ;                  UTILITIES.
900 1408=               TVT.ON=PRPAGE+8
910 140E=               TVTOFF=PRPAGE+$0E
920 1414=               PR.ON =PRPAGE+$14
930 141A=               PR.OFF=PRPAGE+$1A
940 1440=               PR.CHR=PRPAGE+$40
950 1472=               CR.LF =PRPAGE+$72
960 147D=               SPACE =PRPAGE+$7D
970 1496=               SPACES=PRPAGE+$96
980 1483=               PR.BYT=PRPAGE+$83
990 14E4=               PRINT:=PRPAGE+$E4
1000 1512=              PUSHSL=PRPAGE+$112
1010 152B=              POP.SL=PRPAGE+$12B
1020                ;
1030                ;
1040                ;
1050                ;
1060                ;
1070                ;
1080                ;
1090                ;
1100                ;
1110                ;
1120                ;
1130                ; ********************************************
1140                ;
1150                ;         VARIABLES
```

```
            ;
            ; **********************************************
            ;
            ;
            ;
1550               *=$1550
            ;
            ;
            ;
            ;
            ;
1550 00     COUNTR .BYTE 0        THIS BYTE COUNTS THE LINES
            ;                     DUMPED BY TVDUMP.
            ;
1551 04     NUMLNS .BYTE 4        NUMBER OF LINES TO BE
            ;                     DUMPED BY TVDUMP.
            ;
            ;
1552 0000   SA     .WORD 0        POINTER TO START OF MEMORY
            ;                     TO BE DUMPED BY PRDUMP.
1554 FFFF   EA     .WORD $FFFF    POINTER TO LAST BYTE TO
            ;                     BE DUMPED BY PRDUMP.
            ;
            ;
1556 00     COLUMN .BYTE 0        DATA CELL: USED-BY PRLINE
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ; **********************************************
            ;
            ;      TVDUMP
            ;
            ; **********************************************
            ;
            ;
            ;
            ;
            ;
1557 200814 TVDUMP JSR TVT.ON     SELECT TVT AS OUTPUT DEVICE.
155A AD5115        LDA NUMLNS     SET COUNTR TO NUMBER OF
155D 8D5015        STA COUNTR     LINES TO BE DUMPED.
            ;
1560 AD0512        LDA SELECT     SET SELECT TO BEGINNING OF
1563 29F8          AND #$F8       A SCREEN LINE, BY ZEROING
1565 8D0512        STA SELECT     3 LSB IN SELECT.
            ;
1568 207214        JSR CR.LF      SKIP TWO LINES ON THE
156B 207214        JSR CR.LF      SCREEN.
            ;
156E 20A115 DUMPLN JSR PR.ADR     PRINT THE SELECTED ADDRESS.
            ;
1571 207214        JSR CR.LF      ADVANCE TO A NEW LINE ON
            ;                     SCREEN.  (NOT NEEDED ON
1740                 ;                     SYSTEMS WITH SCREENS MORE
1750                 ;                     THAN 27 COLUMNS WIDE.)
1760                 ;
1770                 ;
1780 1574 207D14 DMPBYT JSR SPACE          PRINT A SPACE TO THE SCREEN.
1790                 ;
1800 1577 209A15        JSR DUMPSL         DUMP SELECTED BYTE.
1810                 ;
1820 157A 200D13        JSR INC.SL         SELECT NEXT BYTE.
1830                 ;
1840 157D AD0512        LDA SELECT         IS IT THE BEGINNING OF A
1850 1580 2907          AND #07            NEW SCREEN LINE (3 LSB=0?)
1860 1582 D0F0          BNE DMPBYT         IF NOT, DUMP NEXT BYTE...
1870                 ;
1880                 ;
1890 1584 207214        JSR CR.LF          IF SO, ADVANCE TO A NEW LINE
1900                 ;                     ON THE SCREEN.
1910                 ;
1920 1587 AD0512        LDA SELECT         DOES THIS ADDRESS MARK THE
1930 158A 290F          AND #$0F           BEGINNING OF A NEW HEX LINE?
1940                 ;                     (4 LSB = 0?)
1950                 ;
1960 158C D003          BNE IFDONE
1970 158E 207214        JSR CR.LF          IF SO, ADVANCE TO A NEW
1980                 ;                     LINE ON SCREEN.
1990                 ;
2000 1591 CE5015 IFDONE DEC COUNTR         DUMPED LAST LINE YET?
2010 1594 D0D8          BNE DUMPLN         IF NOT, DUMP NEXT LINE.
2020                 ;
2030                 ;
2040 1596 200E14        JSR TVTOFF         DE-SELECT TVT AS OUTPUT
2050                 ;                     DEVICE.
2060                 ;
2070 1599 60            RTS                RETURN TO CALLER.
2080                 ;
2090                 ;
2100                 ;
2110                 ;
2120                 ;
2130                 ;
2140                 ;
2150                 ;
2160                 ;
2170                 ; ********************************************
2180                 ;
2190                 ;          DUMP SELECTED BYTE
2200                 ;
2210                 ; ********************************************
2220                 ;
2230                 ;
2240                 ;
2250                 ;
2260                 ;
2270 159A 209412 DUMPSL JSR GET.SL         GET CURRENTLY-SELECTED BYTE
2280 159D 208314        JSR PR.BYT         AND PRINT IT IN HEX FORMAT.
2290 15A0 60            RTS                RETURN TO CALLER.
2300                 ;
2310                 ;
```

```
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;         PRINT SELECTED ADDRESS
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
             ;
15A1 AD0612 PR.ADR LDA SELECT+1   FIRST PRINT THE HIGH BYTE...
15A4 208314        JSR PR.BYT
15A7 AD0512        LDA SELECT     ...THEN PRINT THE LOW BYTE.
15AA 208314        JSR PR.BYT
15AD 60            RTS
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;       PRINTING HEXDUMP
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
15AE 20C915 PRDUMP JSR TITLE      DISPLAY THE TITLE
15B1 20E915        JSR SETADS     LET USER SET START ADDRESS
             ;                    AND END ADDRESS OF MEMORY TO
             ;                    BE DUMPED.
             ;                    (SETADS RETURNS W/SELECT=EA.)
15B4 20A017        JSR GOTOSA     SET SELECT=SA.
15B7 201414        JSR PR.ON      SELECT PRINTER FOR OUTPUT.
             ;
15BA 20EB16        JSR HEADER     OUTPUT HEXDUMP HEADER.
             ;
             ;
15BD 204217 HXLOOP JSR PRLINE     DUMP ONE LINE.
15C0 10FB          BPL HXLOOP     DUMPED LAST LINE? IF NOT,
             ;                    DUMP NEXT LINE.
```

```
2900                    ;
2910 15C2 207214              JSR CR.LF        IF SO, GO TO A NEW LINE.
2920                    ;
2930 15C5 201A14              JSR PR.OFF       DE-SELECT PRINTER FOR OUTPUT.
2940                    ;
2950 15C8 60                  RTS              RETURN TO CALLER.
2960                    ;
2970                    ;
2980                    ;
2990                    ;
3000                    ;
3010                    ;
3020                    ;
3030                    ;
3040                    ;
3050                    ;
3060                    ; ********************************************
3070                    ;
3080                    ;       PRINT THE HEXDUMP TITLE TO SCREEN
3090                    ;
3100                    ; ********************************************
3110                    ;
3120                    ;
3130                    ;
3140                    ;
3150 15C9 200011 TITLE        JSR CLR.TV       CLEAR THE SCREEN.
3160 15CC 200814              JSR TVT.ON       SELECT SCREEN FOR OUTPUT.
3170 15CF 20E414              JSR PRINT:       OUTPUT THE FOLLOWING TEXT:
3180 15D2 7F                  .BYTE TEX        TEXT STRING MUST START
3190                    ;                      WITH A START OF TEXT CHAR.
3200 15D3 0D                  .BYTE CR,'PRINTING HEXDUMP',CR,LF,LF
3200 15D4 50
3200 15D5 52
3200 15D6 49
3200 15D7 4E
3200 15D8 54
3200 15D9 49
3200 15DA 4E
3200 15DB 47
3200 15DC 20
3200 15DD 48
3200 15DE 45
3200 15DF 58
3200 15E0 44
3200 15E1 55
3200 15E2 4D
3200 15E3 50
3200 15E4 0D
3200 15E5 0A
3200 15E6 0A
3210 15E7 FF                  .BYTE ETX        TEXT STRING MUST END WITH
3220                    ;                      AN END OF TEXT CHARACTER.
3230 15E8 60                  RTS              RETURN TO CALLER.
3240                    ;
3250                    ;
3260                    ;
3270                    ;
3280                    ;
```

```
3290                ;
3300                ;
3310                ;
3320                ;
3330                ;
3340                ; ******************************************
3350                ;
3360                ;    LET USER SET STARTING ADDRESS AND
3370                ;
3380                ;       END ADDRESS OF A BLOCK OF MEMORY:
3390                ;
3400                ; ******************************************
3410                ;
3420                ;
3430                ;
3440                ;
3450                ;
3460 15E9 200814 SETADS JSR TVT.ON      SELECT SCREEN FOR OUTPUT
3470 15EC 20E414        JSR PRINT:      PUT PROMPT ON SCREEN:
3480 15EF 7F            .BYTE TEX
3490 15F0 0D            .BYTE CR,LF,'SET STARTING ADDRESS '
3490 15F1 0A
3490 15F2 53
3490 15F3 45
3490 15F4 54
3490 15F5 20
3490 15F6 53
3490 15F7 54
3490 15F8 41
3490 15F9 52
3490 15FA 54
3490 15FB 43
3490 15FC 4E
3490 15FD 47
3490 15FE 20
3490 15FF 41
3490 1600 44
3490 1601 44
3490 1602 52
3490 1603 45
3490 1604 53
3490 1605 53
3490 1606 20
3500 1607 41            .BYTE 'AND PRESS "Q".'
3500 1608 4E
3500 1609 44
3500 160A 20
3500 160B 50
3500 160C 52
3500 160D 45
3500 160E 53
3500 160F 53
3500 1610 20
3500 1611 22
3500 1612 51
3500 1613 22
3500 1614 2E
3510 1615 FF            .BYTE ETX
```

```
3520 1616 200712        JSR VISMON     CALL VISIBLE MONITOR. SO
3530                ;                  USER CAN SELECT START ADDRESS
3540                ;                  OF THE BLOCK.
3550                ;
3560 1619 206716        JSR SAHERE     SET START ADDRESS (SA)=SELECT
3570                ;
3580                ;
3590                ;
3600                ;
3610                ;
3620                ;
3630                ;                  HAVING SET THE START ADDRESS,
3640                ;                  SA, LET'S SET THE END ADDRESS,
3650                ;                  EA.
3660                ;
3670                ;
3680                ;
3690                ;
3700                ;
3710 161C 200814 SET.EA JSR TVT.ON     SELECT SCREEN FOR OUTPUT.
3720 161F 20E414        JSR PRINT:     PUT PROMPT ON SCREEN:
3730 1622 7F            .BYTE TEX
3740 1623 0D            .BYTE CR,LF,'SET END ADDRESS '
3740 1624 0A
3740 1625 53
3740 1626 45
3740 1627 54
3740 1628 20
3740 1629 45
3740 162A 4E
3740 162B 44
3740 162C 20
3740 162D 41
3740 162E 44
3740 162F 44
3740 1630 52
3740 1631 45
3740 1632 53
3740 1633 53
3740 1634 20
3750 1635 41            .BYTE 'AND PRESS "Q".',ETX
3750 1636 4E
3750 1637 44
3750 1638 20
3750 1639 50
3750 163A 52
3750 163B 45
3750 163C 53
3750 163D 53
3750 163E 20
3750 163F 22
3750 1640 51
3750 1641 22
3750 1642 2E
3750 1643 FF
3760                ;
3770 1644 200712        JSR VISMON     LET USER SELECT END ADDRESS.
3780                ;
```

```
3790 1647 38             SEC              IF USER TRIED TO SET AN
3800 1648 AD0612         LDA SELECT+1     ADDRESS LESS THAN THE
3810 164B CD5315         CMP SA+1         STARTING ADDRESS,
3820 164E 9024           BCC TOOLOW       MAKE USER DO IT OVER.
3830 1650 D008           BNE EAHERE       IF SELECT>SA, SET EA=SELECT.
3840              ;                       THAT WILL MAKE EA>SA,
3850              ;
3860              ;
3870              ;
3880 1652 AD0512         LDA SELECT
3890 1655 CD5215         CMP SA
3900 1658 901A           BCC TOOLOW
3910              ;
3920              ;
3930              ;
3940              ;
3950 165A AD0612 EAHERE LDA SELECT+1     SET EA=SELECT.
3960 165D 8D5515         STA EA+1
3970 1660 AD0512         LDA SELECT
3980 1663 8D5415         STA EA
3990 1666 60             RTS              RETURN WITH EA SET BY CALLER
4000              ;                       (JSR EAHERE); EA SET BY USER
4010              ;                       (JSR SET.EA); OR SA AND EA
4020              ;                       SET BY USER (JSR SETADS).
4030              ;
4040 1667 AD0612 SAHERE LDA SELECT+1     SET SA=SELECT.
4050 166A 8D5315         STA SA+1
4060 166D AD0512         LDA SELECT
4070 1670 8D5215         STA SA
4080 1673 60             RTS              RETURN WITH SA=SELECT.
4090              ;
4100 1674 20E414 TOOLOW JSR PRINT:       SINCE USER SET ENDING
4110              ;                       ADDRESS TOO LOW, PUT A
4120             ;                        PROMPT ON THE SCREEN:
4130 1677 7F             .BYTE TEX
4140 1678 0D             .BYTE CR,LF,LF,LF,' ERROR!!! '
4140 1679 0A
4140 167A 0A
4140 167B 0A
4140 167C 20
4140 167D 45
4140 167E 52
4140 167F 52
4140 1680 4F
4140 1681 52
4140 1682 21
4140 1683 21
4140 1684 21
4140 1685 20
4150 1686 45             .BYTE 'END ADDRESS LESS THAN START ADDRESS,'
4150 1687 4E
4150 1688 44
4150 1689 20
4150 168A 41
4150 168B 44
4150 168C 44
4150 168D 52
4150 168E 45
```

```
4150 168F 53
4150 1690 53
4150 1691 20
4150 1692 4C
4150 1693 45
4150 1694 53
4150 1695 53
4150 1696 20
4150 1697 54
4150 1698 48
4150 1699 41
4150 169A 4E
4150 169B 20
4150 169C 53
4150 169D 54
4150 169E 41
4150 169F 52
4150 16A0 54
4150 16A1 20
4150 16A2 41
4150 16A3 44
4150 16A4 44
4150 16A5 52
4150 16A6 45
4150 16A7 53
4150 16A8 53
4150 16A9 2C
4160 16AA 20             .BYTE ' WHICH IS ',ETX
4160 16AB 57
4160 16AC 48
4160 16AD 49
4160 16AE 43
4160 16AF 48
4160 16B0 20
4160 16B1 49
4160 16B2 53
4160 16B3 20
4160 16B4 FF
4170 16B5 205B16         JSR PR.SA       PRINT START ADDRESS.
4180               ;
4190 16B8 4C1C16         JMP SET.EA      AND LET THE USER SET A
4200               ;                     NEW END ADDRESS.
4210               ;
4220               ;
4230               ;
4240               ;
4250               ;
4260               ;
4270               ;
4280               ;
4290               ;
4300               ; *********************************************
4310               ;
4320               ;         PRINT START ADDRESS
4330               ;
4340               ; *********************************************
4350               ;
4360               ;
```

```
4370                  ;
4380                  ;
4390 16BB A924   PR.SA  LDA #'$        PRINT A DOLLAR SIGN, TO
4400 16BD 204014        JSR PR.CHR     INDICATE HEXADECIMAL.
4410                  ;
4420 16C0 AD5315        LDA SA+1       PRINT HIGH BYTE OF START
4430 16C3 208314        JSR PR.BYT     ADDRESS.
4440                  ;
4450 16C6 AD5215        LDA SA         PRINT LOW BYTE OF START
4460 16C9 208314        JSR PR.BYT
4470 16CC 60            RTS            RETURN TO CALLER.
4480                  ;
4490                  ;
4500                  ;
4510                  ;
4520                  ;
4530                  ;
4540                  ;
4550                  ; *********************************************
4560                  ;
4570                  ;         PRINT END ADDRESS
4580                  ;
4590                  ; *********************************************
4600                  ;
4610                  ;
4620                  ;
4630                  ;
4640                  ;
4650 16CD A924   PR.EA  LDA #'$        PRINT A DOLLAR SIGN, TO
4660 16CF 204014        JSR PR.CHR     INDICATE HEXADECIMAL.
4670 16D2 AD5515        LDA EA+1       PRINT HIGH BYTE OF END
4680 16D5 208314        JSR PR.BYT     ADDRESS.
4690 16D8 AD5415        LDA EA         PRINT LOW BYTE OF END
4700 16DB 208314        JSR PR.BYT     ADDRESS.
4710 16DE 60            RTS            RETURN TO CALLER.
4720                  ;
4730                  ;
4740                  ;
4750                  ;
4760                  ;
4770                  ;
4780                  ;
4790                  ;
4800                  ;
4810                  ;
4820                  ; *********************************************
4830                  ;
4840                  ;         PRINT RANGE OF ADDRESSES
4850                  ;
4860                  ; *********************************************
4870                  ;
4880                  ;
4890                  ;
4900                  ;
4910                  ;
4920 16DF 20BB16 RANGE  JSR PR.SA      PRINT STARTING ADDRESS.
4930 16E2 A92D          LDA #'-        PRINT A HYPHEN.
4940 16E4 204014        JSR PR.CHR
```

```
4950 16E7 20CD16        JSR PR.EA       PRINT END ADDRESS.
4960 16EA 60            RTS             RETURN TO CALLER.
4970               ;
4980               ;
4990               ;
5000               ;
5010               ;
5020               ;
5030               ;
5040               ;
5050               ;
5060               ;
5070               ; ********************************************
5080               ;
5090               ;          PRINT HEADER
5100               ;
5110               ; ********************************************
5120               ;
5130               ;
5140               ;
5150               ;
5160               ;
5170 16EB 20E414 HEADER JSR PRINT:
5180 16EE 7F            .BYTE TEX
5190 16EF 0D            .BYTE CR,LF,LF,'DUMPING '
5190 16F0 0A
5190 16F1 0A
5190 16F2 44
5190 16F3 55
5190 16F4 4D
5190 16F5 50
5190 16F6 49
5190 16F7 4E
5190 16F8 47
5190 16F9 20
5200 16FA FF            .BYTE ETX
5210 16FB 20DF16        JSR RANGE
5220 16FE 207214        JSR CR.LF
5230 1701 20E414        JSR PRINT:
5240 1704 7F            .BYTE TEX,LF,LF
5240 1705 0A
5240 1706 0A
5250 1707 20            .BYTE '         0  1  2  3  4  5  6  7 '
5250 1708 20
5250 1709 20
5250 170A 20
5250 170B 20
5250 170C 20
5250 170D 20
5250 170E 20
5250 170F 30
5250 1710 20
5250 1711 20
5250 1712 31
5250 1713 20
5250 1714 20
5250 1715 32
5250 1716 20
```

```
5250 1717 20
5250 1718 33
5250 1719 20
5250 171A 20
5250 171B 34
5250 171C 20
5250 171D 20
5250 171E 35
5250 171F 20
5250 1720 20
5250 1721 36
5250 1722 20
5250 1723 20
5250 1724 37
5250 1725 20
5250 1726 20
5260 1727 38          .BYTE '8  9  A  B  C  D  E  F'
5260 1728 20
5260 1729 20
5260 172A 39
5260 172B 20
5260 172C 20
5260 172D 41
5260 172E 20
5260 172F 20
5260 1730 42
5260 1731 20
5260 1732 20
5260 1733 43
5260 1734 20
5260 1735 20
5260 1736 44
5260 1737 20
5260 1738 20
5260 1739 45
5260 173A 20
5260 173B 20
5260 173C 46
5270 173D 0D          .BYTE CR,LF,LF,ETX
5270 173E 0A
5270 173F 0A
5270 1740 FF
5280 1741 60          RTS
5290             ;
5300             ;
5310             ;
5320             ;
5330             ;
5340             ;
5350             ;
5360             ;
5370             ;
5380             ;
5390             ; ********************************************
5400             ;
5410             ;          DUMP ONE LINE TO PRINTER
5420             ;
5430             ; ********************************************
```

```
5440                   ;
5450                   ;
5460                   ;
5470                   ;
5480                   ;
5490 1742 207214 PRLINE JSR CR.LF
5500 1745 AD0512        LDA SELECT      DETERMINE STARTING COLUMN.
5510 1748 48            PHA             FOR THIS DUMP.
5520 1749 290F          AND #$0F
5530 174B 8D5615        STA COLUMN      NOW COLUMN HOLDS NUMBER OF
5540                   ;                HEX COLUMN IN WHICH WE DUMP
5550                   ;                THE FIRST BYTE.
5560 174E 68            PLA             SET SELECT=BEGINNING OF A
5570 174F 29F0          AND #$F0        HEX LINE.
5580 1751 8D0512        STA SELECT
5590 1754 20A115        JSR PR.ADR      PRINT LINE'S START ADDRESS.
5600 1757 A203          LDX #3          SPACE 3 TIMES--TO THE
5610 1759 209614        JSR SPACES      FIRST HEX COLUMN.
5620                   ;
5630                   ;
5640 175C AD5615        LDA COLUMN      DO WE DUMP FROM THE FIRST
5650                   ;                HEX COLUMN?
5660 175F F00D          BEQ COL.OK      IF SO, WERE AT THE CORRECT
5670                   ;                COLUMN NOW.
5680                   ;
5690 1761 A203   LOOP   LDX #3          IF NOT, SPACE 3 TIMES FOR
5700 1763 209614        JSR SPACES      EACH BYTE NOT DUMPED.
5710 1766 200D13        JSR INC.SL
5720 1769 CE5615        DEC COLUMN
5730 176C D0F3          BNE LOOP
5740                   ;
5750 176E 209A15 COL.OK JSR DUMPSL      DUMP SELECTED BYTE.
5760 1771 207D14        JSR SPACE       SPACE ONCE.
5770 1774 208317        JSR NEXTSL      SELECT NEXT BYTE
5780                   ;
5790 1777 3009          BMI EXIT        MINUS MEANS WE'VE DUMPED
5800                   ;                THROUGH TO THE END ADDRESS.
5810                   ;
5820                   ;
5830 1779 AD0512 NOT.EA LDA SELECT      DUMPED ENTIRE LINE?
5840 177C 290F          AND #$0F        (4LSB OF SELECT=0?)
5850 177E C900          CMP #0          IF SO, WE'VE DUMPED THE
5860                   ;                ENTIRE LINE.  IF NOT,
5870 1780 D0EC          BNE COL.OK      SELECT NEXT BYTE AND DUMP IT.
5880 1782 60     EXIT   RTS             RETURN MINUS IF EA DUMPED;
5890                   ;                RETURN PLUS IF EA NOT DUMPED.
5900                   ;
5910                   ;
5920                   ;
5930                   ;
5940                   ;
5950                   ;
5960                   ;
5970                   ;
5980                   ;
5990                   ;
6000                   ; *********************************************
6010                   ;
```

```
6020                ;       SELECT NEXT BYTE (IF < END ADDRESS)
6030                ;
6040                ; ********************************************
6050                ;
6060                ;
6070                ;
6080                ;
6090                ;
6100 1783 38       NEXTSL SEC
6110 1784 AD0612          LDA SELECT+1   HIGH BYTE OF SELECT LESS
6120 1787 CD5515          CMP EA+1       THAN HIGH BYTE OF EA?
6130 178A 900B            BCC SL.OK      IF SO, SELECT<END ADDRESS.
6140 178C D00F            BNE NO.INC     IF SELECT>EA, DON'T
6150                ;                    INCREMENT SELECT.
6160                ;
6170 178E 38              SEC            SELECT IS IN SAME PAGE AS EA.
6180 178F AD0512          LDA SELECT
6190 1792 CD5415          CMP EA
6200 1795 B006            BCS NO.INC
6210                ;
6220 1797 200D13 SL.OK    JSR INC.SL     SINCE SELECT <= EA, WE MAY
6230                ;                    INCREMENT SELECT.
6240                ;
6250 179A A900            LDA #0         SET "INCREMENTED" RETURN
6260 179C 60              RTS            CODE AND RETURN.
6270                ;
6280 179D A9FF     NO.INC LDA #$FF       SET "NO INCREMENT" RETURN
6290 179F 60              RTS            CODE AND RETURN.
6300                ;
6310                ;
6320                ;
6330                ;
6340                ;
6350                ;
6360                ; ********************************************
6370                ;
6380                ;          SELECT START ADDRESS
6390                ;
6400                ; ********************************************
6410                ;
6420                ;
6430                ;
6440                ;
6450                ;
6460 17A0 AD5215 GOTOSA LDA SA           SET SELECT=SA.
6470 17A3 8D0512        STA SELECT
6480 17A6 AD5315        LDA SA+1
6490 17A9 8D0612        STA SELECT+1
6500 17AC 60            RTS              RETURN W?SELECT=SA.
```

Appendix C6:

Table-Driven Disassembler (Top Level and Utility Subroutines)

```
      ;       APPENDIX C6: ASSEMBLER LISTING OF
      ;          TABLE-DRIVEN DISASSEMBLER
      ;
      ;       TOP-LEVEL AND UTILITY SUBROUTINES
      ;
      ;
      ;
      ;
      ;     SEE CHAPTER 9 OF BEYOND GAMES: SYSTEM
      ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
      ;
      ;
      ;                  BY KEN SKIER
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ; ***********************************************
      ;
      ;          CONSTANTS
      ;
      ; ***********************************************
      ;
      ;
      ;
      ;
      ;
000D=         CR = $0D         CARRIAGE RETURN.
      ;
000A=         LF = $0A         LINE FEED.
      ;
      ;
007F=         TEX = $7F        THIS CHARACTER MUST START
                               ANY MESSAGE.
      ;
      ;
00FF=         ETX = $FF        THIS CHARACTER MUST END
                               ANY MESSAGE.
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ; ***********************************************
      ;
      ;          EXTERNAL ADDRESSES
      ;
      ; ***********************************************
```

```
              ;
              ;
              ;
              ;
              ;
1200=                 VMPAGE=$1200   STARTING PAGE OF VISIBLE
              ;                      MONITOR CODE.
1205=                 SELECT=VMPAGE+5
1207=                 VISMON=VMPAGE+7
1294=                 GET.SL=VMPAGE+$94
130D=                 INC.SL=VMPAGE+$10D
131A=                 DEC.SL=VMPAGE+$11A
              ;
              ;
1400=                 PRPAGE=$1400   STARTING PAGE OF PRINT
              ;                      UTILITIES.
1408=                 TVT.ON=PRPAGE+8
140E=                 TVTOFF=PRPAGE+$0E
1414=                 PR.ON =PRPAGE+$14
141A=                 PR.OFF=PRPAGE+$1A
1440=                 PR.CHR=PRPAGE+$40
1472=                 CR.LF =PRPAGE+$72
147D=                 SPACE =PRPAGE+$7D
1496=                 SPACES=PRPAGE+$96
1483=                 PR.BYT=PRPAGE+$83
14E4=                 PRINT:=PRPAGE+$E4
1512=                 PUSHSL=PRPAGE+$112
152B=                 POP.SL=PRPAGE+$12B
              ;
              ;
1500=                 HEX.PG=$1500   ADDRESS OF PAGE IN WHICH
              ;                      HEXDUMP CODE STARTS.
              ;
1552=                 SA=HEX.PG+$52
1554=                 EA=SA+2
159A=                 DUMPSL=HEX.PG+$9A
15A1=                 PR.ADR=HEX.PG+$A1
16DF=                 RANGE=HEX.PG+$1DF
15E9=                 SETADS=HEX.PG+$E9
1783=                 NEXTSL=HEX.PG+$283
17A0=                 GOTOSA=HEX.PG+$2A0
              ;
              ;
              ;
              ;
              ;
              ;            DISASSEMBLER TABLES:
              ;
              ;
              ;
1900=                 DSPAGE=$1900   STARTING PAGE OF DISASSEMBLER
              ;
1B1B=                 SUBS  =DSPAGE+$21B
1B50=                 MNAMES=DSPAGE+$250
1C00=                 MCODES=DSPAGE+$300
1D00=                 MODES =DSPAGE+$400
              ;
              ;
```

```
             ;
             ;
             ; ****************************************
             ;
             ;          VARIABLES
             ;
             ; ****************************************
             ;
             ;
             ;
1900                 *=DSPAGE
             ;
             ;
             ;
             ;
             ;
1900 05     DISLNS .BYTE 5         NUMBER OF LINES TO BE
             ;                     DISASSEMBLED BY TV.DIS.
             ;
1901 00     LINUM  .BYTE 0         DATA CELL: USED BY TV.DIS.
             ;
1902 00     LETTER .BYTE 0         COUNTS LETTERS PRINTED IN
             ;                     A MNEMONIC.  USED BY MNEMON.
             ;
1903 00     TEMP.X .BYTE 0         DATA CELL USED BY MNEMON.
             ;
1904 0000   SUBPTR .WORD 0         POINTER TO A SUBROUTINE.
             ;                     SET, USED BY MODE.X
             ;
1906 00     OPBYTS .BYTE 0         DATA CELL: USED BY FINISH.
             ;
1907 00     OPCHRS .BYTE 0         DATA CELL: USED BY FINISH.
             ;
1908 10     ADRCOL .BYTE 16        STARTING COLUMN FOR ADDRESS
             ;                     FIELD.  OSI C-1P OWNERS:
             ;                     FOR NARROW FORMAT, SET
             ;                     ADRCOL=$0B.  SEE NOTES
             ;                     IN LISTING FOR ADDRESS MODE
             ;                     SUBROUTINES.)
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ****************************************
             ;
             ;          TV-DISASSEMBLER
             ;
             ; ****************************************
             ;
             ;
             ;
             ;
             ;
1909 200814 TV.DIS JSR TVT.ON      SELECT SCREEN FOR OUTPUT.
```

```
1750 190C AD0019        LDA DISLNS     INITIALIZE LINE COUNTER WITH
1760 190F 8D0119        STA LINUM      # OF LINES TO DISASSEMBLE.
1770               ;
1780 1912 A9FF          LDA #$FF       SET END ADDRESS TO $FFFF,
1790 1914 8D5415        STA EA         SO NEXTSL WILL ALWAYS
1800 1917 8D5515        STA EA+1       INCREMENT SELECT POINTER.
1810 191A 207214        JSR CR.LF      ADVANCE TO A NEW LINE.
1820               ;
1830 191D 207D19 TVLOOP JSR DSLINE     DISASSEMBLE ONE LINE.
1840 1920 CE0119        DEC LINUM      DONE LAST LINE YET?
1850 1923 D0F8          BNE TVLOOP     IF NOT, DO NEXT ONE.
1860 1925 60            RTS            IF SO, RETURN.
1870               ;
1880               ;
1890               ;
1900               ;
1910               ;
1920               ;
1930               ;
1940               ;
1950               ;
1960               ;
1970               ; ****************************************************
1980               ;
1990               ;       PRINTING DISASSEMBLER
2000               ;
2010               ; ****************************************************
2020               ;
2030               ;
2040               ;
2050               ;
2060               ;
2070 1926 201A14 PR.DIS JSR PR.OFF     DE-SELECT PRINTER
2080 1929 200814        JSR TVT.ON     SELECT SCREEN FOR OUTPUT.
2090 192C 20E414        JSR PRINT:     DISPLAY TITLE.
2100 192F 7F            .BYTE TEX,CR,LF
2100 1930 0D
2100 1931 0A
2110 1932 20            .BYTE '      PRINTING DISASSEMBLER.'
2110 1933 20
2110 1934 20
2110 1935 20
2110 1936 20
2110 1937 50
2110 1938 52
2110 1939 49
2110 193A 4E
2110 193B 54
2110 193C 49
2110 193D 4E
2110 193E 47
2110 193F 20
2110 1940 44
2110 1941 49
2110 1942 53
2110 1943 41
2110 1944 53
2110 1945 53
```

```
2110 1946 45
2110 1947 4D
2110 1948 42
2110 1949 4C
2110 194A 45
2110 194B 52
2110 194C 2E
2120               ;
2130 194D 0D              .BYTE CR,LF,ETX
2130 194E 0A
2130 194F FF
2140               ;
2150 1950 20E915          JSR SETADS      LET USER SET START, END
2160               ;                      ADDRESSES OF MEMORY TO BE
2170               ;                      DISASSEMBLED.
2180 1953 201414          JSR PR.ON       SELECT PRINTER FOR OUTPUT.
2190 1956 20E414          JSR PRINT:
2200 1959 7F              .BYTE TEX,CR,LF
2200 195A 0D
2200 195B 0A
2210 195C 44              .BYTE 'DISASSEMBLING '
2210 195D 49
2210 195E 53
2210 195F 41
2210 1960 53
2210 1961 53
2210 1962 45
2210 1963 4D
2210 1964 42
2210 1965 4C
2210 1966 49
2210 1967 4E
2210 1968 47
2210 1969 20
2220 196A FF              .BYTE ETX
2230 196B 20DF16          JSR RANGE       PRINT RANGE OF MEMORY TO
2240               ;                      BE DISASSEMBLED.
2250 196E 20A017          JSR GOTOSA      SET SELECT=START OF BLOCK.
2260               ;
2270 1971 207214          JSR CR.LF       ADVANCE TO A NEW LINE.
2280 1974 207D19 PRLOOP   JSR DSLINE      DISASSEMBLE ONE LINE.
2290 1977 10FB            BPL PRLOOP      IF IT WASN'T THE LAST LINE,
2300               ;                      DISASSEMBLE THE NEXT ONE.
2310               ;
2320               ;
2330 1979 201A14          JSR PR.OFF      DE-SELECT PRINTER FOR OUTPUT.
2340               ;
2350 197C 60              RTS             RETURN TO CALLER.
2360               ;
2370               ;
2380               ;
2390               ;
2400               ;
2410               ;
2420               ;
2430               ;
2440               ;
2450               ;
```

```
                   ; ********************************************
                   ;
                   ;          DISASSEMBLE ONE LINE.
                   ;
                   ; ********************************************
                   ;
                   ;
                   ;
                   ;
                   ;
1970 209412 DSLINE JSR GET.SL     GET CURRENTLY-SELECTED BYTE.
1980 48            PHA            SAVE IT ON STACK.
1981 209219        JSR MNEMON     PRINT MNEMONIC REPRESENTED
                   ;              BY THAT OPCODE.
1984 207D14        JSR SPACE      SPACE ONCE.
1987 68            PLA            RESTORE OPCODE.
1988 20AF19        JSR OPERND     PRINT OPERAND REQUIRED BY
                   ;              THAT OPCODE.
198B 20011A        JSR FINISH     FINISH THE LINE BY PRINTING
                   ;              FIELDS 3-6.  FINISH LEAVES
                   ;              SELECT POINTING TO LAST
                   ;              BYTE OF INSTRUCTION.
                   ;
198E 208317        JSR NEXTSL     SELECT NEXT BYTE, IF
                   ;              SELECT<EA.
1991 60            RTS            RETURN W/RETURNCODE FROM
                   ;              NEXTSL.  SELECT POINTS TO
                   ;              NEXT OPCODE, OR SELECT=EA.
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ; ********************************************
                   ;
                   ;          PRINT MNEMONIC
                   ;
                   ; ********************************************
                   ;
                   ;
                   ;
                   ;
                   ;
1992 A203   MNEMON LDX #3         WE'LL PRINT THREE LETTERS.
1994 8E0219        STX LETTER
1997 AA            TAX            PREPARE TO USE OPCODE AS AN
                   ;              INDEX.
                   ;
1998 BD001C        LDA MCODES,X   LOOK UP MNEMONIC CODE FOR
                   ;              THAT OPCODE.  MCODES IS
                   ;              TABLE OF MNEMONIC CODES.
                   ;
199B AA            TAX            PREPARE TO USE THAT MNEMONIC
                   ;              CODE AS AN INDEX.
199C BD501B MNLOOP LDA MNAMES,X   GET A MNEMONIC CHARACTER.
```

```
                   ;                      (MNAMES IS A LIST OF
                   ;                      MNEMONIC NAMES.)
                   ;
199F 8E0319               STX TEMP.X      SAVE X-REGISTER, SINCE
                   ;                      PRINTING MAY CHANGE X.
19A2 204014               JSR PR.CHR      PRINT THE MNEMONIC CHARACTER.
19A5 AE0319               LDX TEMP.X      RESTORE X,
19A8 E8                   INX             ADJUST INDEX FOR NEXT LETTER.
19A9 CE0219               DEC LETTER      PRINTED 3 LETTERS YET?
19AC D0EE                 BNE MNLOOP      IF NOT, PRINT NEXT ONE.
19AE 60                   RTS             IF SO, RETURN TO CALLER.
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ; ********************************************
                   ;
                   ;         PRINT OPERAND
                   ;
                   ; ********************************************
                   ;
                   ;
                   ;
                   ;
                   ;
19AF AA          OPERND TAX               LOOK UP ADDRESSING MODE
19B0 BD001D               LDA MODES,X     CODE FOR THIS OPCODE.
                   ;
19B3 AA                   TAX             X NOW INDICATES ADDRESSING
                   ;                      MODE.
                   ;
19B4 20B819               JSR MODE.X      HANDLE THAT ADDRESSING MODE.
19B7 60                   RTS             RETURN TO CALLER.
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ; ********************************************
                   ;
                   ;        HANDLE ADDRESSING MODE "X"
                   ;
                   ; ********************************************
                   ;
                   ;
                   ;
                   ;
```

```
3620                 ;
3630                 ;
3640 19B8 BD1B1B MODE.X LDA SUBS,X     GET LOW BYTE OF Xth POINTER
3650 19BB 8D0419        STA SUBPTR     IN TABLE OF SUBROUTINE
3660                 ;                 POINTERS.
3670 19BE E8            INX            ADJUST INDEX FOR NEXT BYTE.
3680 19BF BD1B1B        LDA SUBS,X     GET HIGH BYTE OF POINTER.
3690 19C2 8D0519        STA SUBPTR+1
3700 19C5 6C0419        JMP (SUBPTR)   JUMP TO SUBROUTINE SPECIFIED
3710                 ;                 BY SUBROUTINE POINTER.
3720                 ;                 THAT SUBROUTINE WILL RETURN
3730                 ;                 TO THE CALLER OF MODE.X,
3740                 ;                 NOT TO MODE.X ITSELF.
3750                 ;
3760                 ;
3770                 ;
3780                 ;
3790                 ;
3800                 ;
3810                 ;
3820                 ;
3830                 ;
3840                 ;
3850                 ; ********************************************
3860                 ;
3870                 ;          DISASSEMBLER UTILITIES
3880                 ;
3890                 ; ********************************************
3900                 ;
3910                 ;
3920                 ;
3930                 ;
3940                 ;
3950                 ;          PRINT ONE-BYTE OPERAND
3960                 ;
3970                 ;
3980                 ;
3990 19C9 200D13 ONEBYT JSR INC.SL     ADVANCE TO BYTE FOLLOWING
4000                 ;                 OPCODE.
4010 19CB 209A15        JSR DUMPSL     DUMP THAT BYTE.
4020 19CE 60            RTS            RETURN TO CALLER.
4030                 ;
4040                 ;
4050                 ;
4060                 ;
4070                 ;
4080                 ;          PRINT TWO-BYTE OPERAND:
4090                 ;
4100                 ;
4110                 ;
4120 19CF 200D13 TWOBYT JSR INC.SL     ADVANCE TO FIRST BYTE OF
4130                 ;                 OPERAND.
4140 19D2 209412        JSR GET.SL     LOAD THAT BYTE INTO ACC.
4150 19D5 48            PHA            SAVE IT.
4160 19D6 200D13        JSR INC.SL     ADVANCE TO 2ND BYTE OF
4170                 ;                 OPERAND.
4180 19D9 209A15        JSR DUMPSL     DUMP IT.
4190 19DC 68            PLA            RESTORE FIRST BYTE TO ACC.
```

```
4200 19DD 208314        JSR PR.BYT     DUMP IT.
4210 19E0 60            RTS            RETURN TO CALLER.
4220               ;
4230               ;
4240               ;
4250               ;
4260               ;
4270               ;    PRINT LEFT, RIGHT PARENTHESES
4280               ;
4290               ;
4300               ;
4310 19E1 A928   LPAREN LDA #'(
4320 19E3 D002          BNE SENDIT
4330               ;
4340               ;
4350 19E5 A929   RPAREN LDA #')
4360               ;
4370 19E7 204014 SENDIT JSR PR.CHR
4380 19EA 60            RTS
4390               ;
4400               ;
4410               ;
4420               ;
4430               ;
4440               ;      PRINT A COMMA AND AN "X"
4450               ;
4460               ;
4470               ;
4480 19EB A92C   XINDEX LDA #',
4490 19ED 204014        JSR PR.CHR     PRINT A COMMA.
4500 19F0 A958          LDA #'X
4510 19F2 204014        JSR PR.CHR     PRINT AN "X".
4520 19F5 60            RTS
4530               ;
4540               ;
4550               ;
4560               ;
4570               ;
4580               ;      PRINT A COMMA AND A "Y"
4590               ;
4600               ;
4610               ;
4620 19F6 A92C   YINDEX LDA #',
4630 19F8 204014        JSR PR.CHR     PRINT COMMA.
4640 19FB A959          LDA #'Y
4650 19FD 204014        JSR PR.CHR     PRINT A "Y".
4660 1A00 60            RTS
4670               ;
4680               ;
4690               ;
4700               ;
4710               ;
4720               ;
4730               ;
4740               ;
4750               ;
4760               ;
4770               ; *******************************************
```

```
                   ;
                   ;        FINISH THE LINE
                   ;
                   ; ********************************************
                   ;
                   ;
                   ;
                   ;          NOTE:      EVERY ADDRESSING MODE
                   ;                     SUBROUTINE MUST END BY
                   ;                     SETTING X=# OF BYTES IN
                   ;                     OPERAND, AND ACC=# OF
                   ;                     CHARACTERS IN OPERAND.
                   ;
                   ;
                   ;
1A01 8D0719 FINISH STA OPCHRS            SAVE THE LENGTH OF THE
1A04 8E0619        STX OPBYTS            OPERAND, IN CHARACTERS AND
                   ;                     IN BYTES.  0 MEANS NO
                   ;                     OPERAND.
                   ;
1A07 CA            DEX                   IF NECESSARY, DECREMENT THE
                   ;                     SELECT POINTER SO IT POINTS
1A08 3006          BMI SEL.OK            TO THE OPCODE.
1A0A 201A13 LOOP.1 JSR DEC.SL
1A0D CA            DEX
1A0E 10FA          BPL LOOP.1
                   ;                     NOW SELECT POINTS TO OPCODE.
                   ;
                   ;
1A10 08     SEL.OK PHP                   SAVE CALLER'S DECIMAL FLAG.
1A11 D8            CLD                   PREPARE FOR BINARY ADDITION.
1A12 38            SEC                   SPACE OVER TO THE COLUMN
1A13 AD0819        LDA ADRCOL            FOR THE ADDRESS FIELD:
1A16 E904          SBC #4                OPERAND FIELD STARTED IN
                   ;                     COLUMN 4...
1A18 ED0719        SBC OPCHRS            AND INCLUDES OPCHRS
                   ;                     CHARACTERS.
1A1B 28            PLP                   RESTORE CALLER'S DECIMAL FLAG
1A1C AA            TAX
1A1D 209614        JSR SPACES            PRINT ENOUGH SPACES TO
                   ;                     REACH ADDRESS COLUMN.
1A20 20A115        JSR PR.ADR            PRINT ADDRESS OF OPCODE.
                   ;
1A23 207D14 LOOP.2 JSR SPACE             SPACE ONCE.
1A26 209A15        JSR DUMPSL            DUMP SELECTED BYTE.
1A29 200D13        JSR INC.SL            SELECT NEXT BYTE.
1A2C CE0619        DEC OPBYTS            DUMPED LAST BYTE IN
                   ;                     INSTRUCTION?
1A2F 10F2          BPL LOOP.2            IF NOT, DUMP NEXT BYTE.
1A31 201A13        JSR DEC.SL            BACK UP SELECT, SO IT POINTS
                   ;                     TO LAST BYTE IN OPERAND.
                   ;
                   ;
                   ;                     IF SO, GO TO A NEW LINE:
                   ;
1A34 207214 FINEND JSR CR.LF             HAVING DISASSEMBLED ONE LINE,
                   ;                     GO TO A NEW LINE.
1A37 60            RTS                   RETURN TO CALLER.
                   ;
```

Appendix C7:

Table-Driven Disassembler (Addressing Mode Subroutines)

```
      ;       APPENDIX C7: ASSEMBLER LISTING OF
      ;          TABLE-DRIVEN DISASSEMBLER:
      ;
      ;          ADDRESSING MODE SUBROUTINES
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;    SEE CHAPTER 9 OF BEYOND GAMES: SYSTEM
      ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
      ;
      ;
      ;                    BY KEN SKIER
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ;
      ; ************************************************
      ;
      ;          CONSTANTS
      ;
      ; ************************************************
      ;
      ;
      ;
      ;
      ;
000D=         CR = $0D         CARRIAGE RETURN.
      ;
000A=         LF = $0A         LINE FEED.
      ;
      ;
007F=         TEX = $7F        THIS CHARACTER MUST START
      ;                        ANY MESSAGE.
      ;
00FF=         ETX = $FF        THIS CHARACTER MUST END
      ;                        ANY MESSAGE.
      ;
      ;
      ;
      ;
      ;
      ;
```

```
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ; ********************************************
            ;
            ;         EXTERNAL ADDRESSES
            ;
            ; ********************************************
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ;
            ;
1200=               VMPAGE=$1200   STARTING PAGE OF VISIBLE
            ;                      MONITOR CODE.
1205=               SELECT=VMPAGE+5
1207=               VISMON=VMPAGE+7
1294=               GET.SL=VMPAGE+$94
130D=               INC.SL=VMPAGE+$10D
131A=               DEC.SL=VMPAGE+$11A
            ;
            ;
1400=               PRPAGE=$1400   STARTING PAGE OF PRINT
            ;                      UTILITIES.
1440=               PR.CHR=PRPAGE+$40
1472=               CR.LF =PRPAGE+$72
147D=               SPACE =PRPAGE+$7D
1496=               SPACES=PRPAGE+$96
1483=               PR.BYT=PRPAGE+$83
14E4=               PRINT:=PRPAGE+$E4
1512=               PUSHSL=PRPAGE+$112
152B=               POP.SL=PRPAGE+$12B
            ;
            ;
1500=               HEX.PG=$1500   ADDRESS OF PAGE IN WHICH
            ;                      HEXDUMP CODE STARTS.
            ;
15A1=               PR.ADR=HEX.PG+$A1
1783=               NEXTSL=HEX.PG+$283
            ;
            ;
1900=               DSPAGE=$1900   START OF DISASSEMBLER CODE.
            ;
19C8=               ONEBYT=DSPAGE+$C8
19CF=               TWOBYT=DSPAGE+$CF
19E1=               LPAREN=DSPAGE+$E1
19E5=               RPAREN=DSPAGE+$E5
19EB=               XINDEX=DSPAGE+$EB
```

```
1160 19F6=                 YINDEX=DSPAGE+$F6
1170               ;
1180               ;
1190               ;
1200               ;
1210               ;
1220               ;
1230               ;
1240 1A40                  *=DSPAGE+$140
1250               ;
1260               ;
1270               ;
1280               ;
1290               ;
1300               ;
1310               ;
1320               ;
1330               ;
1340               ;
1350               ;
1360               ; ********************************************
1370               ;
1380               ;          ADDRESSING MODE SUBROUTINES
1390               ;
1400               ; ********************************************
1410               ;
1420               ;
1430               ;
1440               ;
1450               ;
1460               ;
1470               ;          ABSOLUTE MODE
1480               ;
1490               ;
1500               ;
1510 1A40 20CF19 ABSLUT JSR TWOBYT       PRINT A TWO-BYTE OPERAND.
1520 1A43 A202          LDX #2           OPERAND HAS TWO BYTES...
1530 1A45 A904          LDA #4           ...AND FOUR CHARACTERS.
1540 1A47 60            RTS              RETURN TO CALLER.
1550               ;
1560               ;
1570               ;
1580               ;
1590               ;
1600               ;          ABSOLUTE,X MODE
1610               ;
1620               ;
1630               ;
1640 1A48 20401A ABS.X  JSR ABSLUT
1650 1A4B 20EB19        JSR XINDEX       PRINT A COMMA AND AN "X".
1660 1A4E A202          LDX #2           OPERAND HAS 2 BYTES...
1670 1A50 A906          LDA #6           ...AND SIX CHARACTERS.
1680 1A52 60            RTS              RETURN TO CALLER.
1690               ;
1700               ;
1710               ;
1720               ;
1730               ;
```

```
             ;         ABSOLUTE.Y MODE
             ;
             ;
             ;
1A53 20401A ABS.Y  JSR ABSLUT
1A56 20F619        JSR YINDEX
1A59 A202          LDX #2
1A5B A906          LDA #6
1A5D 60            RTS
             ;
             ;
             ;
             ;
             ;
             ;         ACCUMULATOR MODE
             ;
             ;
1A5E A941   ACC    LDA #'A         PRINT THE LETTER "A"
1A60 204014        JSR PR.CHR
1A63 A200          LDX #0          OPERAND HAS NO BYTES...
1A65 A901          LDA #1          ...AND ONE CHARACTER.
1A67 60            RTS             RETURN TO CALLER.
             ;
             ;
             ;
             ;
             ;
             ;         IMPLIED MODE
             ;
             ;
             ;
1A68 A200   IMPLID LDX #0          OPERAND HAS NO BYTES...
1A6A A900          LDA #0          ...AND NO CHARACTERS.
1A6C 60            RTS
             ;
             ;
             ;
             ;
             ;
             ;         IMMEDIATE MODE
             ;
             ;
             ;
1A6D A923   IMMEDT LDA #'#         PRINT A "#" CHARACTER.
1A6F 204014        JSR PR.CHR
             ;
1A72 A924          LDA #'$         PRINT A DOLLAR SIGN TO
1A74 204014        JSR PR.CHR      INDICATE HEXADECIMAL.
1A77 20C819        JSR ONEBYT      PRINT ONE-BYTE OPERAND IN
             ;                     HEXADECIMAL FORMAT.
1A7A A201          LDX #1          OPERAND HAS ONE BYTE...
1A7C A904          LDA #4          ...AND FOUR CHARACTERS.
1A7E 60            RTS             RETURN TO CALLER.
             ;
             ;
             ;
             ;
             ;
```

```
            ;         INDIRECT MODE
            ;
            ;
            ;
1A7F 20E119 INDRCT JSR LPAREN     PRINT LEFT PARENTHESIS.
1A82 20401A        JSR ABSLUT     PRINT TWO-BYTE OPERAND.
1A85 20E519        JSR RPAREN     PRINT RIGHT PARENTHESIS.
1A88 A906          LDA #6         A HOLDS NUMBER OF CHARACTERS
            ;                     IN OPERAND.
1A8A A202          LDX #2         X HOLDS NUMBER OF BYTES IN
            ;                     OPERAND.
1A8C 60            RTS            RETURN TO CALLER.
            ;
            ;
            ;
            ;
            ;
            ;         INDIRECT,X MODE
            ;
            ;
            ;
1A8D 20E119 IND.X  JSR LPAREN
1A90 20E81A        JSR ZERO.X     PRINT A ZERO PAGE ADDRESS,
            ;                     A COMMA, AND THE LETTER "X".
1A93 20E519        JSR RPAREN
1A96 A201          LDX #1         ONE BYTE IN OPERAND.
1A98 A908          LDA #8         8 CHARACTERS IN OPERAND.
            ;                     (C-IP OWNERS: A9 06, NOT
            ;                     A9 08, FOR NARROW FORMAT.)
1A9A 60            RTS
            ;
            ;
            ;
            ;
            ;
            ;      INDIRECT,Y MODE
            ;
            ;
            ;
1A9B 20E119 IND.Y  JSR LPAREN
1A9E 20DB1A        JSR ZEROPG     PRINT A ZERO PAGE ADDRESS.
1AA1 20E519        JSR RPAREN
1AA4 20F619        JSR YINDEX     PRINT A COMMA AND A "Y".
1AA7 A201          LDX #1         OPERAND HAS 1 BYTE...
1AA9 A908          LDA #8         ...AND 8 CHARACTERS.
            ;                     (C-IP OWNERS: A9 06, NOT
            ;                     A9 08, FOR NARROW FORMAT.)
1AAB 60            RTS
            ;
            ;
            ;
            ;
            ;
            ;         RELATIVE MODE
            ;
            ;
            ;
1AAC 200D13 RELATV JSR INC.SL     SELECT NEXT BYTE.
```

```
2900 1AAF 201215          JSR PUSHSL     SAVE SELECT POINTER ON STACK.
2910 1AB2 209412          JSR GET.SL     GET OPERAND BYTE.
2920 1AB5 48              PHA            SAVE IT ON STACK.
2930 1AB6 200D13          JSR INC.SL     INCREMENT SELECT POINTER
2940               ;                     SO IT POINTS TO NEXT OPCODE.
2950               ;                     (RELATIVE BRANCHES ARE
2960               ;                     RELATIVE TO NEXT OPCODE.)
2970 1AB9 68              PLA            RESTORE OPERAND BYTE TO ACC.
2980 1ABA C900            CMP #0         IS IT PLUS OR MINUS?
2990 1ABC 1003            BPL FORWRD     IF PLUS, IT MEANS A FORWARD
3000               ;                     BRANCH.
3010               ;
3020               ;                     OPERAND IS MINUS, SO WE'LL
3030               ;                     BRANCH BACKWARD.
3040 1ABE CE0612          DEC SELECT+1   BRANCHING BACKWARD IS LIKE
3050               ;                     BRANCHING FORWARD FROM ONE
3060               ;                     PAGE LOWER IN MEMORY.
3070               ;
3080               ;
3090 1AC1 08       FORWRD PHP            SAVE CALLER'S DECIMAL FLAG.
3100 1AC2 D8              CLD            CLEAR DECIMAL MODE, FOR
3110               ;                     BINARY ADDITION.
3120 1AC3 18              CLC            PREPARE TO ADD.
3130 1AC4 6D0512          ADC SELECT     ADD OPERAND BYTE TO SELECT.
3140 1AC7 9003            BCC RELEND
3150 1AC9 EE0612          INC SELECT+1
3160 1ACC 8D0512 RELEND STA SELECT       NOW SELECT POINTS TO ADDRESS
3170               ;                     SPECIFIED BY RELATIVE
3180               ;                     BRANCH INSTRUCTION.
3190 1ACF 28              PLP            RESTORE CALLER'S DECIMAL
3200               ;                     FLAG.
3210 1AD0 20A115          JSR PR.ADR     PRINT ADDRESS SPECIFIED
3220               ;                     BY INSTRUCTION.
3230 1AD3 202B15          JSR POP.SL     RESTORE SELECT=ADDRESS OF
3240               ;                     OPERAND.
3250 1AD6 A201            LDX #1         OPERAND HAD ONE BYTE...
3260 1AD8 A904            LDA #4         AND FOUR CHARACTERS.
3270 1ADA 60              RTS            RETURN TO CALLER.
3280               ;
3290               ;
3300               ;
3310               ;
3320               ;           ZERO PAGE MODE
3330               ;
3340               ;
3350               ;
3360               ;
3370 1ADB A900    ZEROPG LDA #0          PRINT TWO ASCII ZERO'S TO
3380 1ADD 208314          JSR PR.BYT     ALL SELECTED BYTES.
3390               ;                     (C-IP OWNERS: SUBSTITUTE NOPS
3400               ;                     --EA EA EA--FOR JSR PR.BYT.
3410               ;                     TO GET NARROW FORMAT.
3420 1AE0 20C819          JSR ONEBYT     PRINT ONE-BYTE OPERAND.
3430 1AE3 A201            LDX #1         OPERAND HAS ONE BYTE...
3440 1AE5 A904            LDA #4         ...AND FOUR CHARACTERS.
3450               ;                     (C-IP OWNERS:A9 02,
3460               ;                     NOT A9 04, FOR NARROW FORMAT.)
3470 1AE7 60              RTS
```

```
             ;
             ;
             ;
             ;
             ;
             ;          ZERO PAGE, X  MODE
             ;
             ;
             ;
1AE8 20DB1A ZERO.X JSR ZEROPG     PRINT THE ZERO PAGE ADDRESS.
1AEB 20EB19        JSR XINDEX     PRINT A COMMA AND AN "X".
1AEE A201          LDX #1         OPERAND HAS 1 BYTE...
1AF0 A906          LDA #6         ...AND SIX CHARACTERS.
             ;                    (C-IP OWNERS: A9 04,
             ;                    NOT A9 06, FOR NARROW FORMAT.)
1AF2 60            RTS            RETURN TO CALLER.
             ;
             ;
             ;
             ;
             ;
             ;          ZERO PAGE ,Y MODE
             ;
             ;
             ;
1AF3 20DB1A ZERO.Y JSR ZEROPG
1AF6 20F619        JSR YINDEX
1AF9 A201          LDX #1
1AFB A906          LDA #6         (C-IP OWNERS: A9 04 HERE
             ;                    FOR NARROW FORMAT.)
1AFD 60            RTS
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;       A PSEUDO-ADDRESSING MODE
             ;     FOR EMBEDDED TEXT: TEXT MODE.
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
             ;
             ;     THE PSEUDO-OPCODE TEX ($7F) BEGINS ANY
             ; STRING OF TEXT AND PRINT CONTROL CHARACTERS.
             ; THE PSEUDO-TEXT CHARACTER ETX ($FF) ENDS ANY
```

```
                    ; SUCH STRING.  TEX HAS A PSEUDO-ADDRESSING
                    ; MODE: TEXT MODE.  IN TEXT MODE, WE PRINT THE
                    ; STRING AND RETURN, WITHOUT DUMPING THE LINE
                    ; IN HEX.  THE STRING MAY BE OF ANY LENGTH.
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
1AFE 68            TXMODE PLA              POP RETURN ADDRESS TO
1AFF 68                   PLA              OPERND.
                    ;
1B00 68                   PLA              POP RETURN ADDRESS TO
1B01 68                   PLA              DSLINE.
                    ;
                    ;                      NOW DSLINE'S CALLER IS ON
                    ;                      THE STACK.
                    ;
                    ;
1B02 208317               JSR NEXTSL       ADVANCE PAST TEX PSEUDO-OP.
1B05 300D                 BMI TXEXIT       RETURN IF REACHED EA.
1B07 209412               JSR GET.SL       GET THE CHARACTER.
1B0A C9FF                 CMP #ETX         IS IT END OF TEXT?
1B0C F006                 BEQ TXEXIT       IF SO, STRING ENDED.
1B0E 204014               JSR PR.CHR       IF NOT, PRINT CHARACTER.
1B11 18                   CLC              BRANCH BACK TO GET NEXT
1B12 90EE                 BCC TXMODE+4     CHARACTER.
                    ;
                    ;
1B14 207214        TXEXIT JSR CR.LF        ADVANCE TO A NEW LINE.
1B17 208317               JSR NEXTSL       ADVANCE TO NEXT OPCODE.
1B1A 60                   RTS              RETURN TO CALLER OF DSLINE.
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ;
                    ; ********************************************
                    ;
                    ;     TABLE OF ADDRESSING MODE SUBROUTINES
                    ;
                    ; ********************************************
                    ;
                    ;
                    ;
                    ;
                    ;
```

```
4640 1B1B 681A   SUBS   .WORD IMPLID   ADDRESSING MODE 0 IS INVALID,
4650              ;                    HENCE IMPLIED.
4660 1B1D 5E1A          .WORD ACC
4670 1B1F 6D1A          .WORD IMMEDT
4680 1B21 DB1A          .WORD ZEROPG
4690 1B23 E81A          .WORD ZERO.X
4700 1B25 F31A          .WORD ZERO.Y
4710 1B27 401A          .WORD ABSLUT
4720 1B29 481A          .WORD ABS.X
4730 1B2B 531A          .WORD ABS.Y
4740 1B2D 681A          .WORD IMPLID
4750 1B2F AC1A          .WORD RELATV
4760 1B31 8D1A          .WORD IND.X
4770 1B33 9B1A          .WORD IND.Y
4780 1B35 7F1A          .WORD INDRCT
4790 1B37 FE1A          .WORD TXMODE
```

Appendix C8:

Table-Driven Disassembler (Tables)

```
          ;       APPENDIX C8: ASSEMBLER LISTING OF
          ;          TABLE-DRIVEN DISASSEMBLER
          ;
          ;                        TABLES
          ;
          ;
          ;
          ;
          ;     SEE CHAPTER 9 OF BEYOND GAMES: SYSTEM
          ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
          ;
          ;
          ;                      BY KEN SKIER
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ; ********************************************
          ;
          ;          CONSTANTS
          ;
          ; ********************************************
          ;
          ;
          ;
          ;
          ;
          ;
          ;
007F=             TEX = $7F       THIS CHARACTER MUST START
          ;                       ANY MESSAGE.
          ;
00FF=             ETX = $FF       THIS CHARACTER MUST END
          ;                       ANY MESSAGE.
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
          ;
```

```
580                ;
590                ;
600  1900=                DSPAGE=$1900   STARTING PAGE OF DISASSEMBLER
610                ;
620                ;
630                ;
640                ;
650                ;
660                ; ******************************************
670                ;
680                ;          LIST OF MNEMONICS
690                ;
700                ; ******************************************
710                ;
720                ;
730                ;
740  1B50                  *=DSPAGE+$250
750                ;
760                ;
770                ;
780                ;
790                ;
800  1B50 7F       MNAMES .BYTE TEX          SINCE THIS TABLE IS A
                                             STRING OF CHARACTERS, START
                                             IT WITH THE TEX PSEUDO-OP.
810                ;
820                ;
830                ;
840  1B51  42              .BYTE 'BAD'
840  1B52  41
840  1B53  44
850  1B54  41              .BYTE 'ADC'
850  1B55  44
850  1B56  43
860  1B57  41              .BYTE 'AND'
860  1B58  4E
860  1B59  44
870  1B5A  41              .BYTE 'ASL'
870  1B5B  53
870  1B5C  4C
880  1B5D  42              .BYTE 'BCC'
880  1B5E  43
880  1B5F  43
890  1B60  42              .BYTE 'BCS'
890  1B61  43
890  1B62  53
900  1B63  42              .BYTE 'BEQ'
900  1B64  45
900  1B65  51
910  1B66  42              .BYTE 'BIT'
910  1B67  49
910  1B68  54
920  1B69  42              .BYTE 'BMI'
920  1B6A  4D
920  1B6B  49
930  1B6C  42              .BYTE 'BNE'
930  1B6D  4E
930  1B6E  45
940  1B6F  42              .BYTE 'BPL'
940  1B70  50
```

```
 940 1B71 4C
 950 1B72 42          .BYTE 'BRK'
 950 1B73 52
 950 1B74 4B
 960 1B75 42          .BYTE 'BVC'
 960 1B76 56
 960 1B77 43
 970 1B78 42          .BYTE 'BVS'
 970 1B79 56
 970 1B7A 53
 980 1B7B 43          .BYTE 'CLC'
 980 1B7C 4C
 980 1B7D 43
 990 1B7E 43          .BYTE 'CLD'
 990 1B7F 4C
 990 1B80 44
1000 1B81 43          .BYTE 'CLI'
1000 1B82 4C
1000 1B83 49
1010 1B84 43          .BYTE 'CLV'
1010 1B85 4C
1010 1B86 56
1020 1B87 43          .BYTE 'CMP'
1020 1B88 4D
1020 1B89 50
1030 1B8A 43          .BYTE 'CPX'
1030 1B8B 50
1030 1B8C 58
1040 1B8D 43          .BYTE 'CPY'
1040 1B8E 50
1040 1B8F 59
1050 1B90 44          .BYTE 'DEC'
1050 1B91 45
1050 1B92 43
1060 1B93 44          .BYTE 'DEX'
1060 1B94 45
1060 1B95 58
1070 1B96 44          .BYTE 'DEY'
1070 1B97 45
1070 1B98 59
1080 1B99 45          .BYTE 'EOR'
1080 1B9A 4F
1080 1B9B 52
1090 1B9C 49          .BYTE 'INC'
1090 1B9D 4E
1090 1B9E 43
1100 1B9F 49          .BYTE 'INX'
1100 1BA0 4E
1100 1BA1 58
1110 1BA2 49          .BYTE 'INY'
1110 1BA3 4E
1110 1BA4 59
1120 1BA5 4A          .BYTE 'JMP'
1120 1BA6 4D
1120 1BA7 50
1130 1BA8 4A          .BYTE 'JSR'
1130 1BA9 53
1130 1BAA 52
```

```
1140 1BAB 4C            .BYTE 'LDA'
1140 1BAC 44
1140 1BAD 41
1150 1BAE 4C            .BYTE 'LDX'
1150 1BAF 44
1150 1BB0 58
1160 1BB1 4C            .BYTE 'LDY'
1160 1BB2 44
1160 1BB3 59
1170 1BB4 4C            .BYTE 'LSR'
1170 1BB5 53
1170 1BB6 52
1180 1BB7 4E            .BYTE 'NOP'
1180 1BB8 4F
1180 1BB9 50
1190 1BBA 4F            .BYTE 'ORA'
1190 1BBB 52
1190 1BBC 41
1200 1BBD 50            .BYTE 'PHA'
1200 1BBE 48
1200 1BBF 41
1210 1BC0 50            .BYTE 'PHP'
1210 1BC1 48
1210 1BC2 50
1220 1BC3 50            .BYTE 'PLA'
1220 1BC4 4C
1220 1BC5 41
1230 1BC6 50            .BYTE 'PLP'
1230 1BC7 4C
1230 1BC8 50
1240 1BC9 52            .BYTE 'ROL'
1240 1BCA 4F
1240 1BCB 4C
1250 1BCC 52            .BYTE 'ROR'
1250 1BCD 4F
1250 1BCE 52
1260 1BCF 52            .BYTE 'RTI'
1260 1BD0 54
1260 1BD1 49
1270 1BD2 52            .BYTE 'RTS'
1270 1BD3 54
1270 1BD4 53
1280 1BD5 53            .BYTE 'SBC'
1280 1BD6 42
1280 1BD7 43
1290 1BD8 53            .BYTE 'SEC'
1290 1BD9 45
1290 1BDA 43
1300 1BDB 53            .BYTE 'SED'
1300 1BDC 45
1300 1BDD 44
1310 1BDE 53            .BYTE 'SEI'
1310 1BDF 45
1310 1BE0 49
1320 1BE1 53            .BYTE 'STA'
1320 1BE2 54
1320 1BE3 41
1330 1BE4 53            .BYTE 'STX'
```

```
1330 1BE5 54
1330 1BE6 58
1340 1BE7 53            .BYTE 'STY'
1340 1BE8 54
1340 1BE9 59
1350 1BEA 54            .BYTE 'TAX'
1350 1BEB 41
1350 1BEC 58
1360 1BED 54            .BYTE 'TAY'
1360 1BEE 41
1360 1BEF 59
1370 1BF0 54            .BYTE 'TSX'
1370 1BF1 53
1370 1BF2 58
1380 1BF3 54            .BYTE 'TXA'
1380 1BF4 58
1380 1BF5 41
1390 1BF6 54            .BYTE 'TXS'
1390 1BF7 58
1390 1BF8 53
1400 1BF9 54            .BYTE 'TYA'
1400 1BFA 59
1400 1BFB 41
1410 1BFC 54            .BYTE 'TEX'
1410 1BFD 45
1410 1BFE 58
1420                 ;
1430 1BFF FF            .BYTE ETX      SINCE THIS IS THE END OF A
1440                 ;                 STRING OF CHARACTERS, USE
1450                 ;                 ETX TO INDICATE END OF TEXT.
1460                 ;
1470                 ;
1480                 ;
1490                 ;
1500                 ;
1510                 ;
1520                 ;
1530                 ;
1540                 ;
1550                 ;
1560                 ;
1570                 ; ********************************************
1580                 ;
1590                 ;         TABLE OF MNEMONIC CODES
1600                 ;
1610                 ; ********************************************
1620                 ;
1630                 ;
1640                 ;
1650                 ;
1660                 ;
1670                 ;     A MNEMONIC'S CODE IS ITS OFFSET INTO
1680                 ;  MNAMES, THE LIST OF MNEONIC NAMES.
1690                 ;
1700                 ;
1710                 ;
1720 1C00 22        MCODES .BYTE $22,$6A,1,1,1,$6A,$0A,1,$70
1720 1C01 6A
```

```
1720 1C02 01
1720 1C03 01
1720 1C04 01
1720 1C05 6A
1720 1C06 0A
1720 1C07 01
1720 1C08 70
1730 1C09 6A                  .BYTE $6A,$0A,1,1,$6A,$0A,1
1730 1C0A 0A
1730 1C0B 01
1730 1C0C 01
1730 1C0D 6A
1730 1C0E 0A
1730 1C0F 01
1740 1C10 1F                  .BYTE $1F,$6A,1,1,1,$6A,$0A,1
1740 1C11 6A
1740 1C12 01
1740 1C13 01
1740 1C14 01
1740 1C15 6A
1740 1C16 0A
1740 1C17 01
1750 1C18 2B                  .BYTE $2B,$6A,1,1,1,$6A,$0A,1
1750 1C19 6A
1750 1C1A 01
1750 1C1B 01
1750 1C1C 01
1750 1C1D 6A
1750 1C1E 0A
1750 1C1F 01
1760 1C20 58                  .BYTE $58,7,1,1,$16,7,$79,1
1760 1C21 07
1760 1C22 01
1760 1C23 01
1760 1C24 16
1760 1C25 07
1760 1C26 79
1760 1C27 01
1770 1C28 76                  .BYTE $76,7,$79,1,$16,7,$79,1
1770 1C29 07
1770 1C2A 79
1770 1C2B 01
1770 1C2C 16
1770 1C2D 07
1770 1C2E 79
1770 1C2F 01
1780 1C30 19                  .BYTE $19,7,1,1,1,7,$79,1
1780 1C31 07
1780 1C32 01
1780 1C33 01
1780 1C34 01
1780 1C35 07
1780 1C36 79
1780 1C37 01
1790 1C38 88                  .BYTE $88,7,1,1,1,7,$79,1
1790 1C39 07
1790 1C3A 01
1790 1C3B 01
```

```
1790 1C3C 01
1790 1C3D 07
1790 1C3E 79
1790 1C3F 01
1800 1C40 7F                    .BYTE $7F,$49,1,1,1,$49,$64,1
1800 1C41 49
1800 1C42 01
1800 1C43 01
1800 1C44 01
1800 1C45 49
1800 1C46 64
1800 1C47 01
1810 1C48 6D                    .BYTE $6D,$49,$64,1,$55,$49,$64,1
1810 1C49 49
1810 1C4A 64
1810 1C4B 01
1810 1C4C 55
1810 1C4D 49
1810 1C4E 64
1810 1C4F 01
1820 1C50 25                    .BYTE $25,$49,1,1,1,$49,$64,1
1820 1C51 49
1820 1C52 01
1820 1C53 01
1820 1C54 01
1820 1C55 49
1820 1C56 64
1820 1C57 01
1830 1C58 31                    .BYTE $31,$49,1,1,1,$49,$64,1
1830 1C59 49
1830 1C5A 01
1830 1C5B 01
1830 1C5C 01
1830 1C5D 49
1830 1C5E 64
1830 1C5F 01
1840 1C60 82                    .BYTE $82,4,1,1,1,4,$7C,1
1840 1C61 04
1840 1C62 01
1840 1C63 01
1840 1C64 01
1840 1C65 04
1840 1C66 7C
1840 1C67 01
1850 1C68 73                    .BYTE $73,4,$7C,1,$55,4,$7C,1
1850 1C69 04
1850 1C6A 7C
1850 1C6B 01
1850 1C6C 55
1850 1C6D 04
1850 1C6E 7C
1850 1C6F 01
1860 1C70 28                    .BYTE $28,4,1,1,1,4,$7C,1
1860 1C71 04
1860 1C72 01
1860 1C73 01
1860 1C74 01
1860 1C75 04
```

```
1860 1C76 7C
1860 1C77 01
1870 1C78 8E              .BYTE $8E,4,1,1,1,4,$7C,$AC
1870 1C79 04
1870 1C7A 01
1870 1C7B 01
1870 1C7C 01
1870 1C7D 04
1870 1C7E 7C
1870 1C7F AC
1880 1C80 01              .BYTE 1,$91,1,1,$97,$91,$94,1
1880 1C81 91
1880 1C82 01
1880 1C83 01
1880 1C84 97
1880 1C85 91
1880 1C86 94
1880 1C87 01
1890 1C88 46              .BYTE $46,1,$A3,1,$97,$91,$94,1
1890 1C89 01
1890 1C8A A3
1890 1C8B 01
1890 1C8C 97
1890 1C8D 91
1890 1C8E 94
1890 1C8F 01
1900 1C90 0D              .BYTE $0D,$91,1,1,$97,$91,$94,1
1900 1C91 91
1900 1C92 01
1900 1C93 01
1900 1C94 97
1900 1C95 91
1900 1C96 94
1900 1C97 01
1910 1C98 A9              .BYTE $A9,$91,$A3,1,1,$91,1,1
1910 1C99 91
1910 1C9A A3
1910 1C9B 01
1910 1C9C 01
1910 1C9D 91
1910 1C9E 01
1910 1C9F 01
1920 1CA0 61              .BYTE $61,$5B,$5E,1,$61,$5B,$5E,1
1920 1CA1 5B
1920 1CA2 5E
1920 1CA3 01
1920 1CA4 61
1920 1CA5 5B
1920 1CA6 5E
1920 1CA7 01
1930 1CA8 9D              .BYTE $9D,$5B,$9A,1,$61,$5B,$5E,1
1930 1CA9 5B
1930 1CAA 9A
1930 1CAB 01
1930 1CAC 61
1930 1CAD 5B
1930 1CAE 5E
1930 1CAF 01
```

```
1940 1CB0 10            .BYTE $10,$5B,1,1,$61,$5B,$5E,1
1940 1CB1 5B
1940 1CB2 01
1940 1CB3 01
1940 1CB4 61
1940 1CB5 5B
1940 1CB6 5E
1940 1CB7 01
1950 1CB8 34            .BYTE $34,$5B,$9E,1,$61,$5B,$5E,1
1950 1CB9 5B
1950 1CBA 9E
1950 1CBB 01
1950 1CBC 61
1950 1CBD 5B
1950 1CBE 5E
1950 1CBF 01
1960 1CC0 3D            .BYTE $3D,$37,1,1,$3D,$37,$40,1
1960 1CC1 37
1960 1CC2 01
1960 1CC3 01
1960 1CC4 3D
1960 1CC5 37
1960 1CC6 40
1960 1CC7 01
1970 1CC8 52            .BYTE $52,$37,$43,1,$3D,$37,$40,1
1970 1CC9 37
1970 1CCA 43
1970 1CCB 01
1970 1CCC 3D
1970 1CCD 37
1970 1CCE 40
1970 1CCF 01
1980 1CD0 1C            .BYTE $1C,$37,1,1,1,$37,$40,1
1980 1CD1 37
1980 1CD2 01
1980 1CD3 01
1980 1CD4 01
1980 1CD5 37
1980 1CD6 40
1980 1CD7 01
1990 1CD8 2E            .BYTE $2E,$37,1,1,1,$37.$40,1
1990 1CD9 37
1990 1CDA 01
1990 1CDB 01
1990 1CDC 01
1990 1CDD 37
1990 1CDE 40
1990 1CDF 01
2000 1CE0 3A            .BYTE $3A,$85.1,1,$3A,$85,$4C,1
2000 1CE1 85
2000 1CE2 01
2000 1CE3 01
2000 1CE4 3A
2000 1CE5 85
2000 1CE6 4C
2000 1CE7 01
2010 1CE8 4F            .BYTE $4F,$85.$67,1,$3A,$85,$4C.1
2010 1CE9 85
```

```
2010 1CEA 67
2010 1CEB 01
2010 1CEC 3A
2010 1CED 85
2010 1CEE 4C
2010 1CEF 01
2020 1CF0 13            .BYTE $13,$85,1,1,1,$85,$4C,1
2020 1CF1 85
2020 1CF2 01
2020 1CF3 01
2020 1CF4 01
2020 1CF5 85
2020 1CF6 4C
2020 1CF7 01
2030 1CF8 8B            .BYTE $8B,$85,1,1,1,$85,$4C,1
2030 1CF9 85
2030 1CFA 01
2030 1CFB 01
2030 1CFC 01
2030 1CFD 85
2030 1CFE 4C
2030 1CFF 01
2040             ;
2050             ;
2060             ;
2070             ;
2080             ;
2090             ;
2100             ;
2110             ;
2120             ;
2130             ;
2140             ;
2150             ; ********************************************
2160             ;
2170             ;        TABLE OF ADDRESSING MODE CODES
2180             ;
2190             ; ********************************************
2200             ;
2210             ;
2220             ;
2230             ;
2240             ;     AN ADDRESSING MODE'S CODE IS ITS OFFSET
2250             ; INTO SUBS, THE TABLE OF ADDRESSING MODE
2260             ; SUBROUTINES.
2270             ;
2280             ;
2290             ;
2300             ;
2310             ;
2320             ;
2330 1D00 12     MODES  .BYTE 18,22,0,0,0,6,6,0
2330 1D01 16
2330 1D02 00
2330 1D03 00
2330 1D04 00
2330 1D05 06
2330 1D06 06
```

```
2330 1D07 00
2340 1D08 12              .BYTE 18,4,2,0,0,12,12,0
2340 1D09 04
2340 1D0A 02
2340 1D0B 00
2340 1D0C 00
2340 1D0D 0C
2340 1D0E 0C
2340 1D0F 00
2350 1D10 14              .BYTE 20,24.0,0,0.14,14,0
2350 1D11 18
2350 1D12 00
2350 1D13 00
2350 1D14 00
2350 1D15 0E
2350 1D16 0E
2350 1D17 00
2360 1D18 12              .BYTE 18,16,0,0.0,22,22,0
2360 1D19 10
2360 1D1A 00
2360 1D1B 00
2360 1D1C 00
2360 1D1D 16
2360 1D1E 16
2350 1D1F 00
2370 1D20 0C              .BYTE 12,22,0,0,6,6,6,0
2370 1D21 16
2370 1D22 00
2370 1D23 00
2370 1D24 06
2370 1D25 06
2370 1D26 06
2370 1D27 00
2380 1D28 12              .BYTE 18,4,2,0,12,12,12,0
2380 1D29 04
2380 1D2A 02
2380 1D2B 00
2380 1D2C 0C
2380 1D2D 0C
2380 1D2E 0C
2380 1D2F 00
2390 1D30 14              .BYTE 20.24,0,0.0,8,8,0
2390 1D31 18
2390 1D32 00
2350 1D33 00
2390 1D34 00
2390 1D35 08
2390 1D36 08
2390 1D37 00
2400 1D38 12              .BYTE 16,16.0,0,0,14,14,0
2400 1D39 10
2400 1D3A 00
2400 1D3B 00
2400 1D3C 00
2400 1D3D 0E
2400 1D3E 0E
2400 1D3F 00
2410 1D40 12              .BYTE 18,22,0,0.0,6,6,0
```

```
2410 1D41 16
2410 1D42 00
2410 1D43 00
2410 1D44 00
2410 1D45 06
2410 1D46 06
2410 1D47 00
2420 1D48 12                  .BYTE 18,12,2,0,12,12,12,0
2420 1D49 0C
2420 1D4A 02
2420 1D4B 00
2420 1D4C 0C
2420 1D4D 0C
2420 1D4E 0C
2420 1D4F 00
2430 1D50 14                  .BYTE 20,24,0,0,0,8,8,0
2430 1D51 18
2430 1D52 00
2430 1D53 00
2430 1D54 00
2430 1D55 08
2430 1D56 08
2430 1D57 00
2440 1D58 12                  .BYTE 18,16,0,0,0,14,14,0
2440 1D59 10
2440 1D5A 00
2440 1D5B 00
2440 1D5C 00
2440 1D5D 0E
2440 1D5E 0E
2440 1D5F 00
2450 1D60 12                  .BYTE 18,22,0,0,0,6,6,0
2450 1D61 16
2450 1D62 00
2450 1D63 00
2450 1D64 00
2450 1D65 06
2450 1D66 06
2450 1D67 00
2460 1D68 12                  .BYTE 18,4,2,0,26,12,12,0
2460 1D69 04
2460 1D6A 02
2460 1D6B 00
2460 1D6C 1A
2460 1D6D 0C
2460 1D6E 0C
2460 1D6F 00
2470 1D70 14                  .BYTE 20,24,0,0,0,8,8,0
2470 1D71 18
2470 1D72 00
2470 1D73 00
2470 1D74 00
2470 1D75 08
2470 1D76 08
2470 1D77 00
2480 1D78 12                  .BYTE 18,16,0,0,0,14,14,28
2480 1D79 10
2480 1D7A 00
```

```
2480 1D7B 00
2480 1D7C 00
2480 1D7D 0E
2480 1D7E 0E
2480 1D7F 1C
2490
2500 1D80 00            .BYTE 0,22,0,0,6,6,6,0
2500 1D81 16
2500 1D82 00
2500 1D83 00
2500 1D84 06
2500 1D85 06
2500 1D86 06
2500 1D87 00
2510 1D88 12            .BYTE 18,0,18,0,12,12,12,0
2510 1D89 00
2510 1D8A 12
2510 1D8B 00
2510 1D8C 0C
2510 1D8D 0C
2510 1D8E 0C
2510 1D8F 00
2520 1D90 14            .BYTE 20,24,0,0,8,8,10,0
2520 1D91 18
2520 1D92 00
2520 1D93 00
2520 1D94 08
2520 1D95 08
2520 1D96 0A
2520 1D97 00
2530 1D98 12            .BYTE 18,16,18,0,0,14,0,0
2530 1D99 10
2530 1D9A 12
2530 1D9B 00
2530 1D9C 00
2530 1D9D 0E
2530 1D9E 00
2530 1D9F 00
2540 1DA0 04            .BYTE 4,22,4,0,6,6,6,0
2540 1DA1 16
2540 1DA2 04
2540 1DA3 00
2540 1DA4 06
2540 1DA5 06
2540 1DA6 06
2540 1DA7 00
2550 1DA8 12            .BYTE 18,4,18,0,12,12,12.0
2550 1DA9 04
2550 1DAA 12
2550 1DAB 00
2550 1DAC 0C
2550 1DAD 0C
2550 1DAE 0C
2550 1DAF 00
2560 1DB0 14            .BYTE 20,24,0.0,8,8,10,0
2560 1DB1 18
2560 1DB2 00
2560 1DB3 00
```

```
2560 1DB4 08
2560 1DB5 08
2560 1DB6 0A
2560 1DB7 00
2570 1DB8 14                    .BYTE 20,16,18,0,14,14,16,0
2570 1DB9 10
2570 1DBA 12
2570 1DBB 00
2570 1DBC 0E
2570 1DBD 0E
2570 1DBE 10
2570 1DBF 00
2580 1DC0 04                    .BYTE 4,22,0,0,6,6,6,0
2580 1DC1 16
2580 1DC2 00
2580 1DC3 00
2580 1DC4 06
2580 1DC5 06
2580 1DC6 06
2580 1DC7 00
2590 1DC8 12                    .BYTE 18,4,18,0,12,12,12,0
2590 1DC9 04
2590 1DCA 12
2590 1DCB 00
2590 1DCC 0C
2590 1DCD 0C
2590 1DCE 0C
2590 1DCF 00
2600 1DD0 14                    .BYTE 20,24,0,0,0,8,8,0
2600 1DD1 18
2600 1DD2.00
2600 1DD3 00
2600 1DD4 00
2600 1DD5 08
2600 1DD6 08
2600 1DD7 00
2610 1DD8 12                    .BYTE 18,16,0,0,0,14,14,0
2610 1DD9 10
2610 1DDA 00
2610 1DDB 00
2610 1DDC 00
2610 1DDD 0E
2610 1DDE 0E
2610 1DDF 00
2620 1DE0 04                    .BYTE 4,22,0,0,6,6,6,0
2620 1DE1 16
2620 1DE2 00
2620 1DE3 00
2620 1DE4 06
2620 1DE5 06
2620 1DE6 06
2620 1DE7 00
2630 1DE8 12                    .BYTE 18,4,18,0,12,12,12,0
2630 1DE9 04
2630 1DEA 12
2630 1DEB 00
2630 1DEC 0C
2630 1DED 0C
```

```
2630 1DEE 0C
2630 1DEF 00
2640 1DF0 14            .BYTE 20,24,0,0,0,8,8,0
2640 1DF1 18
2640 1DF2 00
2640 1DF3 00
2640 1DF4 00
2640 1DF5 08
2640 1DF6 08
2640 1DF7 00
2650 1DF8 12            .BYTE 18,16.0,0,0.14.14,0
2650 1DF9 10
2650 1DFA 00
2650 1DFB 00
2650 1DFC 00
2650 1DFD 0E
2650 1DFE 0E
2650 1DFF 00
```

Appendix C9:

Move Utilities

```
                  ;      APPENDIX C9: ASSEMBLER LISTING OF
                  ;                   MOVE UTILITIES
                  ;
                  ;
                  ;
                  ;      SEE CHAPTER 10 OF BEYOND GAMES: SYSTEMS
                  ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER.
                  ;
                  ;                    BY KEN SKIER
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ; ********************************************
                  ;
                  ;          CONSTANTS
                  ;
                  ; ********************************************
                  ;
                  ;
                  ;
                  ;
                  ;
000D=                   CR=$0D          CARRIAGE RETURN.
000A=                   LF=$0A          LINE FEED.
007F=                   TEX=$7F         START OF TEXT CHARACTER.
00FF=                   ETX=$FF         END OF TEXT CHARACTER.
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ; ********************************************
                  ;
                  ;          EXTERNAL ADDRESSES
                  ;
                  ; ********************************************
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
1200=                   VMPAGE=$1200    STARTING PAGE OF VISIBLE
                  ;                     MONITOR CODE.
                  ;
1205=                   SELECT=VMPAGE+5
1207=                   VISMON=VMPAGE+7
                  ;
                  ;
                  ;
1400=                   PRPAGE=$1400    STARTING PAGE OF PRINT CODE.
                  ;
```

```
590 1408=               TVT.ON=PRPAGE+8
600 14E4=               PRINT:=PRPAGE+$E4
610 1512=               PUSHSL=PRPAGE+$112
620 152B=               POP.SL=PRPAGE+$12B
630               ;
640               ;
650 1500=               HEX.PG=$1500   ADDRESS OF PAGE IN WHICH
660               ;                    HEXDUMP CODE STARTS.
670               ;                    (HEXDUMP CODE STARTS AT
680               ;                    $1550, BUT IT'S EASIER TO
690               ;                    COUNT FROM $1500.)
700               ;
710 15E9=               SETADS=HEX.PG+$E9
720               ;
730               ;
740               ;
750               ;
760               ;
770               ;
780               ;
790               ;
800               ; *********************************************
810               ;
820               ;       VARIABLES
830               ;
840               ; *********************************************
850               ;
860               ;
870               ;
880               ;
890               ;
900 17B0                *=$17B0
910               ;
920               ;
930 1552=               SA=HEX.PG+$52  POINTER TO START ADDRESS
940               ;                    OF BLOCK TO BE MOVED.
950               ;
960 1554=               EA=SA+2        POINTER TO END OF BLOCK TO
970               ;                    BE MOVED.
1000              ;
1010 17B0 0000    NUM   .WORD 0        NUMBER OF BYTES IN BLOCK
1020              ;                    TO BE MOVED.  ZERO MEANS
1030              ;                    BLOCK CONTAINS 1 BYTE.
1040              ;
1050              ;
1060 17B2 0000    DEST  .WORD 0        POINTER TO BLOCK'S
1070              ;'                   DESTINATION.
1080              ;
1090              ;
1100              ;
1110              ;
1120              ;
1130              ;
1140              ;
1150 0000=              GETPTR=0       THESE TWO "PAGE POINTERS"
1160 0002=              PUTPTR=GETPTR+2 GET AND PUT BYTES.
1170              ;
1180 .            ;
```

```
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;          MOVE TOOL
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
             ;
             ;
17B4 200814 MOVER  JSR TVT.ON     SELECT SCREEN FOR OUTPUT.
17B7 20E414        JSR PRINT:     DISPLAY A TITLE.
17BA 7F            .BYTE TEX,CR,LF
17BB 0D
17BC 0A
17BD 20            .BYTE '     MOVE TOOL.'
17BE 20
17BF 20
17C0 20
17C1 20
17C2 4D
17C3 4F
17C4 56
17C5 45
17C6 20
17C7 54
17C8 4F
17C9 4F
17CA 4C
17CB 2E
17CC 0D            .BYTE CR,LF,LF,ETX
17CD 0A
17CE 0A
17CF FF
             ;
17D0 20E915        JSR SETADS     GET START ADDRESS, END
             ;                    ADDRESS FROM USER.
             ;
17D3 20B918        JSR SET.DA     GET DESTINATION ADDRESS
             ;                    FROM USER.
             ;                    WITH THOSE POINTERS SET,
             ;                    WE'RE READY TO EXECUTE MOV.EA:
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
```

```
                  ;
                  ;  MOV.EA:    MOVE BLOCK SPECIFIED BY SA, EA, DEST
                  ;
                  ; *********************************************
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;  RETURN CODES:
                  ;
                  ;
0000=                    ERROR=0         THIS RETURN CODE MEANS
                  ;                      SA < EA, SO MOVE ABORTED.
00FF=                    OKAY=$FF        THIS RETURN CODE MEANS
                  ;                      MOVE ACCOMPLISHED.
                  ;
                  ;
17D6 AE5515 MOV.EA LDX EA+1              SET NUM = EA - SA:
17D9 38            SEC
17DA AD5415        LDA EA
17DD ED5215        SBC SA
17E0 8DB017        STA NUM
17E3 B002          BCS MOVE.1
17E5 CA            DEX
17E6 38            SEC
17E7 8A     MOVE.1 TXA
17E8 ED5315        SBC SA+1
17EB 8DB117        STA NUM+1
17EE B003          BCS MOVNUM
                  ;
17F0 A900   ER.RTN LDA #ERROR            IF EA < SA,
17F2 60            RTS                   RETURN WITH ERROR CODE.
                  ;
                  ;
                  ;
                  ;
                  ; *********************************************
                  ;
                  ; MOVNUM: MOVE BLOCK SPECIFIED BY SA, NUM, DEST.
                  ;
                  ; *********************************************
                  ;
                  ;
                  ;
17F3 A003   MOVNUM LDY #3                SAVE ZERO PAGE BYTES THAT
17F5 B90000 LOOP.1 LDA GETPTR,Y          WILL BE CHANGED.
17F8 48            PHA
17F9 88            DEY
17FA 10F9          BPL LOOP.1
                  ;
                  ;
17FC 38            SEC                   IF DEST>SA, BRANCH TO MOVE-UP
17FD AD5315        LDA SA+1
1800 CDB317        CMP DEST+1
1803 9040          BCC MOVEUP
1805 D018          BNE MOVEDN
                  ;                      IF DEST<SA, BRANCH T
```

```
                 ;                       MOVE-DOWN.
1807 AD5215              LDA SA
180A CDB217              CMP DEST
180D 9036                BCC MOVEUP
180F D00E                BNE MOVEDN      IF DEST=SA,
1811 A000        OK.RTN  LDY #0          RETURN BEARING "OKAY" CODE.
                 ;                       RESTORE ZERO PAGE BYTES
1813 68          LOOP.2  PLA             THAT WERE CHANGED.
1814 990000              STA GETPTR,Y
1817 C8                  INY
1818 C004                CPY #4
181A D0F7                BNE LOOP.2
181C A9FF                LDA #OKAY       RETURN W/"OKAY" CODE.
181E 60                  RTS
                 ;
                 ;
                 ;
181F 20A418      MOVEDN  JSR LOPAGE      SET PAGE POINTERS TO LOWEST
                 ;                       PAGES IN ORIGIN, DESTINATION
                 ;                       BLOCKS.
                 ;
                 ;
1822 A000                LDY #0          INITIALIZE PAGE INDEX TO
                 ;                       BOTTOM OF PAGE.
                 ;
1824 AEB117              LDX NUM+1       USE X TO COUNT THE NUMBER
                 ;                       OF PAGES TO MOVE.  MORE THAN
                 ;                       ONE PAGE TO MOVE?
1827 F00E                BEQ LESSDN      IF NOT, MOVE LESS THAN A
                 ;                       PAGE.
                 ;
                 ;                       IF SO,
1829 B100        PAGEDN  LDA (GETPTR),Y  MOVE A PAGE DOWN,
182B 9102                STA (PUTPTR),Y  STARTING AT THE BOTTOM.
182D C8                  INY             INCREMENT PAGE INDEX.
182E D0F9                BNE PAGEDN      IF PAGE NOT MOVED, MOVE
                 ;                       NEXT BYTE...
                 ;
1830 E601                INC GETPTR+1    INCREMENT PAGE POINTERS.
1832 E603                INC PUTPTR+1
1834 CA                  DEX             DECREMENT PAGE COUNT.
1835 D0F2                BNE PAGEDN      IF A PAGE LEFT TO MOVE,
                 ;                       MOVE IT AS A PAGE.
                 ;
1837 88          LESSDN  DEY
1838 C8                  INY             MOVE LESS THAN A PAGE
1839 B100                LDA (GETPTR),Y  DOWN, STARTING AT THE
183B 9102                STA (PUTPTR),Y  BOTTOM.
183D CCB017              CPY NUM         MOVED LAST BYTE?
1840 D0F6                BNE LESSDN+1    IF NOT, MOVE NEXT BYTE...
1842 4C1118              JMP OK.RTN      IF SO, RETURN BEARING
                 ;                       "OKAY" CODE.
                 ;
                 ;
                 ;
1845 ADB117      MOVEUP  LDA NUM+1       MORE THAN A PAGE TO MOVE?
1848 F048                BEQ LESSUP      IF NOT, MOVE LESS THAN A
                 ;                       PAGE.
```

```
              ;
              ;
              ;
              ;                       TO MOVE MORE THAN A PAGE,
              ;                       SET PAGE POINTERS TO
              ;                       HIGHEST PAGES IN ORIGIN,
              ;                       DESTINATION BLOCKS.
              ;
              ;
              ;                       TO DO THIS, FIRST
              ;                       SET (X,Y) = NUM - $FF,
              ;                       (RELATIVE ADDRESS OF
              ;                       HIGHEST PAGE IN A BLOCK.)
              ;
              ;
184A ACB117          LDY NUM+1
184D ADB017          LDA NUM
1850 38              SEC
1851 E9FF            SBC #$FF
1853 B001            BCS NEXT.1
1855 88              DEY
1856 AA       NEXT.1 TAX
              ;
              ;                       NOW (X,Y) - NUM - $FF.
              ;                       X IS LOW BYTE, Y IS HIGH BYTE
              ;
              ;
1857 8403            STY PUTPTR+1
1859 8A              TXA
185A 18              CLC
185B 6D5215          ADC SA
185E 8500            STA GETPTR
1860 9001            BCC NEXT.2
1862 C8              INY
              ;
              ;
1863 98       NEXT.2 TYA
1864 6D5315          ADC SA+1
1867 8501            STA GETPTR+1
              ;
              ;    PTR=SA+NUM-$FF.
              ;                       (LAST PAGE IN SOURCE BLOCK.)
              ;
              ;
1869 8A              TXA
186A 18              CLC
186B 6DB217          ADC DEST
186E 8502            STA PUTPTR
1870 9002            BCC NEXT.3
1872 E603            INC PUTPTR+1
              ;
              ;
1874 A503     NEXT.3 LDA PUTPTR+1
1876 6DB317          ADC DEST+1
1879 8503            STA PUTPTR+1
              ;                       NOW PUTPTR=DEST+NUM-$FF.
              ;                       (LAST PAGE IN DEST BLOCK.)
              ;
```

```
                 ;
                 ;
187B AEB117             LDX NUM+1      LOAD X WITH NUMBER OF
                 ;                     PAGES TO MOVE.
                 ;
187E A0FF        PAGEUP LDY #$FF       SET PAGE INDEX TO TOP OF
                 ;                     PAGE.
1880 B100        LOOP.3 LDA (GETPTR),Y MOVE A PAGE UP, STARTING
1882 9102               STA (PUTPTR),Y AT THE TOP OF THE BLOCK.
1884 88                 DEY            DECREMENT PAGE INDEX.
                 ;                     ABOUT TO MOVE LAST BYTE
                 ;                     IN PAGE?
1885 D0F9               BNE LOOP.3     IF NOT, HANDLE NEXT BYTE.
                 ;                     AS BEFORE.
                 ;
                 ;
                 ;
1887 B100               LDA (GETPTR),Y IF SO, MOVE THIS BYTE FROM
1889 9102               STA (PUTPTR),Y SOURCE TO DESTINATION.
188B C601               DEC GETPTR+1
188D C603               DEC PUTPTR+1   DECREMENT PAGE POINTERS.
188F CA                 DEX            DECREMENT PAGE COUNTER.
1890 D0EC               BNE PAGEUP     IF A PAGE LEFT TO MOVE,
                 ;                     MOVE IT AS A PAGE....
                 ;
                 ;
1892 20A418      LESSUP JSR LOPAGE     MOVE LESS THAN A PAGE UP,
1895 ACB017             LDY NUM        STARTING AT THE TOP.
                 ;
1898 B100        MOVE.6 LDA (GETPTR),Y COPY A BYTE FROM ORIGIN
189A 9102               STA (PUTPTR),Y TO DESTINATION.
189C 88                 DEY            DECREMENT PAGE INDEX.
189D C0FF               CPY #$FF       COPIED THE LAST BYTE?
189F D0F7               BNE MOVE.6     IF NOT, HANDLE AS BEFORE...
18A1 4C1118             JMP OK.RTN     IF SO, RETURN BEARING
                 ;                     "OKAY" CODE.
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ; *********************************************
                 ;
                 ;      SET PAGE POINTERS TO BOTTOM OF
                 ;        ORIGIN, DESTINATION BLOCKS.
                 ;
                 ; *********************************************
                 ;
                 ;
                 ;
                 ;
                 ;
```

```
3900 18A4 AD5215 LOPAGE LDA SA
3910 18A7 8500          STA GETPTR
3920 18A9 AD5315        LDA SA+1
3930 18AC 8501          STA GETPTR+1
3940                ;
3950                ;
3960 18AE ADB217        LDA DEST
3970 18B1 8502          STA PUTPTR
3980 18B3 ADB317        LDA DEST+1
3990 18B6 8503          STA PUTPTR+1
4000                ;
4010                ;
4020 18B8 60            RTS
4030                ;
4040                ;
4050                ;
4060                ;
4070                ;
4080                ;
4090                ;
4100                ;
4110                ; ********************************************
4120                ;
4130                ;      LET USER SET DESTINATION ADDRESS
4140                ;
4150                ; ********************************************
4160                ;
4170                ;
4180                ;
4190                ;
4200                ;
4210                ;
4220                ;
4230                ;
4240                ;
4250                ;
4260                ;
4270                ;
4280                ;
4290 18B9 200814 SET.DA JSR TVT.ON     LET USER SET DESTINATION
4300 18BC 20E414        JSR PRINT:
4310 18BF 7F            .BYTE TEX,CR,LF
4310 18C0 0D
4310 18C1 0A
4320 18C2 53             BYTE 'SET DESTINATION AND PRESS Q.'
4320 18C3 45
4320 18C4 54
4320 18C5 20
4320 18C6 44
4320 18C7 45
4320 18C8 53
4320 18C9 54
4320 18CA 49
4320 18CB 4E
4320 18CC 41
4320 18CD 54
4320 18CE 49
4320 18CF 4F
```

```
4320 18D0 4E
4320 18D1 20
4320 18D2 41
4320 18D3 4E
4320 18D4 44
4320 18D5 20
4320 18D6 50
4320 18D7 52
4320 18D8 45
4320 18D9 53
4320 18DA 53
4320 18DB 20
4320 18DC 51
4320 18DD 2E
4330 18DE FF              .BYTE ETX
4340 18DF 200712          JSR VISMON      LET USER SET AN ADDRESS.
4350 18E2 AD0512 DAHERE LDA SELECT      SET DEST=SELECT.
4360 18E5 8DB217          STA DEST
4370 18E8 AD0612          LDA SELECT+1
4380 18EB 8DB317          STA DEST+1
4390               ;
4400 18EE 60              RTS             RETURN WITH DEST=SELECT.
```

Appendix C10:

Simple Text Editor (Top Level and Display Subroutines)

```
           ;        APPENDIX C10: ASSEMBLER LISTING OF
           ;             A SIMPLE TEXT EDITOR
           ;            TOP LEVEL AND DISPLAY SUBROUTINES
           ;
           ;
           ;
           ;
           ;
           ;      SEE CHAPTER 11 OF BEYOND GAMES: SYSTEMS
           ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
           ;
           ;
           ;                      BY KEN SKIER
           ;
           ;
           ;
           ;
           ;
           ;
           ;
           ;
           ;
           ;
           ;
           ; ********************************************
           ;
           ;         CONSTANTS
           ;
           ; ********************************************
           ;
           ;
           ;
           ;
           ;
000D=          CR = $0D       CARRIAGE RETURN.
           ;
000A=          LF = $0A       LINE FEED.
           ;
           ;
007F=          TEX = $7F      THIS CHARACTER MUST START
                              ANY MESSAGE.
           ;
           ;
00FF=          ETX = $FF      THIS CHARACTER MUST END
                              ANY MESSAGE.
           ;
           ;
0049=          INSCHR=' I     GRAPHIC FOR INSERT MODE
004F=          OVRCHR=' O     GRAPHIC FOR OVERSTRIKE MODE.
           ;
           ;
           ;
           ;
           ;
           ;
           ;
           ;
           ; ********************************************
           ;
           ;         EXTERNAL ADDRESSES
```

```
          ;
          ; ********************************************
          ;
          ;
          ;
0000=            TV.PTR=0        POINTER TO A SCREEN ADDRESS.
1000=            PARAMS=$1000    SYSTEM DATA BLOCK.
          ;
          ;
1003=            TVCOLS=PARAMS+3
1004=            TVROWS=PARAMS+4
1007=            ARROW=PARAMS+7
          ;
          ;
          ;
1100=            TVSUBS=$1100
1113=            CLR.XY=TVSUBS+$13
112B=            TVHOME=TVSUBS+$2B
113C=            TVTOXY=TVSUBS+$3C
1176=            TVDOWN=TVSUBS+$76
117F=            TVSKIP=TVSUBS+$7F
1181=            TVPLUS=TVSUBS+$81
119B=            TV.PUT=TVSUBS+$9B
11A3=            VUBYTE=TVSUBS+$A3
11C4=            TVPUSH=TVSUBS+$C4
11D3=            TV.POP=TVSUBS+$D3
          ;
          ;
1200=            VMPAGE=$1200    STARTING PAGE OF VISIBLE
          ;                      MONITOR CODE.
1205=            SELECT=VMPAGE+5
1294=            GET.SL=VMPAGE+$94
130D=            INC.SL=VMPAGE+$10D
131A=            DEC.SL=VMPAGE+$11A
          ;
          ;
1400=            PRPAGE=$1400    STARTING PAGE OF PRINT
          ;                      UTILITIES.
1408=            TVT.ON=PRPAGE+8
140E=            TVTOFF=PRPAGE+$0E
1414=            PR.ON =PRPAGE+$14
141A=            PR.OFF=PRPAGE+$1A
1440=            PR.CHR=PRPAGE+$40
14E4=            PRINT:=PRPAGE+$E4
1512=            PUSHSL=PRPAGE+$112
152B=            POP.SL=PRPAGE+$12B
          ;
          ;
1500=            HEX.PG=$1500    ADDRESS OF PAGE IN WHICH
          ;                      HEXDUMP CODE STARTS.
          ;
1552=            SA=HEX.PG+$52
1554=            EA=SA+2
15E9=            SETADS=HEX.PG+$E9
1783=            NEXTSL=HEX.PG+$283
17A0=            GOTOSA=HEX.PG+$2A0
          ;
          ;
```

```
1170 1E00=              EDPAGE=$1E00   STARTING PAGE OF EDITOR.
1180 1EC8=              EDITIT=EDPAGE+$C8
1190              ;
1200              ;
1210              ;
1220              ;
1230              ;
1240              ;
1250              ; ********************************************
1260              ;
1270              ;          VARIABLES
1280              ;
1290              ; ********************************************
1300              ;
1310              ;
1320              ;
1330 1E00               *=EDPAGE
1340              ;
1350              ;
1360              ;
1370 1E00 00      COUNTR .BYTE 0        COUNTER USED BY LINE.2.
1380 1E01 00      EDMODE .BYTE 0        FLAG: 0=OVERSTRIKE,
1390              ;                           1=INSERT.
1400              ;
1410              ;
1420              ;
1430              ; ***********************************************
1440              ;
1450              ;          TEXT EDITOR: TOP LEVEL
1460              ;
1470              ; ***********************************************
1480              ;
1490              ;
1500              ;
1510              ;
1520              ;
1530              ;
1540 1E02 200F1E EDITOR JSR SETBUF      INITIALIZE BUFFER POINTERS.
1550 1E05 20371E EDLOOP JSR SHOWIT      SHOW USER A PORTION OF
1560              ;                     EDIT BUFFER.
1570 1E08 20C81E        JSR EDITIT      LET THE USER EDIT THE BUFFER
1580              ;                     OR MOVE ABOUT WITHIN IT.
1590 1E0B 18            CLC
1600 1E0C 18            CLC             LOOP BACK TO SHOW THE
1610 1E0D 90F6          BCC EDLOOP      CURRENT TEXT.
1620              ;
1630              ;
1640              ;
1650              ;
1660              ;
1670              ;
1680              ;
1690              ;
1700              ;
1710              ;
1720              ; ********************************************
1730              ;
1740              ;           INITIALIZE BUFFER POINTERS
```

```
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
1E0F 200814 SETBUF JSR TVT.ON      SELECT SCREEN.
1E12 20E414        JSR PRINT:      DISPLAY "SET UP EDIT BUFFER."
1E15 7F            .BYTE TEX,CR,LF,LF
1E16 0D
1E17 0A
1E18 0A
1E19 53            .BYTE 'SET UP EDIT BUFFER.
1E1A 45
1E1B 54
1E1C 20
1E1D 55
1E1E 50
1E1F 20
1E20 45
1E21 44
1E22 49
1E23 54
1E24 20
1E25 42
1E26 55
1E27 46
1E28 46
1E29 45
1E2A 52
1E2B 2E
1E2C 0D            .BYTE CR,LF,LF,ETX
1E2D 0A
1E2E 0A
1E2F FF
1E30 20E915        JSR SETADS      LET USER SET LOCATION AND
             ;                     SIZE OF EDIT BUFFER.
1E33 20A017        JSR GOTOSA      SET SELECT=START OF BUFFER.
1E36 60            RTS             RETURN TO CALLER.
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;      DISPLAY A PORTION OF EDIT BUFFER
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
1E37 20C411 SHOWIT JSR TVPUSH      SAVE THE ZERO PAGE BYTES
             ;                     WE'LL USE.
```

```
1E3A 202B11          JSR TVHOME     SET HOME POSITION OF EDIT
                ;                   DISPLAY.
                ;
                ;
1E3D AE0310          LDX TVCOLS     CLEAR THREE ROWS FOR
1E40 A003            LDY #3         THE EDIT DISPLAY.
1E42 201311          JSR CLR.XY
                ;
                ;
1E45 202B11          JSR TVHOME     RESTORE TV.PTR TO HOME
                ;                   POSITION OF EDIT DISPLAY.
1E48 207611          JSR TVDOWN     SET TV.PTR TO BEGINNING
1E4B 20C411          JSR TVPUSH     OF LINE TWO AND SAVE IT.
1E4E 205E1E          JSR LINE.2     DISPLAY TEXT IN LINE TWO.
                ;
                ;
1E51 20D311          JSR TV.POP     SET TV.PTR TO BEGINNING OF
1E54 207611          JSR TVDOWN     OF THIRD LINE OF EDIT
                ;                   DISPLAY.
1E57 20891E          JSR LINE.3     DISPLAY THIRD LINE OF EDIT
                ;                   DISPLAY.
                ;
1E5A 20D311          JSR TV.POP     RESTORE ZERO PAGE BYTES USED.
1E5D 60              RTS            RETURN TO CALLER, WITH EDIT
                ;                   DISPLAY ON SCREEN, REST OF
                ;                   SCREEN UNCHANGED, AND ZERO
                ;                   PAGE PRESERVED.
                ;
                ;
                ;
                ;
                ;
                ;
                ; ********************************************
                ;
                ;         DISPLAY TEXT LINE
                ;
                ; ********************************************
                ;
                ;
                ;
                ;
                ;
1E5E 201215 LINE.2 JSR PUSHSL       SAVE SELECT POINTER.
1E61 AD0310        LDA TVCOLS       SET X EQUAL TO
1E64 4A            LSR A            HALF THE WIDTH
1E65 AA            TAX              OF THE SCREEN.
1E66 CA            DEX
1E67 CA            DEX
                ;
1E68 201A13 LOOP.1 JSR DEC.SL       DECREMENT SELECT...
1E6B CA            DEX
1E6C 10FA          BPL LOOP.1       ...X TIMES.
                ;
1E6E AD0310        LDA TVCOLS       INITIALIZE COUNTR.
1E71 8D001E        STA COUNTR       (WE'LL DISPLAY TVCOLS
                ;                   CHARACTERS.)
1E74 209412 LOOP.2 JSR GET.SL       GET A CHARACTER FROM BUFFER.
```

```
1E77 209B11          JSR TV.PUT      PUT IT ON SCREEN.
1E7A 207F11          JSR TVSKIP      GO TO NEXT SCREEN POSITION.
1E7D 200D13          JSR INC.SL      ADVANCE TO NEXT BYTE IN
                ;                    BUFFER.
1E80 CE001E          DEC COUNTR      DONE LAST CHARACTER IN ROW?
1E83 10EF            BPL LOOP.2      IF NOT, DO NEXT CHARACTER.
                ;
                ;
1E85 202B15          JSR POP.SL      RESTORE SELECT FROM STACK.
1E88 60              RTS             RETURN TO CALLER.
                ;
                ;
                ;
                ;
                ;
                ; *********************************************
                ;
                ;         DISPLAY STATUS LINE
                ;
                ; *********************************************
                ;
                ;
                ;
                ;
                ;
1E89 AD0310 LINE.3 LDA TVCOLS        SELECT CENTER POSITION...
1E8C 4A              LSR A           A=TVCOLS/2
1E8D E902            SBC #2          A=(TVCOLS/2)-2
1E8F 208111          JSR TVPLUS      NOW TV.PTR IS POINTING TWO
                ;                    CHARACTERS TO THE LEFT OF
                ;                    CENTER OF LINE 3 OF THE
                ;                    EDIT DISPLAY.
1E92 AD011E          LDA EDMODE      WHAT IS CURRENT MODE?
1E95 C901            CMP #1          IS IT INSERT MODE?
1E97 D005            BNE OVMODE      IF NOT, IT MUST BE OVERSTRIKE
                ;                    MODE.
1E99 A949            LDA #INSCHR     IF SO, GET INSERT GRAPHIC.
1E9B 18              CLC
1E9C 9002            BCC TVMODE
1E9E A94F   OVMODE LDA #OVRCHR       LOAD A W/OVERSTRIKE CHARACTER.
1EA0 209B11 TVMODE JSR TV.PUT        PUT MODE GRAPHIC ON SCREEN.
1EA3 A902            LDA #2          MOVE TWO POSITIONS TO THE
1EA5 208111          JSR TVPLUS      RIGHT, SO TV.PTR POINTS TO
                ;                    CENTER OF LINE 3 OF EDIT
                ;                    DISPLAY.
1EA8 AD0710          LDA ARROW       DISPLAY AN UP-ARROW HERE.
1EAB 209B11          JSR TV.PUT
                ;
1EAE A902            LDA #2          GO TWO POSITIONS TO THE
1EB0 208111          JSR TVPLUS      RIGHT, SO TV.PTR POINTS TO
                ;                    FIELD RESERVED FOR THE
                ;                    ADDRESS OF THE CURRENT CHARACTER
1EB3 AD0612          LDA SELECT+1    DISPLAY ADDRESS OF CURRENT
1EB6 20A311          JSR VUBYTE
1EB9 AD0512          LDA SELECT
1EBC 20A311          JSR VUBYTE
                ;
1EBF 60              RTS             RETURN TO CALLER.
```

Appendix C11:

Simple Text Editor (EDITIT Subroutine)

```
                   ;       APPENDIX C11: ASSEMBLER LISTING OF
                   ;            A SIMPLE TEXT EDITOR
                   ;          EDITIT SUBROUTINE
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;     SEE CHAPTER 11 OF BEYOND GAMES: SYSTEMS
                   ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
                   ;
                   ;
                   ;                   BY KEN SKIER
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ; *********************************************
                   ;
                   ;          CONSTANTS
                   ;
                   ; *********************************************
                   ;
                   ;
                   ;
                   ;
                   ;
     000D=              CR = $0D         CARRIAGE RETURN.
                   ;
     000A=              LF = $0A         LINE FEED.
                   ;
                   ;
     007F=              TEX = $7F        THIS CHARACTER MUST START
                   ;                     ANY MESSAGE.
                   ;
     00FF=              ETX = $FF        THIS CHARACTER MUST END
                   ;                     ANY MESSAGE.
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ;
                   ; *********************************************
                   ;
                   ;          EXTERNAL ADDRESSES
                   ;
```

```
         ; ********************************************
         ;
         ;
         ;
         ;
         ;
1200=          VMPAGE=$1200   STARTING PAGE OF VISIBLE
         ;                    MONITOR CODE.
1205=          SELECT=VMPAGE+5
1207=          VISMON=VMPAGE+7
1294=          GET.SL=VMPAGE+$94
12E0=          GETKEY=VMPAGE+$E0
130D=          INC.SL=VMPAGE+$10D
131A=          DEC.SL=VMPAGE+$11A
132D=          PUT.SL=VMPAGE+$12D
         ;
         ;
1400=          PRPAGE=$1400   STARTING PAGE OF PRINT
         ;                    UTILITIES.
1414=          PR.ON =PRPAGE+$14
141A=          PR.OFF=PRPAGE+$1A
1440=          PR.CHR=PRPAGE+$40
14E4=          PRINT:=PRPAGE+$E4
1512=          PUSHSL=PRPAGE+$112
152B=          POP.SL=PRPAGE+$12B
         ;
         ;
1500=          HEX.PG=$1500   ADDRESS OF PAGE IN WHICH
         ;                    HEXDUMP CODE STARTS.
         ;
1552=          SA=HEX.PG+$52
1554=          EA=SA+2
1667=          SAHERE=HEX.PG+$167
1783=          NEXTSL=HEX.PG+$283
17A0=          GOTOSA=HEX.PG+$2A0
         ;
         ;
17B0=          MOVERS=$17B0   START OF MOVE OBJECT CODE.
17B2=          DEST  =MOVERS+2
17D6=          MOV.EA=MOVERS+$26
18E2=          DAHERE=MOVERS+$132
         ;
1E00=          EDPAGE=$1E00   STARTING PAGE OF EDITOR.
1EC0=          EDKEYS=EDPAGE+$C0
         ;
         ;
         ;
         ;
         ;
         ;
         ; ********************************************
         ;
         ;          VARIABLES
         ;
         ; ********************************************
         ;
         ;
         ;
```

```
1E00                 *=EDPAGE
             ;
             ;
             ;
1E01=                EDMODE=EDPAGE+1      0=OVERSTRIKE MODE.
             ;                            1=INSERT.
             ;
1EC0                 *=EDKEYS
             ;
             ;          EDIT FUNCTION KEYS
             ;
             ;                        THE EDITOR RECOGNIZES THE
             ;                        FOLLOWING KEYS AS FUNCTION KEYS.
             ;                        ASSIGN A FUNCTION TO A KEY
             ;                        BY STORING THE DESIRED KEY
             ;                        CODE FROM YOUR SYSTEM'S
             ;                        KEYHANDLER INTO ONE OF THE
             ;                        FOLLOWING DATA BYTES:
             ;
             ;
1EC0 06     FLSHKY .BYTE $06          THIS KEY FLUSHES THE
             ;                        BUFFER OF ANY TEXT.  $06 IS
             ;                        CONTROL-F.  THUS, CONTROL-F
             ;                        TO FLUSH THE BUFFER.
             ;
             ;
1EC1 03     MODEKY .BYTE $03          THIS KEY CAUSES THE EDIT
             ;                        TO CHANGE MODES. FROM INSERT
             ;                        TO OVERSTRIKE, AND VICE VERSA.
             ;                        $03 IS CONTROL-C.  THUS,
             ;                        CONTROL-C TO Change modes.
             ;
1EC2 3E     NEXTKY .BYTE '>'          THIS KEY SELECTS THE NEXT
             ;                        CHARACTER IN THE BUFFER.
             ;
             ;                        SUBSTITUTE RIGHT-ARROW IF
             ;                        YOUR KEYBOARD HAS IT.
             ;
1EC3 3C     PREVKY .BYTE '<'          SELECT PREVIOUS CHARACTER
             ;                        IN THE BUFFER.  SUBSTITUTE
             ;                        LEFT-ARROW IF YOUR KEYBOARD
             ;                        HAS IT.
             ;
1EC4 10     PRTKEY .BYTE $10          THIS KEY PRINTS THE BUFFER.
             ;                        CONTROL-P
             ;                        to Print the buffer.
             ;
1EC5 7F     RUBKEY .BYTE $7F          THIS KEY RUBS OUT THE
             ;                        CURRENT CHARACTER.  IF YOU
             ;                        HAVE DELETE KEY BUT NOT RUBOUT,
             ;                        USE YOUR SYSTEM'S CODE FOR
             ;                        THE DELETE KEY.
             ;
             ;
1EC6 51     QUITKY .BYTE 'Q'          TWO QUIT KEYS IN A ROW
             ;                        CAUSE THE EDITOR TO RETURN
             ;                        TO ITS CALLER.
             ;
```

```
1720             ;
1730             ;
1740             ;
1750             ;
1760             ;                   OTHER VARIABLES:
1770             ;
1780 1EC7 00     TEMPCH .BYTE 0      THIS BYTE USED BY EDITIT.
1790             ;
1800             ;
1810             ;
1820             ;
1830             ;
1840             ;
1850             ;
1860             ;
1870             ;
1880             ;
1890             ; ************************************************
1900             ;
1910             ;         TEXT EDITOR: UPDATE SUBROUTINE
1920             ;
1930             ; ************************************************
1940             ;
1950             ;
1960             ;
1970             ;
1980             ;
1990             ;
2000             ;
2010 1EC8 20E012 EDITIT JSR GETKEY   GET A KEYSTROKE FROM USER
2020             ;                   USER.
2030 1ECB CDC61E        CMP QUITKY   IS IT THE "QUIT" KEY?
2040 1ECE D017          BNE DO.KEY   IF NOT, DO WHAT THE KEY
2050             ;                   REQUIRES.
2060             ;
2070 1ED0 48            PHA          IF IT IS THE "QUIT" KEY, SAVE
2080 1ED1 20E012        JSR GETKEY   IT AND GET A NEW KEY FROM
2090             ;                   USER.
2100 1ED4 CDC61E        CMP QUITKY   IS THIS A "QUIT" KEY, TOO?
2110 1ED7 D004          BNE NOTEND   IF NOT, THEN THIS IS NOT THE
2120             ;                   END OF THE EDIT SESSION.
2130             ;
2140             ;                   END THE EDT SESSION?
2150 1ED9 68     ENDEDT PLA          POP FIRST "QUIT" KEY FROM
2160             ;                   STACK.
2170 1EDA 68            PLA          POP RETURN ADDRESS TO
2180 1EDB 68            PLA          EDITOR'S TOP LEVEL.
2190 1EDC 60            RTS          RETURN TO EDITOR'S CALLER.
2200             ;
2210 1EDD 8DC71E NOTEND STA TEMPCH   SAVE TH KEY THAT FOLLOWED
2220             ;                   THE "QUIT" KEY.
2230 1EE0 68            PLA          POP FIRST "QUIT" KEY FROM STACK.
2240 1EE1 20E71E        JSR DO.KEY   DO WHAT IT REQUIRES.
2250 1EE4 ADC71E        LDA TEMPCH   RECOVER THE KEY THAT FOLLOWED
2260             ;                   THE "QUIT" KEY.
2270             ;
2280             ;                   "DO.KEY" DOES WHAT THE KEY
2290             ;                   IN THE ACCUMULATOR REQUIRES:
```

```
                    ;
1EE7 CDC11E DO.KEY CMP MODEKY     IS IT THE "CHANGE MODE" KEY?
1EEA D00B          BNE IFNEXT     IF NOT, PERFORM NEXT TEST.
1EEC CE011E        DEC EDMODE     IF SO, CHANGE THE EDITOR'S
1EEF 1005          BPL DO.END     MODE.
1EF1 A901          LDA #1
1EF3 8D011E        STA EDMODE
1EF6 60     DO.END RTS            RETURN TO CALLER.
                   ;
                   ;
1EF7 CDC21E IFNEXT CMP NEXTKY     IS IT THE "NEXT" KEY?
1EFA D004          BNE IFPREV     IF NOT, PERFORM NEXT TEST.
                   ;
1EFC 20791F        JSR NEXTCH     IF SO, ADVANCE TO NEXT
                   ;              CHARACTER...
1EFF 60            RTS            ...AND RETURN.
                   ;
                   ;
1F00 CDC31E IFPREV CMP PREVKY     IS IT THE "PREVIOUS" KEY?
1F03 D004          BNE IF.RUB     IF NOT, PERFORM NEXT TEST.
1F05 20871F        JSR PREVSL     IF SO, BACK UP TO PREVIOUS
1F08 60            RTS            CHARACTER AND RETURN.
                   ;
                   ;
1F09 CDC51E IF.RUB CMP RUBKEY     IS IT THE "RUBOUT" KEY?
1F0C D004          BNE IF.PRT     IF NOT, PERFORM NEXT TEST.
1F0E 20D01F        JSR DELETE     IF SO, DELETE CURRENT
1F11 60            RTS            CHARACTER AND RETURN.
                   ;
                   ;
1F12 CDC41E IF.PRT CMP PRTKEY     IS IT THE "PRINT" KEY?
1F15 D004          BNE IFFLSH     IF NOT, PERFORM NEXT TEST.
1F17 20C51F        JSR PRTBUF     IF SO, PRINT THE BUFFER...
1F1A 60            RTS            ...AND RETURN.
                   ;
                   ;
                   ;
1F1B CDC01E IFFLSH CMP FLSHKY     IS IT THE "FLUSH" KEY?
1F1E D004          BNE CHARKY     IF NOT, IT MUST BE A CHARACTER
                   ;              KEY.
1F20 20B41F        JSR FLUSH      IF SO, FLUSH THE BUFFER.
1F23 60            RTS            AND RETURN.
                   ;
                   ;
                   ;
                   ;
                   ;    OK.  IT'S NOT AN EDITOR FUNCTION KEY, SO IT
                   ; MUST BE A CHARACTER KEY.  DEPENDING ON THE
                   ; CURRENT MODE, WE'LL EITHER INSERT OR OVERSTRIKE
                   ;                         THE CURRENT CHARACTER.
                   ;
1F24 AE011E CHARKY LDX EDMODE     ARE WE IN OVERSTRIKE MODE?
1F27 F004          BEQ STRIKE     IF SO, OVERSTRIKE THE CURRENT
                   ;              CHARACTER.
1F29 20341F        JSR INSERT     IF NOT, INSERT THE CHARACTER.
1F2C 60            RTS            RETURN.
                   ;
1F2D 202D13 STRIKE JSR PUT.SL     REPLACE CURRENT CHARACTER
```

```
2880                ;                WITH NEW CHARACTER.
2890 1F30 208317           JSR NEXTSL    SELECT NEXT CHARACTER.
2900 1F33 60               RTS           RETURN.
2910                ;
2920                ;
2930                ;
2940                ;
2950                ;
2960 1F34 48        INSERT PHA           SAVE THE CHARACTER TO BE
2970                ;                    INSERTED, WHILE WE MAKE ROOM
2980                ;                    FOR IT IN THE BUFFER...
2990 1F35 201215           JSR PUSHSL    SAVE THE CURRENT ADDRESS.
3000 1F38 AD5315           LDA SA+1      SAVE THE BUFFER'S ADDRESS.
3010 1F3B 48               PHA
3020 1F3C AD5215           LDA SA
3030 1F3F 48               PHA
3040                ;
3050                ;
3060 1F40 AD5515           LDA EA+1      SAVE BUFFER'S END ADDRESS.
3070 1F43 48               PHA
3080 1F44 AD5415           LDA EA
3090 1F47 48               PHA
3100                ;
3110                ;
3120 1F48 206716           JSR SAHERE    SET SA=SELECT, SO CURRENT
3130                ;                    LOCATION WILL BE START OF
3140                ;                    THE BLOCK WE'LL MOVE.
3150                ;
3160                ;
3170                ;
3180 1F4B 206317           JSR NEXTSL    ADVANCE TO NEXT CHARACTER
3190                ;                    POSITION IN THE BUFFER.
3200 1F4E 3011             BMI ENDINS    IF WE'RE AT THE END OF THE
3210                ;                    BUFFER, WE'LL OVERSTRIKE
3220                ;                    INSTEAD OF INSERTING.
3230                ;
3240                ;
3250 1F50 20E218           JSR DAHERE    SET DEST=SELECT.
3260                ;                    DESTINATION OF BLOCK MOVE
3270                ;                    WILL BE ONE BYTE ABOVE
3280                ;                    BLOCK'S INITIAL LOCATION.
3290                ;
3300                ;
3310 1F53 AD5415           LDA EA        DECREMENT END ADDRESS
3320 1F56 D004             BNE *+6
3330 1F58 CE5515           DEC EA+1
3340 1F5B CE5415           DEC EA
3350                ;
3360                ;
3370                ;
3380 1F5E 20D617    OPENUP JSR MOV.EA    OPEN UP ONE BYTE OF SPACE
3390                ;                    AT CURRENT CHARACTER'S
3400                ;                    LOCATION, BY MOVING TO DEST
3410                ;                    THE BLOCK SPECIFIED BY SA, EA.
3420                ;
3430                ;
3440 1F61 68        ENDINS PLA           RESTORE EA SO IT POINTS
3450 1F62 8D5415           STA EA        TO END OF BUFFER.
```

```
1F65 68            PLA
1F66 8D5515        STA EA+1
             ;
             ;
1F69 68            PLA            RESTORE SA SO IT POINTS TO
1F6A 8D5215        STA SA         START OF BUFFER.
1F6D 68            PLA
1F6E 8D5315        STA SA+1
             ;
             ;
1F71 202B15        JSR POP.SL     RESTORE SELECT SO IT POINTS
             ;                    TO CURRENT CHARACTER POSITION.
             ;
             ;
1F74 68            PLA            RESTORE NEW CHARACTER TO
             ;                    ACCUMULATOR.  WE'VE CREATED
             ;                    A ONE-BYTE SPACE FOR IT, SO
1F75 202D1F        JSR STRIKE     WE NEED ONLY OVERSTRIKE IT
1F78 60            RTS            AND RETURN.
1F79 209412 NEXTCH JSR GET.SL     GET CURRENT CHARACTER.
1F7C C9FF          CMP #ETX       IS IT END OF TEXT CHARACTER?
1F7E F004          BEQ AN.ETX     IF SO, RETURN TO CALLER,
             ;                    BEARING A NEGATIVE RETURN CODE.
             ;
1F80 208317        JSR NEXTSL     IF NOT, SELECT NEXT BYTE IN
             ;                    BUFFER.
1F83 60            RTS            RETURN PLUS IF WE INCREMENTED
             ;                    SELECT; MINUS IF SELECT
             ;                    ALREADY EQUALLED EA.
             ;
1F84 A9FF   AN.ETX LDA #$FF       SINCE WE'RE ON AN ETX, WE
1F86 60            RTS            WILL RETURN MINUS, WITHOUT
             ;                    INCREMENTING SELECT.
             ;
             ;
             ;
             ;
1F87 38     PREVSL SEC            PREPARE TO COMPARE.
1F88 AD5315        LDA SA+1       IS SELECT IN A HIGHER PAGE
1F8B CD0612        CMP SELECT+1   THAN START OF BUFFER?
1F8E 900C          BCC SL.OK      IF SO, SELECT MAY BE DECREMENTED
1F90 D010          BNE NOT.OK     IF SELECT IS IN A LOWER
             ;                    PAGE THAN SA, IT'S NOT OK.
             ;
             ;                    SELECT IS IN SAME PAGE AS SA.
1F92 AD5215        LDA SA         IS SELECT>SA?
1F95 CD0512        CMP SELECT
1F98 F017          BEQ NO.DEC     IF SELECT=SA, DON'T DECREMENT
             ;                    SELECT.
1F9A B006          BCS NOT.OK     IF SELECT<SA, DON'T DECREMENT
             ;                    SELECT.
1F9C 201A13 SL.OK  JSR DEC.SL     SELECT>SA, SO WE MAY
             ;                    DECREMENT SELECT AND IT
             ;                    WILL REMAIN IN THE BUFFER.
1F9F A900          LDA #0         SET A POSITIVE RETURN CODE...
1FA1 60            RTS            ...AND RETURN.
             ;
             ;
```

```
4040 1FA2 AD5215 NOT.OK LDA SA          SINCE SELECT<SA, IT IS NOT
4050 1FA5 8D0512        STA SELECT      EVEN IN THE EDIT BUFFER.  SO
4060 1FA8 AD5315        LDA SA+1        MAKE SELECT LEGAL, BY SETTING
4070 1FAB 8D0612        STA SELECT+1    IT EQUAL TO SA.
4080 1FAE A900          LDA #0          SET A POSITIVE RETURN CODE...
4090 1FB0 60            RTS             ...AND RETURN.
4100               ;
4110               ;
4120 1FB1 A9FF   NO.DEC LDA #$FF        SELECT=SA, SO CHANGE
4130 1FB3 60            RTS             NOTHING.  RETURN WITH
4140               ;                    NEGATIVE RTURN CODE.
4150               ;
4160               ;
4170               ;
4180 1FB4 20A017 FLUSH  JSR GOTOSA      SET SELECT=SA.
4190 1FB7 A9FF   FLOOP  LDA #ETX        PUT AN ETX CHARACTER
4200 1FB9 202D13        JSR PUT.SL      INTO THE BUFFER.
4210 1FBC 208317        JSR NEXTSL      ADVANCE TO NEXT POSITION IN
4220               ;                    BUFFER.
4230 1FBF 10F6          BPL FLOOP       IF WE HAVEN'T REACHED END
4240               ;                    OF BUFFER, PUT AN ETX INTO
4250               ;                    THIS POSITION, TOO.
4260               ;
4270 1FC1 20A017        JSR GOTOSA      HAVING FILLED BUFFER WITH
4280               ;                    ETC CHARACTERS, RESET SELECT
4290               ;                    TO BEGINNING OF BUFFER.
4300 1FC4 60            RTS             RETURN.
4310 1FC5 20A017 PRTBUF JSR GOTOSA      SET SELECT TO START OF BUFFER
4320 1FC8 201414        JSR PR.ON       SELECT PRINTER FOR OUTPUT.
4330 1FCB 209412 PRLOOP JSR GET.SL       GET CURRENT CHARACTER.
4340 1FCE C9FF          CMP #ETX        IS IT ETX?
4350 1FD0 F008          BEQ ENDPRT      IF SO, WE'RE DONE.
4360 1FD2 204014        JSR PR.CHR      IF NOT, PRINT IT.
4370 1FD5 208317        JSR NEXTSL      SELECT NEXT CHARACTER
4380 1FD8 10F1          BPL PRLOOP      IF WE HAVEN'T REACHED THE
4390               ;                    END OF THE BUFFER, HANDLE
4400               ;                    THE CURRENT CHARACTER AS BEFORE.
4410 1FDA 4C1A14 ENDPRT JMP PR.OFF      HAVING REACHED END OF MESSAGE
4420               ;                    OR END OF BUFFER, RETURN TO
4430               ;                    CALLER OF EDITIT, DESELECTING
4440               ;                    THE PRINTER AS WE DO SO.
4450               ;
4460               ;
4470 1FDD 201215 DELETE JSR PUSHSL      SAVE CURRENT ADDRESS.
4480 1FE0 AD5315        LDA SA+1        SAVE BUFFER'S START ADDRESS.
4490 1FE3 48            PHA
4500 1FE4 AD5215        LDA SA
4510 1FE7 48            PHA
4520               ;
4530 1FE8 20E218        JSR DAHERE      SET DEST=SELECT, BECAUSE
4540               ;                    WE'LL MOVE A BLOCK OF TEXT
4550               ;                    DOWN TO HERE, TO CLOSE UP
4560               ;                    THE BUFFER AT THE CURRENT
4570               ;                    CHARACTER.
4580 1FEB 208317        JSR NEXTSL      ADVANCE BY ONE BYTE THROUGH
4590               ;                    BUFFER, IF POSSIBLE.
4600 1FEE 206716        JSR SAHERE      SET SA=SELECT, BECAUSE THIS
4610               ;                    IS THE START OF THE BLOCK WE'LL
```

```
4620                  ;                            MOVE DOWN.
4630                  ;                            NOTE: THE ENDING ADDRESS OF
4640                  ;                            THE BLOCK IS THE END ADDRESS
4650                  ;                            OF THE TEXT BUFFER.
4660 1FF1 20D617            JSR MOV.EA             MOVE BLOCK SPECIFIED BY
4670                  ;                            SA, EA TO DEST.
4680                  ;
4690                  ;
4700 1FF4 68                PLA                    RESTORE INITIAL SA (WHICH
4710 1FF5 8D5215            STA SA                 IS THE START ADDRESS OF THE
4720 1FF8 68                PLA                    TEXT BUFFER, NOT OF THE BLOCK
4730 1FF9 8D5315            STA SA+1               WE JUST MOVED.)
4740 1FFC 202B15            JSR POP.SL             RESTORE CURRENT ADDRESS.
4750 1FFF 60                RTS                    RETURN TO CALLER.
```

Appendix C12:

Extending the Visible Monitor

```
         ;      APPENDIX C12: ASSEMBLER LISTING OF
         ;         VISIBLE MONITOR EXTENSIONS
         ;
         ;
         ;
         ;
         ;
         ;    SEE CHAPTER 12 OF BEYOND GAMES: SYSTEM
         ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ;
         ; ********************************************
         ;
         ;           EXTERNAL ADDRESSES
         ;
         ; ********************************************
         ;
         ;
         ;
         ;
         ;
         ;
1400=           PRPAGE=$1400   STARTING PAGE OF PRINT
         ;                     UTILITIES.
1400=           PRINTR=PRPAGE
1402=           USER  =PRPAGE+2
         ;
         ;
1500=           HEX.PG=$1500   ADDRESS OF PAGE IN WHICH
         ;                     HEXDUMP CODE STARTS.
         ;
1557=           TVDUMP=HEX.PG+$57
15AE=           PRDUMP=HEX.PG+$AE
         ;
         ;
1900=           DSPAGE=$1900   STARTING PAGE OF DISASSEMBLER
```

```
1909=                    TV.DIS=DSPAGE+9
1926=                    PR.DIS=DSPAGE+$26
                ;
17B0=                    MOVERS=$17B0   START OF MOVE OBJECT CODE.
17B4=                    MOVER =MOVERS+4
                ;
                ;
1E00=                    EDPAGE=$1E00   ADDRESS OF PAGE IN WHICH
                ;                       EDITOR CODE BEGINS.
1E02=                    EDITOR=EDPAGE+2
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
10B0                     *=$10B0
                ;
                ;
                ; ********************************************
                ;
                ;       EXTENSIONS TO THE VISIBLE MONITOR
                ;
                ; ********************************************
                ;
                ;
                ;
10B0 C950     EXTEND CMP #'P          IS IT THE 'P' KEY?
10B2 D009            BNE IF.U         IF NOT, PERFORM NEXT TEST.
10B4 AD0014          LDA PRINTR       IF SO, TOGGLE THE PRINTER
10B7 49FF            EOR #$FF         FLAG...
10B9 8D0014          STA PRINTR
10BC 60              RTS              AND RETURN TO CALLER.
                ;
10BD C955     IF.U   CMP #'U          IS IT THE 'U' KEY?
10BF D009            BNE IF.H         IF NOT, PERFORM NEXT TEST.
10C1 AD0214          LDA USER         IF SO, TOGGLE THE USER-
10C4 49FF            EOR #$FF         PROVIDED OUTPUT FLAG...
10C6 8D0214          STA USER
10C9 60              RTS              AND RETURN.
                ;
10CA C948     IF.H   CMP #'H          IS IT THE 'H' KEY?
10CC D00D            BNE IF.M         IF NOT, PERFORM NEXT TEST.
10CE AD0014          LDA PRINTR       IS THE PRINTER SELECTED?
10D1 D004            BNE NEXT.1       IF SO, PRINT A HEXDUMP.
10D3 205715          JSR TVDUMP       IF NOT, DUMP TO SCREEN...
10D6 60              RTS          AND RETURN.
10D7 20AE15 NEXT.1   JSR PRDUMP       PRINT A HEXDUMP...
10DA 60              RTS              ...AND RETURN.
                ;
10DB C94D     IF.M   CMP #'M          IS IT THE 'M' KEY?
10DD D004            BNE IF.DIS       IF NOT, PRFORM NEXT TEST.
10DF 20B417          JSR MOVER        IF SO, LET USER SPECIFY AND
10E2 60              RTS              AND MOVE A BLOCK OF MEMORY.
                ;
10E3 C93F     IF.DIS CMP #'?          IS IT THE '?' KEY?
```

```
1160 10E5 D00D          BNE IF.T       IF NOT, PERFORM NEXT TEST.
1170 10E7 AD0014        LDA PRINTR     IS THE PRINTER SELECTED?
1180 10EA D004          BNE NEXT.2     IF SO, PRINT A DISASSEMBLY.
1190 10EC 200919        JSR TV.DIS     IF NOT, DISASSEMBLE TO THE
1200 10EF 60            RTS            SCREEN AND RETURN.
1210 10F0 202619 NEXT.2 JSR PR.DIS     PRINT A DISASSEMBLY...
1220 10F3 60            RTS            AND RETURN.
1230             ;
1240 10F4 C954   IF.T   CMP #'T        IS IT THE 'T' KEY?
1250 10F6 D004          BNE EXIT       IF NOT, RETURN.
1260 10F8 20021E        JSR EDITOR     IF SO, CALL THE SIMPLE
1270 10FB 60            RTS            TEXT EDITOR AND RETURN.
1280             ;
1290 10FC 60     EXIT   RTS            EXTEND THE VISIBLE MONITOR
1300             ;                     EVEN FURTHER BY REPLACING
1310             ;                     THIS 'RTS' WITH A 'JMP' TO
1320             ;                     MORE TEST-AND-BRANCH CODE.
```

Appendix C13:

System Data Block for the Ohio Scientific C-1P

```
                 ;         APPENDIX C13: ASSEMBLER LISTING OF
                 ;             SYSTEM DATA BLOCK
                 ;        FOR THE OHIO SCIENTIFIC C-1P
                 ;
                 ;
                 ;
                 ;
                 ;      SEE APPENDIX B1 OF BEYOND GAMES: SYSTEM
                 ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
                 ;
                 ;
                 ;                     BY KEN SKIER
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ; ********************************************
                 ;
                 ;           SCREEN PARAMETERS
                 ;
                 ; ********************************************
                 ;
                 ;
                 ;
                 ;
                 ;
 1000                    *=$1000
                 ;
                 ;
                 ;
                 ;
                 ;
 1000 65D0      HOME    .WORD $D065     THIS IS THE ADDRESS OF THE
                 ;                      CHARACTER IN THE UPPER LEFT
                 ;                      CORNER OF THE SCREEN.  THE
                 ;                      ADDRESS OF HOME WILL VARY AS
                 ;                      A FUNCTION OF YOUR VIDEO MONITOR
                 ;                      I SET MINE TO $D065.  IF YOU
                 ;                      CAN'T SEE THE VISIBLE MONITOR
                 ;                      DISPLAY, ADJUST THE LOW BYTE.
                 ;
                 ;
                 ;
 1002 20        ROWINC .BYTE 32         ADDRESS DIFFERENCE FROM ONE
                 ;                      ROW TO THE NEXT.
 1003 18        TVCOLS .BYTE $18        NUMBER OF COLUMNS ON SCREEN.
                 ;                      COUNTING FROM ZERO.
 1004 18        TVROWS .BYTE $18        NUMBER OF ROWS ON SCREEN,
                 ;                      COUNTING FROM ZERO.
```

```
1005 D3     HIPAGE .BYTE $D3      HIGHEST PAGE IN SCREEN MEMORY.
1006 20     BLANK  .BYTE $20      OSI DISPLAY CODE FOR A BLANK.
1007 10     ARROW  .BYTE $10      OSI DISPLAY CODE FOR AN UP-ARROW
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;           INPUT/OUTPUT VECTORS
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
             ;
1008 EDFE   ROMKEY .WORD $FEED    POINTER TO ROUTINE THAT GETS
             ;                    AN ASCII CHARACTER FROM THE
             ;                    KEYBOARD.  (NOTE: $FFEB IS
             ;                    THE GENERAL CHARACTER-INPUT
             ;                    ROUTINE FOR OSI BASIC-IN-ROM
             ;                    COMPUTERS.)
             ;
             ;
100A 2DBF   ROMTVT .WORD $BF2D    POINTER TO ROUTINE TO PRINT
             ;                    AN ASCII CHARACTER ON THE SCREEN
             ;                    (NOTE: $FFEE IS THE
             ;                    CHARACTER-OUTPUT ROUTINE FOR
             ;                    OSI BASIC-IN-ROM COMPUTERS.)
             ;
             ;
100C B1FC   ROMPRT .WORD $FCB1    POINTER TO ROUTINE TO SEND AN
             ;                    ASCII CHARACTER TO THE PRINTER
             ;                    (ACTUALLY, TO THE CASSETTE PORT.
             ;
             ;
100E 1010   USROUT .WORD DUMMY    POINTER TO USER-WRITTEN OUTPUT
             ;                    ROUTINE.  (SET HERE TO DUMMY
             ;                    UNTIL YOU SET IT TO POINT
             ;                    TO YOUR OWN CHARACTER-OUTPUT
             ;                    ROUTINE.)
             ;
             ;
1010 60     DUMMY  RTS            THIS IS A DUMMY SUBROUTINE.
             ;                    IT DOES NOTHING BUT RETURN.
             ;
             ;
             ;
             ;
             ;
             ;
```

```
                ; ******************************************
                ;
                ;      CONVERT ASCII CHARACTER TO DISPLAY CODE
                ;
                ; ******************************************
                ;
                ;
                ;
                ;
                ;
1011 60         FIXCHR RTS            SINCE OSI DISPLAY CODES ARE
                ;                     THE SAME AS THE CORRESPONDING
                ;                     ASCII CHARACTERS, NO CONVERSION
                ;                     IS NECESSARY; FIXCHR IS A DUMMY.
```

Appendix C14:

System Data Block for the PET 2001

```
                ;          APPENDIX C14: ASSEMBLER LISTING OF
                ;             SYSTEM DATA BLOCK
                ;              FOR THE PET 2001
                ;
                ;
                ;
                ;
                ;       SEE APPENDIX B2 OF BEYOND GAMES: SYSTEM
                ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
                ;
                ;
                ;                    BY KEN SKIER
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ;
                ; ********************************************
                ;
                ;         SCREEN PARAMETERS
                ;
                ; ********************************************
                ;
                ;
                ;
                ;
                ;
1000                  *=$1000
                ;
                ;
                ;
                ;
                ;
1000 0080       HOME   .WORD $8000    THIS IS THE ADDRESS OF THE
                ;                     CHARACTER IN THE UPPER LEFT
                ;                     CORNER OF THE SCREEN.
1002 28         ROWINC .BYTE $28      ADDRESS DIFFERENCE FROM ONE
                ;                     ROW TO THE NEXT.
1003 27         TVCOLS .BYTE 39       NUMBER OF COLUMNS ON SCREEN,
                ;                     COUNTING FROM ZERO.
1004 18         TVROWS .BYTE 24       NUMBER OF ROWS ON SCREEN,
                ;                     COUNTING FROM ZERO.
1005 83         HIPAGE .BYTE $83      HIGHEST PAGE IN SCREEN MEMORY.
1006 20         BLANK  .BYTE $20      PET DISPLAY CODE FOR A BLANK.
                ;                     (IN NORMAL VIDEO MODE.)
1007 1E         ARROW  .BYTE $1E      PET DISPLAY CODE FOR UP-ARROW.
                ;
                ;
                ;
                ;
```

```
                  ;
                  ;
                  ;
                  ;
                  ;
                  ; ********************************************
                  ;
                  ;            INPUT/OUTPUT VECTORS
                  ;
                  ; ********************************************
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
1008 2A10        ROMKEY .WORD PETKEY   POINTER TO ROUTINE THAT GETS
                  ;                    AN ASCII CHARACTER FROM THE
                  ;                    KEYBOARD.  (NOTE: PETKEY
                  ;                    CALLS A ROM SUBROUTINE, BUT
                  ;                    PETKEY IS NOT A PET ROM
                  ;                    SUBROUTINE.)
                  ;
                  ;
100A D2FF        ROMTVT .WORD $FFD2    POINTER TO ROUTINE TO PRINT
                  ;                    AN ASCII CHARACTER ON THE SCREEN
                  ;
                  ;
100C 1010        ROMPRT .WORD DUMMY    POINTER TO ROUTINE TO SEND AN
                  ;                    ASCII CHARACTER TO THE PRINTER
                  ;                    (SET TO DUMMY UNTIL YOU MAKE
                  ;                    IT POINT TO THE CHARACTER-
                  ;                    OUTPUT ROUTINE THAT DRIVES
                  ;                    YOUR PRINTER.)
                  ;
                  ;
100E 1010        USROUT .WORD DUMMY    POINTER TO USER-WRITTEN OUTPUT
                  ;                    ROUTINE.  (SET HERE TO DUMMY
                  ;                    UNTIL YOU SET IT TO POINT
                  ;                    TO YOUR OWN CHARACTER-OUTPUT
                  ;                    ROUTINE.)
                  ;
                  ;
1010 60          DUMMY  RTS            THIS IS A DUMMY SUBROUTINE.
                  ;                    IT DOES NOTHING BUT RETURN.
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ; ********************************************
                  ;
                  ;     CONVERT ASCII CHARACTER TO DISPLAY CODE
                  ;
                  ; ********************************************
                  ;
                  ;
```

```
1190                ;
1200                ;
1210                ;
1220 1011 297F   FIXCHR AND #$7F      CLEAR BIT 7, TO MAKE IT
1230                ;                 A LEGAL ASCII CHARACTER.
1240 1013 38            SEC           PREPARE TO COMPARE.
1250 1014 C940          CMP #$40      IS IT LESS THAN $40? (IS
1260                ;                 IT A NUMBER OR PUNCTUATION
1270                ;                 MARK?)
1280 1016 9011          BCC FIXEND    IF SO, NO CONVERSION NEEDED.
1290                ;
1300 1018 C960          CMP #$60      IS IT BETWEEN $40 AND $60?
1310                ;
1320 101A 900A          BCC SUB.40    IF SO, SUBTRACT $40 TO
1330                ;                 CONVERT FROM ASCII TO PET.
1340                ;
1350                ;                 IT'S >= $60, SO WE MUST
1370 101C A20E          LDX #14       SET PET DISPLAY MODE FOR
1380 101E 8D4CE8        STA 59468     CHARACTER SET THAT INCLUDES
1390                ;                 LOWER CASE ALPHA CHARACTERS.
1400 1021 E920          SBC #$20      SUBTRACT $20 TO CONVERT
1410                ;                 LOWER CASE ASCII TO PET CODE.
1420 1023 18            CLC
1430 1024 9003          BCC FIXEND
1435                ;
1440 1026 38     SUB.40 SEC           PREPARE TO SUBTRACT.
1450 1027 E940          SBC #$40      SUBTRACT $40 TO CONVERT ASCII
1460                ;                 UPPER CASE CHAR TO PET CODE.
1470 1029 60     FIXEND RTS           RETURN, WITH A HOLDING
1480                ;                 PET DISPLAY CODE FOR ASCII
1490                ;                 ORIGINALLY IN A.
1500                ;
1510                ;
1520                ;
1530                ;
1540                ;
1550                ; ********************************************
1560                ;
1570                ;    GET AN ASCII CHARACTER FROM THE KEYBOARD
1580                ;
1590                ; ********************************************
1600                ;
1610                ;
1620                ;
1630                ;
1640 102A 20E4FF PETKEY JSR $FFE4     SCAN THE PET KEYBOARD
1650 102D 297F          AND #$7F      CLEAR BIT 7, TO BE SURE
1660                ;                 IT'S A LEGAL ASCII CHARACTER.
1670 102F F0F9          BEQ PETKEY    ZERO MEANS NO KEY, SO
1680                ;                 SCAN AGAIN.
1690                ;
1700 1031 60            RTS           RETURN WITH ASCII CHARACTER
1710                ;                 FROM THE KEYBOARD.
```

Appendix C15:

System Data Block for the Apple II

```
                  ;          APPENDIX C15: ASSEMBLER LISTING OF
                  ;             SYSTEM DATA BLOCK
                  ;                FOR THE APPLE II
                  ;
                  ;
                  ;
                  ;
                  ;        SEE APPENDIX B3 OF BEYOND GAMES: SYSTEM
                  ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
                  ;
                  ;
                  ;                    BY KEN SKIER
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ; ********************************************
                  ;
                  ;          SCREEN PARAMETERS
                  ;
                  ; ********************************************
                  ;
                  ;
                  ;
                  ;
                  ;
1000                      *=$1000
                  ;
                  ;
                  ;
                  ;
                  ;
1000 0004         HOME    .WORD $0400    THIS IS THE ADDRESS OF THE
                  ;                      CHARACTER IN THE UPPER LEFT
                  ;                      CORNER OF THE SCREEN.
                  ;                      (WHEN YOU ARE DISPLAYING
                  ;                      LOW-RESOLUTION GRAPHICS AND
                  ;                      TEXT PAGE 1.)
1002 80           ROWINC  .BYTE $80      ADDRESS DIFFERENCE FROM ONE
                  ;                      ROW TO THE NEXT.
1003 27           TVCOLS  .BYTE 39       NUMBER OF COLUMNS ON SCREEN,
                  ;                      COUNTING FROM ZERO.
1004 07           TVROWS  .BYTE 7        NUMBER OF ROWS ON SCREEN,
                  ;                      COUNTING FROM ZERO.
1005 07           HIPAGE  .BYTE $07      HIGHEST PAGE IN SCREEN MEMORY.
                  ;                      (WITH LOW-RES PAGE 1 SELECTED.)
1006 A0           BLANK   .BYTE $A0      APPLE II DISPLAY CODE FOR
                  ;                      A BLANK: A DARK BOX, USED AS
                  ;                      A SPACE WHEN APPLE II IS IN
```

```
 580                ;              NORMAL DISPLAY MODE (WHITE
 590                ;              CHARACTERS ON A DARK
 600                ;              BACKGROUND.)
 610 1007 DE       ARROW  .BYTE $DE   APPLE II DISPLAY CODE FOR
 620                ;              A CARAT (USED BECAUSE APPLE
 630                ;              II HAS NO UP-ARROW.)
 640                ;
 650                ;
 660                ;
 670                ;
 680                ;
 690                ;
 700                ;
 710                ;
 720                ;
 730                ; *********************************************
 740                ;
 750                ;           INPUT/OUTPUT VECTORS
 760                ;
 770                ; *********************************************
 780                ;
 790                ;
 800                ;
 810                ;
 820                ;
 830                ;
 840 1008 1410     ROMKEY .WORD APLKEY   POINTER TO ROUTINE THAT GETS
 850                ;              AN ASCII CHARACTER FROM THE
 860                ;              KEYBOARD.  (NOTE: APLKEY
 870                ;              CALLS A ROM SUBROUTINE, BUT
 880                ;              APLKEY IS NOT AN APPLE ROM
 890                ;              SUBROUTINE.)
 900                ;
 910                ;
 920 100A 1A10     ROMTVT .WORD APLTVT   POINTER TO ROUTINE TO PRINT
 930                ;              AN ASCII CHARACTER ON THE SCREEN
 940                ;
 950                ;
 960 100C 1010     ROMPRT .WORD DUMMY    POINTER TO ROUTINE TO SEND AN
 970                ;              ASCII CHARACTER TO THE PRINTER
 980                ;              (SET TO DUMMY UNTIL YOU MAKE
 990                ;              IT POINT TO THE CHARACTER-
1000                ;              OUTPUT ROUTINE THAT DRIVES
1010                ;              YOUR PRINTER.)
1020                ;                   YOU MAY WISH TO
1030                ;              SET ROMPRT SO IT POINTS TO
1040                ;              $FDED, THE APPLE II'S
1050                ;              GENERAL CHARACTER OUTPUT
1060                ;              ROUTINE.  $FDED WILL PRINT TO
1070                ;              A PRINTER IF YOU TELL
1080                ;              YOUR APPLE II ROM SOFTWARE
1090                ;              TO SELECT  YOUR PRINTER AS
1100                ;              AN OUTPUT DEVICE.  DO THAT
1110                ;              IN BASIC BY TYPING "PR #N",
1120                ;              WHERE N IS THE NUMBER OF THE
1130                ;              SLOT HOLDING THE CIRCUIT CARD
1140                ;              THAT DRIVES YOUR PRINTER.
```

```
             ;
             ;
             ;
100E 1010   USROUT .WORD DUMMY    POINTER TO USER-WRITTEN OUTPUT
             ;                    ROUTINE.  (SET HERE TO DUMMY
             ;                    UNTIL YOU SET IT TO POINT
             ;                    TO YOUR OWN CHARACTER-OUTPUT
             ;                    ROUTINE.)
             ;
             ;
1010 60     DUMMY  RTS            THIS IS A DUMMY SUBROUTINE.
             ;                    IT DOES NOTHING BUT RETURN.
             ;
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;      CONVERT ASCII CHARACTER TO DISPLAY CODE
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
             ;
1011 0980   FIXCHR ORA #$80       SET BIT 7, SO CHARACTER
             ;                    WILL DISPLAY IN NORMAL MODE.
1013 60            RTS            RETURN.
             ;
             ;
             ;
             ;
             ;
             ; ********************************************
             ;
             ;    GET AN ASCII CHARACTER FROM THE KEYBOARD
             ;
             ; ********************************************
             ;
             ;
             ;
             ;
1014 2035FD APLKEY JSR $FD35      GET KEYBOARD CHARACTER WITH
             ;                    BIT 7 SET.
1017 297F          AND #$7F       CLEAR BIT 7.
             ;
1019 60            RTS            RETURN WITH ASCII CHARACTER
             ;                    FROM THE KEYBOARD.
             ;
             ;
             ;
             ;
             ;
             ;
             ;
```

```
            ;
            ; ********************************************
            ;
            ;      PRINT AN ASCII CHARACTER ON THE SCREEN
            ;
            ; ********************************************
            ;
            ;
            ;
            ;
            ;
101A 0980   APLTVT ORA #$80       SET BIT 7 SO CHARACTER WILL
            ;                     PRINT IN NORMAL MODE.
101C 20FDFB        JSR $FBFD      CALL APPLE II ROM ROUTINE TO
            ;                     PRINT A CHARACTER TO SCREEN.
101F 60            RTS            RETURN TO CALLER.
```

Appendix C16:

System Data Block for the Atari 800

```
               ;        APPENDIX C16: ASSEMBLER LISTING OF
               ;           SYSTEM DATA BLOCK
               ;              FOR THE ATARI 800
               ;
               ;
               ;
               ;
               ;      SEE APPENDIX B4 OF BEYOND GAMES: SYSTEM
               ; SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER
               ;
               ;
               ;                    BY KEN SKIER
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ;
               ; *******************************************
               ;
               ;         EXTERNAL ADDRESSES
               ;
               ; *******************************************
               ;
               ;
               ;
               ;
               ;
               ;
0000=                   TV.PTR=0
               ;
1100=                   TVSUBS=$1100
1113=                   CLR.XY=TVSUBS+$13
112B=                   TVHOME=TVSUBS+$2B
113C=                   TVTOXY=TVSUBS+$3C
1176=                   TVDOWN=TVSUBS+$76
11C4=                   TVPUSH=TVSUBS+$C4
11D3=                   TV.POP=TVSUBS+$D3
117C=                   VUCHAR=TVSUBS+$7C
               ;
1500=                   HEX.PG=$1500
1552=                   SA=HEX.PG+$52
1554=                   EA=SA+2
               ;
1700=                   MOV.PG=$1700
17B2=                   DEST=MOV.PG+$B2
17D6=                   MOV.EA=MOV.PG+$D6
               ;
               ;
               ;
```

```
580                 ;
590                 ;
600                 ;
610                 ; ********************************************
620                 ;
630                 ;         SCREEN PARAMETERS
640                 ;
650                 ; ********************************************
660                 ;
670                 ;
680                 ;
690                 ;
700                 ;
710 1000                *=$1000
720                 ;
730                 ;
740                 ;
750                 ;
760 1000 427C     HOME    .WORD $7C42     ADDRESS OF THE
770                 ;                     CHARACTER IN THE UPPER LEFT
780                 ;                     CORNER OF THE SCREEN.
790                 ;                     (FOR AN ATARI 800 W/32K RAM,
800                 ;                     IN SCREEN MODE 0.)
810                 ;                     YOU MUST USE SCREEN MODE 0.
820                 ;                     APPENDIX B4 INCLUDES A BASIC
830                 ;                     PROGRAM TO START THE VISIBLE
840                 ;                     MONITOR.  IT SETS HOME FOR
850                 ;                     YOUR SYSTEM.
860                 ;           NOTE:     IF HOME IS LESS THAN $2000
870                 ;                     (8192 DECIMAL), THE SCREEN
880                 ;                     WILL INTERFERE WITH THE
890                 ;                     SOFTWARE IN THIS BOOK.
900                 ;
910                 ;                     IF YOU TRY TO RUN THIS
920                 ;                     SOFTWARE ON AN 8K SYSTEM, DON'T
930                 ;                     USE THE DISASSEMBLER OR THE
940                 ;                     SIMPLE TEXT EDITOR, BECAUSE
950                 ;                     SCREEN OPERATIONS WILL WRITE
960                 ;                     OVER THEM, AND THEY'LL CRASH.
970                 ;
980  1002 28      ROWINC .BYTE 40         ADDRESS DIFFERENCE FROM ONE
990                 ;                     ROW TO THE NEXT.
1000 1003 27      TVCOLS .BYTE 39         NUMBER OF COLUMNS ON SCREEN,
1010                ;                     COUNTING FROM ZERO.
1020 1004 17      TVROWS .BYTE 23         NUMBER OF ROWS ON SCREEN,
1030                ;                     COUNTING FROM ZERO.
1040 1005 7F      HIPAGE .BYTE $7F        HIGHEST PAGE IN SCREEN
1050                ;                     MEMORY.  LIKE HOME, HIPAGE
1060                ;                     VARIES ACCORDING TO THE
1070                ;                     AMOUNT OF RAM IN YOUR ATARI.
1080                ;                     HIPAGE IS SET FOR YOUR SYSTEM
1090                ;                     WHEN YOU RUN THE BASIC PROGRAM
1100                ;                     IN APPENDIX B4 TO START
1110                ;                     THE VISIBLE MONITOR.
1120                ;
1130 1006 00      BLANK  .BYTE 0          ATARI DISPLAY CODE FOR A BLANK
1140 1007 7B      ARROW  .BYTE $7B        ATARI DISPLAY CODE FOR
1150                ;                     AN UP-ARROW.
```

```
1160                ;
1170                ;
1180                ;
1190                ;
1200                ;
1210                ;
1220                ;
1230                ;
1240                ; ********************************************
1250                ;
1260                ;           INPUT/OUTPUT VECTORS
1270                ;
1280                ; ********************************************
1290                ;
1300                ;
1310                ;
1320                ;
1330                ;
1340                ;
1350 1008 2810     ROMKEY .WORD ATRKEY    POINTER TO ROUTINE THAT GETS
1360                ;                     AN ASCII CHARACTER FROM THE
1370                ;                     KEYBOARD.
1380                ;
1390                ;
1400 100A 3610     ROMTVT .WORD TVTSIM    POINTER TO ROUTINE TO PRINT
1410                ;                     AN ASCII CHARACTER ON THE SCREEN
1420                ;
1430                ;
1440 100C 1010     ROMPRT .WORD DUMMY     POINTER TO ROUTINE TO SEND AN
1450                ;                     ASCII CHARACTER TO THE PRINTER
1460                ;                     (SET TO DUMMY UNTIL YOU MAKE
1470                ;                     IT POINT TO THE CHARACTER-
1480                ;                     OUTPUT ROUTINE
1490                ;                     THAT DRIVES YOUR PRINTER.
1500                ;
1510                ;
1520                ;
1530 100E 1010     USROUT .WORD DUMMY     POINTER TO USER-WRITTEN OUTPUT
1540                ;                     ROUTINE.  (SET HERE TO DUMMY
1550                ;                     UNTIL YOU SET IT TO POINT
1560                ;                     TO YOUR OWN CHARACTER-OUTPUT
1570                ;                     ROUTINE.)
1580                ;
1590                ;
1600 1010 60       DUMMY  RTS             THIS IS A DUMMY SUBROUTINE.
1610                ;                     IT DOES NOTHING BUT RETURN.
1620                ;
1630                ;
1640                ;
1650                ;
1660                ;
1670                ;
1680                ; ********************************************
1690                ;
1700                ;     CONVERT ASCII CHARACTER TO DISPLAY CODE
1710                ;
1720                ; ********************************************
1730                ;
```

```
1740                 ;
1750                 ;
1760                 ;
1770                 ;
1780 1011 297F   FIXCHR AND #$7F       CLEAR BIT 7 SO CHARACTER IS
1790                 ;                 A LEGITIMATE ASCII CHARACTER.
1800 1013 38            SEC            PREPARE TO COMPARE.
1810 1014 C920          CMP #$20       IS CHARACTER < $20?
1820 1016 9008          BCC BADCHR     IF SO, IT'S NOT A VIEWABLE
1830                 ;                 ASCII CHARACTER, SO RETURN
1840                 ;                 A BLANK.
1850                 ;
1860 1018 C960          CMP #$60       IS CHARACTER < $60?
1870 101A 9008          BCC SUB.20     IF SO, SUBTRACT $20 AND RETURN.
1880 101C C97B          CMP #$7B       CHARACTER < $7B?
1890 101E 9007          BCC FIXEND     IF SO, NO CONVERSION IS NEEDED.
1900                 ;
1910 1020 AD0610 BADCHR LDA BLANK      THE CHARACTER IS NOT A
1920                 ;                 VIEWABLE ASCII CHARACTER,
1930 1023 60            RTS            SO RETURN A BLANK.
1940 1024 38     SUB.20 SEC            PREPARE TO SUBTRACT.
1950 1025 E920          SBC #$20       SUBTRACT $20 TO CONVERT ASCII
1960                 ;                 TO ATARI DISPLAY CODE.
1970 1027 60     FIXEND RTS            RETURN WITH ATARI DISPLAY
1980                 ;                 CODE FOR ORIGINAL ASCII
1990                 ;                 CHARACTER.
2000                 ;
2010                 ;
2020                 ;
2030                 ;
2040                 ;
2050                 ;
2060                 ;
2070                 ;
2080                 ; ********************************************
2090                 ;
2100                 ;    GET AN ASCII CHARACTER FROM THE KEYBOARD
2110                 ;
2120                 ; ********************************************
2130                 ;
2140                 ;
2150                 ;
2160                 ;
2170                 ;
2180                 ;
2190                 ;
2200                 ;
2210 1028 ADFC02 ATRKEY LDA $02FC     HAS A KEY BEEN DEPRESSED?
2220 102B C9FF          CMP #$FF       $FF MEANS NO KEY.
2230 102D F0F9          BEQ ATRKEY     IF NOT, LOOK AGAIN.
2240                 ;
2250                 ;                 A KEY HAS GONE DOWN.
2260                 ;                 ACCUMULATOR HOLDS ITS
2270                 ;                 HARDWARE KEY-CODE.
2280 102F A8            TAY            PREPARE TO USE THAT CODE AS
2290                 ;                 AS AN INDEX.
2300                 ;
2310                 ;
```

```
1030 B9000F            LDA ATRKYS,Y      LOOK UP CHARACTER FOR THAT
                 ;                       KEY AND SHIFT STATE.
1033 60                RTS               RETURN WITH ASCII CHARACTER
                 ;                       FOR THAT KEY AND SHIFT STATE.
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ;
                 ; ********************************************
                 ;
                 ;     PRINT AN ASCII CHARACTER ON THE SCREEN
                 ;
                 ; ********************************************
                 ;
                 ;
                 ;
000D=                  CR=$0D            ASCII CARRIAGE RETURN.
000A=                  LF=$0A            ASCII LINEFEED CHARACTER.
                 ;
                 ;
                 ;
1034 00         TVCHAR .BYTE 0           THIS BYTE HOLDS CHARACTER
                 ;                       TO BE DISPLAYED. (ALSO,
                 ;                       CHARACTER MOST RECENTLY
                 ;                       DISPLAYED, USING TVTSIM.)
1035 00         TV.COL .BYTE 0           THIS BYTE HOLDS COLUMN IN
                 ;                       WHICH CHARACTER WILL NEXT
                 ;                       APPEAR.  WE MAY THINK OF IT
                 ;                       AS THE POSITION OF AN
                 ;                       ELECTRONIC "PRINT-HEAD".
                 ;
                 ;
                 ;
1036 C90D       TVTSIM CMP #CR           IS CHARACTER AN ASCII
                 ;                       CARRIAGE RETURN?
1038 D006              BNE LFTEST        IF NOT, PERFORM NEXT TEST.
103A A900       RESET  LDA #0            RESET TV COLUMN TO
103C 8D3510            STA TV.COL        LEFT MARGIN AND
103F 60                RTS               RETURN.
                 ;
1040 C90A       LFTEST CMP #LF           IS IT A LINEFEED CHARACTER?
1042 D003              BNE CHSAVE    IF  NOT, HANDLE IT AS A CHARACTER
1044 4C800E            JMP SCROLL        SCROLL TEXT UP FOR A LINEFEED.
                 ;
                 ;                       SINCE IT'S NOT CR OR LF,
1047 8D3410     CHSAVE STA TVCHAR        LET'S SAVE IT.
104A 20C411            JSR TVPUSH        SAVE ZERO PAGE BYTES WE'LL USE.
                 ;
104D AC0410            LDY TVROWS        SET TV.PTR TO CURRENT
1050 AE3510            LDX TV.COL        POSITION OF "PRINT-HEAD".
1053 203C11            JSR TVTOXY
                 ;
1056 AD3410            LDA TVCHAR        GET CHARACTER TO BE DISPLAYED.
1059 207C11            JSR VUCHAR        SHOW IT.
105C EE3510            INC TV.COL        ADVANCE "PRINT-HEAD" TO NEXT
```

```
                  ;                          SCREEN POSITION.
                  ;
105F AD3510              LDA TV.COL       HAS "PRINT-HEAD" REACHED
1062 CD0310              CMP TVCOLS       RIGHT EDGE OF SCREEN?
                  ;
1065 D006                BNE TVTEND       IF NOT, PREPARE TO RETURN.
1067 203A10              JSR RESET        IF SO, RESET "PRINT-HEAD" TO
106A 20800E              JSR SCROLL       LEFT MARGIN AND SCROLL TEXT.
106D 20D311 TVTEND JSR TV.POP             RESTORE ZERO PAGE BYTES
                  ;
1070 60                  RTS              WE USED, AND RETURN.
                  ;
                  ;
                  ;
                  ;
                  ;
                  ;
                  ; *********************************************
                  ;
                  ;          SCROLL TEXT UP ON SCREEN
                  ;
                  ; *********************************************
                  ;
                  ;
                  ;
                  ;
0E80                         *=$0E80
                  ;
                  ;
                  ;
                  ;
                  ;
0E80 20C411 SCROLL JSR TVPUSH             SAVE ZERO PAGE BYTES WE'LL
                  ;                       USE.
                  ;                       SCROLLING IS SIMPLY MOVING
                  ;                       THE CONTENTS OF SCREEN MEMORY
                  ;                       UP BY ONE ROW. BEFORE WE
                  ;                       MOVE ANYTHING, HOWEVER, LET'S
                  ;                       SAVE SA, EA, AND DEST--
                  ;                       THE MOVE PARAMETERS.
                  ;
0E83 ADB317              LDA DEST+1
0E86 48                  PHA
0E87 ADB217              LDA DEST
0E8A 48                  PHA
0E8B AD5515              LDA EA+1
0E8E 48                  PHA
0E8F AD5415              LDA EA
0E92 48                  PHA
0E93 AD5315              LDA SA+1
0E96 48                  PHA
0E97 AD5215              LDA SA
0E9A 48                  PHA
                  ;                       NOW SA, EA, AND DEST ARE SAVED.
                  ;
0E9B 202B11              JSR TVHOME       SET TV.PTR TO HOME POSITION.
0E9E A500                LDA TV.PTR       SET DEST=HOME, SINCE WE'LL
0EA0 8DB217              STA DEST         MOVE THE CONTENTS OF SCREEN
```

```
3480 0EA3 A501          LDA TV.PTR+1   MEMORY TOWARDS THE HOME
3490 0EA5 8DB317        STA DEST+1     ADDRESS.
3500                 ;
3510 0EA8 207611        JSR TVDOWN     SET SA=ADDRESS OF SCREEN
3520 0EAB A500          LDA TV.PTR     POSITION AT COLUMN 0, ROW 1.
3530 0EAD 8D5215        STA SA         THAT MARKS THE START OF
3540 0EB0 A501          LDA TV.PTR+1   OF THE BLOCK TO BE MOVED.
3550 0EB2 8D5315        STA SA+1
3560                 ;
3570 0EB5 AE0310        LDX TVCOLS     SET EA=ADDRESS OF POSITION
3580 0EB8 AC0410        LDY TVROWS     IN BOTTOM RIGHT CORNER OF
3590 0EBB 203C11        JSR TVTOXY     THE SCREEN.
3600 0EBE A500          LDA TV.PTR
3610 0EC0 8D5415        STA EA
3620 0EC3 A501          LDA TV.PTR+1   EA WILL MARK THE END OF
3630 0EC5 8D5515        STA EA+1       THE BLOCK TO BE  MOVED.
3640                 ;
3650                 ;                 NOW SA, EA, AND DEST SPECIFY
3660                 ;                 THE BLOCK TO BE MOVED, AND
3670                 ;                 ITS DESTINATION.
3680 0EC8 20D617        JSR MOV.EA     MOVE THE BLOCK.
3690 0ECB AC0410        LDY TVROWS     SET TV.PTR TO BOTTOM LEFT
3700 0ECE A200          LDX #0         CORNER OF SCREEN.
3710 0ED0 203C11        JSR TVTOXY
3720 0ED3 AE0310        LDX TVCOLS     CLEAR THIS ROW.
3730 0ED6 A001          LDY #1
3740 0ED8 201311        JSR CLR.XY
3750 0EDB 68            PLA        RESTORE THE MOVE
3760 0EDC 8D5215        STA SA         PARAMETERS: SA, EA, AND DEST.
3770 0EDF 68            PLA
3780 0EE0 8D5315        STA SA+1
3790 0EE3 68            PLA
3800 0EE4 8D5415        STA EA
3810 0EE7 68            PLA
3820 0EE8 8D5515        STA EA+1
3830 0EEB 68            PLA
3840 0EEC 8DB217        STA DEST
3850 0EEF 68            PLA
3860 0EF0 8DB317        STA DEST+1
3870 0EF3 20D311        JSR TV.POP     RESTORE ZERO PAGE BYTES WE
3880                 ;                 USED.
3890 0EF6 60            RTS            RETURN.
3900                 ;
3910                 ;
3920                 ;
3930                 ;
3940                 ;
3950                 ;
3960                 ;
3970                 ;
3980                 ;
3990                 ;
4000                 ; ******************************************
4010                 ;
4020                 ;     KEYBOARD DEFINITION TABLE
4030                 ;
4040                 ; ******************************************
4050                 ;
```

```
4060                ;
4070                ;
4080                ;
4090                ;
4100                ;
4110 0F00                   *=$0F00
4120                ;
4130                ;
4140                ;
4150                ;
4160                ;
4170 0027=                APOSTR=$27      ASCII APOSTROPHE.
4180 005E=                CARAT=$5E       ASCII CARAT.
4190 001B=                ESC=$1B         ASCII ESCAPE CHARACTER.
4200 0020=                SPACE=$20       ASCII SPACE.
4210 0009=                TAB=9           ASCII TAB CHARACTER.
4220 005B=                BACKSL=$5B      ASCII BACKSLASH CHARACTER.
4230 0008=                BACKSP=8        ASCII BACKSPACE CHARACTER.
4240 005A=                LBRAKT=$5A      ASCII LEFT BRACKET.
4250 005D=                RBRAKT=$5D      ASCII RIGHT BRACKET.
4260 007F=                DELETE=$7F      ASCII DELETE CHARACTER.
4270                ;
4280                ;
4290                ;
4300 0F00 6C     ATRKYS .BYTE 'lj;',0,0,'k+*o',0,'pu',CR,'i-='
4300 0F01 6A
4300 0F02 3B
4300 0F03 00
4300 0F04 00
4300 0F05 6B
4300 0F06 2B
4300 0F07 2A
4300 0F08 6F
4300 0F09 00
4300 0F0A 70
4300 0F0B 75
4300 0F0C 0D
4300 0F0D 69
4300 0F0E 2D
4300 0F0F 3D
4310 0F10 76            .BYTE 'v',0,'c',0,0,'bxz4',0,'36',ESC,'521'
4310 0F11 00
4310 0F12 63
4310 0F13 00
4310 0F14 00
4310 0F15 62
4310 0F16 78
4310 0F17 7A
4310 0F18 34
4310 0F19 00
4310 0F1A 33
4310 0F1B 36
4310 0F1C 1B
4310 0F1D 35
4310 0F1E 32
4310 0F1F 31
4320 0F20 2C            .BYTE ', .n',0,'m/',0,'r',0,'ey',TAB,'twq'
4320 0F21 20
```

```
4320 0F22 2E
4320 0F23 6E
4320 0F24 00
4320 0F25 6D
4320 0F26 2F
4320 0F27 00
4320 0F28 72
4320 0F29 00
4320 0F2A 65
4320 0F2B 79
4320 0F2C 09
4320 0F2D 74
4320 0F2E 77
4320 0F2F 71
4330 0F30 39                  .BYTE '9',0,'07',BACKSP,'8<>fhd',0,0,'gsa'
4330 0F31 00
4330 0F32 30
4330 0F33 37
4330 0F34 08
4330 0F35 38
4330 0F36 3C
4330 0F37 3E
4330 0F38 66
4330 0F39 68
4330 0F3A 64
4330 0F3B 00
4330 0F3C 00
4330 0F3D 67
4330 0F3E 73
4330 0F3F 61
4340             ;
4350             ;
4360             ;                          FOLLOWING 64 BYTES CONTAIN
4370             ;                          ASCII CODES FOR SHIFTED KEYS.
4380             ;
4390             ;
4400 0F40 4C                  .BYTE 'LJ:',0,0,'K',BACKSL,CARAT
4400 0F41 4A
4400 0F42 3A
4400 0F43 00
4400 0F44 00
4400 0F45 4B
4400 0F46 5B
4400 0F47 5E
4410 0F48 4F                  .BYTE 'O',0,'PU',CR,'I-='
4410 0F49 00
4410 0F4A 50
4410 0F4B 55
4410 0F4C 0D
4410 0F4D 49
4410 0F4E 2D
4410 0F4F 3D
4420 0F50 56                  .BYTE 'V',0,'C',0,0,'BXZ4',0,'36',ESC,'%"!'
4420 0F51 00
4420 0F52 43
4420 0F53 00
4420 0F54 00
4420 0F55 42
```

```
4420 0F56 58
4420 0F57 5A
4420 0F58 34
4420 0F59 00
4420 0F5A 33
4420 0F5B 36
4420 0F5C 1B
4420 0F5D 25
4420 0F5E 22
4420 0F5F 21
4430 0F60 5A              .BYTE LBRAKT,SPACE,RBRAKT,'N',0,'M?',0
4430 0F61 20
4430 0F62 5D
4430 0F63 4E
4430 0F64 00
4430 0F65 4D
4430 0F66 3F
4430 0F67 00
4440 0F68 52              .BYTE 'R',0,'EY',TAB,'TWQ'
4440 0F69 00
4440 0F6A 45
4440 0F6B 59
4440 0F6C 09
4440 0F6D 54
4440 0F6E 57
4440 0F6F 51
4450 0F70 28              .BYTE '(',0,')',APOSTR,DELETE,'@',0,0
4450 0F71 00
4450 0F72 29
4450 0F73 27
4450 0F74 7F
4450 0F75 40
4450 0F76 00
4450 0F77 00
4460 0F78 46              .BYTE 'FHD',0,0,'GSA'
4460 0F79 48
4460 0F7A 44
4460 0F7B 00
4460 0F7C 00
4460 0F7D 47
4460 0F7E 53
4460 0F7F 41
4470            ;
4480            ;                   THE FOLLOWING 128 BYTES
4490            ;                   CONTAIN CHARACTER CODES FOR
4500            ;                   CONTROL SHIFTED KEYS.  EDITOR
4510            ;                   FUNCTION KEYS ARE DEFINED.
4520            ;
4530            ;
4540 0F80 00              .BYTE 0,0,0,0,0,0,0,0,0,0,$10,0,0,0,0,0
4540 0F81 00
4540 0F82 00
4540 0F83 00
4540 0F84 00
4540 0F85 00
4540 0F86 00
4540 0F87 00
4540 0F88 00
```

```
4540 0F89 00
4540 0F8A 10
4540 0F8B 00
4540 0F8C 00
4540 0F8D 00
4540 0F8E 00
4540 0F8F 00
4550 0F90 00                    .BYTE 0,0,3,0,0,0,0,0,0,0,0.0.0,0,0.0
4550 0F91 00
4550 0F92 03
4550 0F93 00
4550 0F94 00
4550 0F95 00
4550 0F96 00
4550 0F97 00
4550 0F98 00
4550 0F99 00
4550 0F9A 00
4550 0F9B 00
4550 0F9C 00
4550 0F9D 00
4550 0F9E 00
4550 0F9F 00
4560 0FA0 00                    .BYTE 0,0,0,0,0,0,0,0,0,0,0,0,0,0.0,0
4560 0FA1 00
4560 0FA2 00
4560 0FA3 00
4560 0FA4 00
4560 0FA5 00
4560 0FA6 00
4560 0FA7 00
4560 0FA8 00
4560 0FA9 00
4560 0FAA 00
4560 0FAB 00
4560 0FAC 00
4560 0FAD 00
4560 0FAE 00
4560 0FAF 00
4570 0FB0 00                    .BYTE 0,0,0,0,0,0,0,0,6,0,0,0,0,0,0,0
4570 0FB1 00
4570 0FB2 00
4570 0FB3 00
4570 0FB4 00
4570 0FB5 00
4570 0FB6 00
4570 0FB7 00
4570 0FB8 06
4570 0FB9 00
4570 0FBA 00
4570 0FBB 00
4570 0FBC 00
4570 0FBD 00
4570 0FBE 00
4570 0FBF 00
4580 0FC0 00                    .BYTE 0,0,0.0,0,0.0.0,0,0,0,0,0,0,0,0
4580 0FC1 00
4580 0FC2 00
```

```
4580 0FC3 00
4580 0FC4 00
4580 0FC5 00
4580 0FC6 00
4580 0FC7 00
4580 0FC8 00
4580 0FC9 00
4580 0FCA 00
4580 0FCB 00
4580 0FCC 00
4580 0FCD 00
4580 0FCE 00
4580 0FCF 00
4590 0FD0 00            .BYTE 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
4590 0FD1 00
4590 0FD2 00
4590 0FD3 00
4590 0FD4 00
4590 0FD5 00
4590 0FD6 00
4590 0FD7 00
4590 0FD8 00
4590 0FD9 00
4590 0FDA 00
4590 0FDB 00
4590 0FDC 00
4590 0FDD 00
4590 0FDE 00
4590 0FDF 00
4600 0FE0 00            .BYTE 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
4600 0FE1 00
4600 0FE2 00
4600 0FE3 00
4600 0FE4 00
4600 0FE5 00
4600 0FE6 00
4600 0FE7 00
4600 0FE8 00
4600 0FE9 00
4600 0FEA 00
4600 0FEB 00
4600 0FEC 00
4600 0FED 00
4600 0FEE 00
4600 0FEF 00
4610 0FF0 00            .BYTE 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
4610 0FF1 00
4610 0FF2 00
4610 0FF3 00
4610 0FF4 00
4610 0FF5 00
4610 0FF6 00
4610 0FF7 00
4610 0FF8 00
4610 0FF9 00
4610 0FFA 00
4610 0FFB 00
4610 0FFC 00
```

```
4610 0FFD 00
4610 0FFE 00
4610 0FFF 00
```

Appendix D1:

Screen Utilities

```
APPENDIX D1:            SCREEN UTILITIES

SEE CHAPTER 5 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER.


DUMPING $1100-$11FF

         0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F

1100    20 C4 11 20 2B 11 AE 03 10 AC 04 10 20 13 11 20
1110    D3 11 60 8E 2A 11 98 AA AD 06 10 AC 2A 11 91 00
1120    88 10 FB 20 76 11 CA 10 EF 60 19 A2 00 A0 00 18
1130    90 0A AD 04 10 4A A8 AD 03 10 4A AA 38 EC 03 10
1140    90 03 AE 03 10 38 CC 04 10 90 03 AC 04 10 AD 00
1150    10 85 00 AD 01 10 85 01 08 D8 8A 18 65 00 90 03
1160    E6 01 18 C0 00 F0 0B 18 6D 02 10 90 02 E6 01 88
1170    D0 F5 85 00 28 60 AD 02 10 18 90 05 20 9B 11 A9
1180    01 08 D8 18 65 00 90 02 E6 01 85 00 38 AD 05 10
1190    C5 01 B0 05 AD 01 10 85 01 28 60 20 11 10 A0 00
11A0    91 00 60 48 4A 4A 4A 4A 20 B6 11 20 7C 11 68 20
11B0    B6 11 20 7C 11 60 08 D8 29 0F C9 0A 30 02 69 06
11C0    69 30 28 60 68 AA 68 A8 A5 01 48 A5 00 48 98 48
11D0    8A 48 60 68 AA 68 A8 68 85 00 68 85 01 98 48 8A
11E0    48 60 00 00 00 00 00 00 00 00 00 00 00 00 00 00
11F0    00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

Appendix D2:

Visible Monitor (Top Level and Display Subroutines)

```
APPENDIX D2:      THE VISIBLE MONITOR  (TOP LEVEL AND DISPLAY SUBROUTINES)

SEE CHAPTER 6 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTE

.

DUMPING $1200-$12DF

         0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F


1200     00 0C 00 00 31 05 12 08 D8 20 12 12 20 E3 12 18
1210     90 F6 20 C4 11 20 25 12 20 34 12 20 5C 12 20 AF
1220     12 20 D3 11 60 A2 02 A0 02 20 3C 11 A2 19 A0 03
1230     20 13 11 60 A2 0D A0 02 20 3C 11 A0 00 8C 51 12
1240     B9 52 12 20 7C 11 EE 51 12 AC 51 12 C0 0A D0 F0
1250     60 0A 41 20 20 58 20 20 59 20 20 50 A2 02 A0 03
1260     20 3C 11 AD 05 12 20 A3 11 AD 05 12 20 A3 11 20
1270     7F 11 20 94 12 48 20 A3 11 20 7F 11 68 20 7C 11
1280     20 7F 11 A2 00 BD 01 12 20 A3 11 20 7F 11 E8 E0
1290     04 D0 F2 60 A5 02 48 A6 03 AD 05 12 85 02 AD 06
12A0     12 85 03 A0 00 B1 02 A8 68 85 02 86 03 98 60 A2
12B0     02 A0 04 20 3C 11 AC 00 12 38 C0 07 90 05 A0 00
12C0     8C 00 12 B9 CD 12 A8 AD 07 10 91 00 60 03 06 08
12D0     0B 0E 11 14 00 00 00 00 00 00 00 00 00 00 00 00
```

Appendix D3:

Visible Monitor (Update Subroutine)

```
APPENDIX D3:        THE VISIBLE MONITOR  (UPDATE SUBROUTINE)

SEE CHAPTER 6 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER.


DUMPING $12E0-$13FF

          0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F

12E0     6C 08 10 20 E0 12 C9 3E D0 10 EE 00 12 AD 00 12
12F0     C9 07 D0 05 A9 00 8D 00 12 60 C9 3C D0 0B CE 00
1300     12 10 05 A9 06 8D 00 12 60 C9 20 D0 09 EE 05 12
1310     D0 03 EE 06 12 60 C9 0D D0 0C AD 05 12 D0 03 CE
1320     06 12 CE 05 12 60 AE 00 12 E0 02 D0 1B A8 A5 00
1330     48 A6 01 AD 05 12 85 00 AD 06 12 85 01 98 A0 00
1340     91 00 86 01 68 85 00 60 C9 47 D0 23 AC 03 12 AE
1350     02 12 AD 04 12 48 AD 01 12 28 20 6C 13 08 8D 01
1360     12 8E 02 12 8C 03 12 68 8D 04 12 60 6C 05 12 48
1370     20 D5 13 30 4B A8 68 98 AE 00 12 D0 14 A2 03 18
1380     0E 05 12 2E 06 12 CA 10 F6 98 0D 05 12 8D 05 12
1390     60 E0 01 D0 18 29 0F 48 20 94 12 0A 0A 0A 0A 29
13A0     F0 8D AC 13 68 0D AC 13 20 2D 13 60 00 CA CA CA
13B0     A0 03 18 1E 01 12 68 10 F9 1D 01 12 9D 01 12 60
13C0     68 C9 7F D0 04 20 00 11 60 C9 51 D0 04 68 68 28
13D0     60 20 B0 10 60 38 E9 30 90 0F C9 0A 90 0E E9 07
13E0     C9 10 B0 05 38 C9 0A B0 03 A9 FF 60 A2 00 60 00
13F0     00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

Appendix D4:

Print Utilities

```
APPENDIX D4:            PRINT UTILITIES

SEE CHAPTER 7 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTE


DUMPING $1400-$154F

        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F

1400    FF FF 00 20 00 00 0C 15 A9 FF 8D 01 14 60 A9 00
1410    8D 01 14 60 A9 FF 8D 00 14 60 A9 00 8D 00 14 60
1420    A9 FF 8D 02 14 60 A9 00 8D 02 14 60 20 08 14 20
1430    14 14 20 20 14 60 20 0E 14 20 1A 14 20 26 14 60
1440    C9 00 F0 24 8D 03 14 AD 01 14 F0 06 AD 03 14 20
1450    69 14 AD 00 14 F0 06 AD 03 14 20 6C 14 AD 02 14
1460    F0 06 AD 03 14 20 6F 14 60 6C 0A 10 6C 0C 10 6C
1470    0E 10 A9 0D 20 40 14 A9 0A 20 40 14 60 A9 20 20
1480    40 14 60 48 4A 4A 4A 4A 20 B6 11 20 40 14 68 20
1490    B6 11 20 40 14 60 A9 20 8E 04 14 48 AE 04 14 F0
14A0    0A CE 04 14 20 40 14 68 18 90 F0 68 60 8E 04 14
14B0    AE 04 14 F0 09 CE 04 14 20 72 14 18 90 F2 60 8E
14C0    05 14 B5 01 48 B5 00 48 AE 05 14 A1 00 C9 FF F0
14D0    0C F6 00 D0 02 F6 01 20 40 14 18 90 EB 68 95 00
14E0    68 95 01 60 68 AA 68 A8 20 12 15 8E 05 12 8C 06
14F0    12 20 0D 13 20 0D 13 20 94 12 C9 FF F0 06 20 40
1500    14 18 90 F0 AE 05 12 AC 06 12 20 2B 15 98 48 8A
1510    48 60 68 8D 06 14 68 8D 07 14 AD 06 12 48 AD 05
1520    12 48 AD 07 14 48 AD 06 14 48 60 68 8D 06 14 68
1530    8D 07 14 68 8D 05 12 68 8D 06 12 AD 07 14 48 AD
1540    06 14 48 60 00 00 00 00 00 00 00 00 00 00 00 00
```

Appendix D5:

Two Hexdump Tools

```
APPENDIX D5:           TWO HEXDUMP TOOLS

SEE CHAPTER 8 OF BEYOND .GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER


DUMPING $1550-$17AF


        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F


1550   00 04 50 15 AF 17 00 20 08 14 AD 51 15 8D 50 15
1560   AD 05 12 29 F8 8D 05 12 20 72 14 20 72 14 20 A1
1570   15 20 72 14 20 7D 14 20 9A 15 20 0D 13 AD 05 12
1580   29 07 D0 F0 20 72 14 AD 05 12 29 0F D0 03 20 72
1590   14 CE 50 15 D0 D8 20 0E 14 60 20 94 12 20 83 14
15A0   60 AD 06 12 20 83 14 AD 05 12 20 83 14 60 20 C9
15B0   15 20 E9 15 20 A0 17 20 14 14 20 EB 16 20 42 17
15C0   10 FB 20 72 14 20 1A 14 60 20 00 11 20 08 14 20
15D0   E4 14 7F 0D 50 52 49 4E 54 49 4E 47 20 48 45 58
15E0   44 55 4D 50 0D 0A 0A FF 60 20 08 14 20 E4 14 7F
15F0   0D 0A 53 45 54 20 53 54 41 52 54 49 4E 47 20 41
1600   44 44 52 45 53 53 20 41 4E 44 20 50 52 45 53 53
1610   20 22 51 22 2E FF 20 07 12 20 67 16 20 08 14 20
1620   E4 14 7F 0D 0A 53 45 54 20 45 4E 44 20 41 44 44
1630   52 45 53 53 20 41 4E 44 20 50 52 45 53 53 20 22
1640   51 22 2E FF 20 07 12 38 AD 06 12 CD 53 15 90 24
1650   D0 08 AD 05 12 CD 52 15 90 1A AD 06 12 8D 55 15
1660   AD 05 12 8D 54 15 60 AD 06 12 8D 53 15 AD 05 12
1670   8D 52 15 60 20 E4 14 7F 0D 0A 0A 0A 20 45 52 52
1680   4F 52 21 21 21 20 45 4E 44 20 41 44 44 52 45 53
1690   53 20 4C 45 53 53 20 54 48 41 4E 20 53 54 41 52
16A0   54 20 41 44 44 52 45 53 53 2C 20 57 48 49 43 48
16B0   20 49 53 20 FF 20 BB 16 4C 1C 16 A9 24 20 40 14
16C0   AD 53 15 20 83 14 AD 52 15 20 83 14 60 A9 24 20
16D0   40 14 AD 55 15 20 83 14 AD 54 15 20 83 14 60 20
16E0   BB 16 A9 2D 20 40 14 20 CD 16 60 20 E4 14 7F 0D
16F0   0A 0A 44 55 4D 50 49 4E 47 20 FF 20 DF 16 20 72
1700   14 20 E4 14 7F 0A 0A 20 20 20 20 20 20 20 20 30
1710   20 20 31 20 20 32 20 20 33 20 20 34 20 20 35 20
```

```
1720    20 36 20 20 37 20 20 38 20 20 39 20 20 41 20 20
1730    42 20 20 43 20 20 44 20 20 45 20 20 46 0D 0A 0A
1740    FF 60 20 72 14 AD 05 12 48 29 0F 8D 56 15 68 29
1750    F0 8D 05 12 20 A1 15 A2 03 20 96 14 AD 56 15 F0
1760    0D A2 03 20 96 14 20 0D 13 CE 56 15 D0 F3 20 9A
1770    15 20 7D 14 20 83 17 30 09 AD 05 12 29 0F C9 00
1780    D0 EC 60 38 AD 06 12 CD 55 15 90 0B D0 0F 38 AD
1790    05 12 CD 54 15 B0 06 20 0D 13 A9 00 60 A9 FF 60
17A0    AD 52 15 8D 05 12 AD 53 15 8D 06 12 60 00 00 00
```

Appendix D6:

Table-Driven Disassembler (Top Level and Utility Subroutines)

```
APPENDIX D6:    TABLE-DRIVEN DISASSEMBLER  (TOP LEVEL AND UTILITY SUBROUTINES)

SEE CHAPTER 9 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER


DUMPING $1900-$1A3F

         0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F

1900    05 00 00 5A 40 1A FF 04 10 20 08 14 AD 00 19 8D
1910    01 19 A9 FF 8D 54 15 8D 55 15 20 72 14 20 7D 19
1920    CE 01 19 D0 F8 60 20 1A 14 20 08 14 20 E4 14 7F
1930    0D 0A 20 20 20 20 20 50 52 49 4E 54 49 4E 47 20
1940    44 49 53 41 53 53 45 4D 42 4C 45 52 2E 0D 0A FF
1950    20 E9 15 20 14 14 20 E4 14 7F 0D 0A 44 49 53 41
1960    53 53 45 4D 42 4C 49 4E 47 20 FF 20 DF 16 20 A0
1970    17 20 72 14 20 7D 19 10 FB 20 1A 14 60 20 94 12
1980    48 20 92 19 20 7D 14 68 20 AF 19 20 01 1A 20 83
1990    17 60 A2 03 8E 02 19 AA BD 00 1C AA BD 50 1B 8E
19A0    03 19 20 40 14 AE 03 19 E8 CE 02 19 D0 EE 60 AA
19B0    BD 00 1D AA 20 B8 19 60 BD 1B 1B 8D 04 19 E8 BD
19C0    1B 1B 8D 05 19 6C 04 19 20 0D 13 20 9A 15 60 20
19D0    0D 13 20 94 12 48 20 0D 13 20 9A 15 68 20 83 14
19E0    60 A9 28 D0 02 A9 29 20 40 14 60 A9 2C 20 40 14
19F0    A5 58 20 40 14 60 A9 2C 20 40 14 A9 59 20 40 14
1A00    60 8D 07 19 8E 06 19 CA 30 06 20 1A 13 CA 10 FA
1A10    08 D8 38 AD 08 19 E9 04 ED 07 19 28 AA 20 96 14
1A20    20 A1 15 20 7D 14 20 9A 15 20 0D 13 CE 06 19 10
1A30    F2 20 1A 13 20 72 14 60 00 00 00 00 00 00 00 00
```

Appendix D7:

Table-Driven Disassembler (Addressing Mode Subroutines)

```
APPENDIX D7:     TABLE-DRIVEN DISASSEMBLER   (ADDRESSING MODE SUBROUTINES)

SEE CHAPTER 9 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTE


DUMPING $1A40-$1B4F

        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F

1A40   20 CF 19 A2 02 A9 04 60 20 40 1A 20 EB 19 A2 02
1A50   A9 06 60 20 40 1A 20 F6 19 A2 02 A9 06 60 A9 41
1A60   20 40 14 A2 00 A9 01 60 A2 00 A9 00 60 A9 23 20
1A70   40 14 A9 24 20 40 14 20 C8 19 A2 01 A9 04 60 20
1A80   E1 19 20 40 1A 20 E5 19 A9 06 A2 02 60 20 E1 19
1A90   20 E8 1A 20 E5 19 A2 01 A9 08 60 20 E1 19 20 DB
1AA0   1A 20 E5 19 20 F6 19 A2 01 A9 08 60 20 0D 13 20
1AB0   12 15 20 94 12 48 20 0D 13 68 C9 00 10 03 CE 06
1AC0   12 08 D8 18 6D 05 12 90 03 EE 06 12 8D 05 12 28
1AD0   20 A1 15 20 2B 15 A2 01 A9 04 60 A9 00 20 83 14
1AE0   20 C8 19 A2 01 A9 04 60 20 DB 1A 20 EB 19 A2 01
1AF0   A9 06 60 20 DB 1A 20 F6 19 A2 01 A9 06 60 68 68
1B00   68 68 20 83 17 30 0D 20 94 12 C9 FF F0 06 20 40
1B10   14 18 90 EE 20 72 14 20 83 17 60 68 1A 5E 1A 6D
1B20   1A DB 1A E8 1A F3 1A 40 1A 48 1A 53 1A 68 1A AC
1B30   1A 8D 1A 9B 1A 7F 1A FE 1A 00 00 00 00 00 00 00
1B40   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

Appendix D8:

Table-Driven Disassembler (Tables)

```
APPENDIX D8:              TABLE-DRIVEN DISASSEMBLER   (TABLES)

SEE CHAPTER 9 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER


DUMPING $1B50-$1DFF


         0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F


1B50    7F 42 41 44 41 44 43 41 4E 44 41 53 4C 42 43 43
1B60    42 43 53 42 45 51 42 49 54 42 4D 49 42 4E 45 42
1B70    50 4C 42 52 4B 42 56 43 42 56 53 43 4C 43 43 4C
1B80    44 43 4C 49 43 4C 56 43 4D 50 43 50 58 43 50 59
1B90    44 45 43 44 45 58 44 45 59 45 4F 52 49 4E 43 49
1BA0    4E 58 49 4E 59 4A 4D 50 4A 53 52 4C 44 41 4C 44
1BB0    58 4C 44 59 4C 53 52 4E 4F 50 4F 52 41 50 48 41
1BC0    50 48 50 50 4C 41 50 4C 50 52 4F 4C 52 4F 52 52
1BD0    54 49 52 54 53 53 42 43 53 45 43 53 45 44 53 45
1BE0    49 53 54 41 53 54 58 53 54 59 54 41 58 54 41 59
1BF0    54 53 58 54 58 41 54 58 53 54 59 41 54 45 58 FF
1C00    22 6A 01 01 01 6A 0A 01 70 6A 0A 01 01 6A 0A 01
1C10    1F 6A 01 01 01 6A 0A 01 2B 6A 01 01 01 6A 0A 01
1C20    58 07 01 01 16 07 79 01 76 07 79 01 16 07 79 01
1C30    19 07 01 01 01 07 79 01 68 07 01 01 01 07 79 01
1C40    7F 49 01 01 01 49 64 01 6D 49 64 01 55 49 64 01
1C50    25 49 01 01 01 49 64 01 31 49 01 01 01 49 64 01
1C60    82 04 01 01 01 04 7C 01 73 04 7C 01 55 04 7C 01
1C70    28 04 01 01 01 04 7C 01 8E 04 01 01 01 04 7C AC
1C80    01 91 01 01 97 91 94 01 46 01 A3 01 97 91 94 01
1C90    0D 91 01 01 97 91 94 01 A9 91 A3 01 01 91 01 01
1CA0    61 5B 5E 01 61 5B 5E 01 9D 5B 9A 01 61 5B 5E 01
1CB0    10 5B 01 01 61 5B 5E 01 34 5B 9E 01 61 5B 5E 01
1CC0    3D 37 01 01 3D 37 40 01 52 37 43 01 3D 37 40 01
1CD0    1C 37 01 01 01 37 40 01 2E 37 01 01 01 37 40 01
1CE0    3A 85 01 01 3A 85 4C 01 4F 85 67 01 3A 85 4C 01
1CF0    13 85 01 01 01 85 4C 01 8B 85 01 01 01 85 4C 01
1D00    12 16 00 00 00 06 06 00 12 04 02 00 00 0C 0C 00
1D10    14 18 00 00 00 0E 0E 00 12 10 00 00 00 16 16 00
```

```
1D20    0C 16 00 00 06 06 06 00 12 04 02 00 0C 0C 0C 00
1D30    14 18 00 00 00 08 08 00 12 10 00 00 00 0E 0E 00
1D40    12 16 00 00 00 06 06 00 12 0C 02 00 0C 0C 0C 00
1D50    14 18 00 00 00 08 08 00 12 10 00 00 00 0E 0E 00
1D60    12 16 00 00 00 06 06 00 12 04 02 00 1A 0C 0C 00
1D70    14 18 00 00 00 08 08 00 12 10 00 00 00 0E 0E 1C
1D80    00 16 00 00 06 06 06 00 12 00 12 00 0C 0C 0C 00
1D90    14 18 00 00 08 08 0A 00 12 10 12 00 00 0E 00 00
1DA0    04 16 04 00 06 06 06 00 12 04 12 00 0C 0C 0C 00
1DB0    14 18 00 00 08 08 0A 00 14 10 12 00 0E 0E 10 00
1DC0    04 16 00 00 06 06 06 00 12 04 12 00 0C 0C 0C 00
1DD0    14 18 00 00 00 08 08 00 12 10 00 00 00 0E 0E 00
1DE0    04 16 00 00 06 06 06 00 12 04 12 00 0C 0C 0C 00
1DF0    14 18 00 00 00 08 08 00 12 10 00 00 00 0E 0E 00
```

Appendix D9:

Move Utilities

```
APPENDIX D9:              MOVE UTILITIES

SEE CHAPTER 10 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER



DUMPING $17B0-$18FF

        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F


17B0    C7 00 39 04 20 08 14 20 E4 14 7F 0D 0A 20 20 20
17C0    20 20 4D 4F 56 45 20 54 4F 4F 4C 2E 0D 0A 0A FF
17D0    20 E9 15 20 B9 18 AE 55 15 38 AD 54 15 ED 52 15
17E0    8D B0 17 B0 02 CA 38 8A ED 53 15 8D B1 17 B0 03
17F0    A9 00 60 A0 03 B9 00 00 48 88 10 F9 38 AD 53 15
1800    CD B3 17 90 40 D0 18 AD 52 15 CD B2 17 90 36 D0
1810    0E A0 00 68 99 00 00 C8 C0 04 D0 F7 A9 FF 60 20
1820    A4 18 A0 00 AE B1 17 F0 0E B1 00 91 02 C8 D0 F9
1830    E6 01 E6 03 CA D0 F2 88 C8 B1 00 91 02 CC B0 17
1840    D0 F6 4C 11 18 AD B1 17 F0 48 AC B1 17 AD B0 17
1850    38 E9 FF B0 01 88 AA 84 03 8A 18 6D 52 15 85 00
1860    90 01 C8 98 6D 53 15 85 01 8A 18 6D B2 17 85 02
1870    90 02 E6 03 A5 03 6D B3 17 85 03 AE B1 17 A0 FF
1880    B1 00 91 02 88 D0 F9 B1 00 91 02 C6 01 C6 03 CA
1890    D0 EC 20 A4 18 AC B0 17 B1 00 91 02 88 C0 FF D0
18A0    F7 4C 11 18 AD 52 15 85 00 AD 53 15 85 01 AD B2
18B0    17 85 02 AD B3 17 85 03 60 20 08 14 20 E4 14 7F
18C0    0D 0A 53 45 54 20 44 45 53 54 49 4E 41 54 49 4F
18D0    4E 20 41 4E 44 20 50 52 45 53 53 20 51 2E FF 20
18E0    07 12 AD 05 12 8D B2 17 AD 06 12 8D B3 17 60 00
18F0    00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

Appendix D10:

Simple Text Editor

```
APPENDIX D10:             A SIMPLE TEXT EDITOR

SEE CHAPTER 11 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPL
BY KEN SKIER


DUMPING $1E00-$1FFF


         0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F


1E00     FF 01 20 0F 1E 20 37 1E 20 C8 1E 18 18 90 F6 20
1E10     08 14 20 E4 14 7F 0D 0A 0A 53 46 54 20 55 50 20
1E20     45 44 49 54 20 42 55 46 46 45 52 2E 0D 0A 0A FF
1E30     20 E9 15 20 A0 17 60 20 C4 11 20 2B 11 AE 03 10
1E40     A0 03 20 13 11 20 2B 11 20 76 11 20 C4 11 20 5E
1E50     1E 20 D3 11 20 76 11 20 89 1E 20 D3 11 60 20 12
1E60     15 AD 03 10 4A AA CA CA 20 1A 13 CA 10 FA AD 03
1E70     10 8D 00 1E 20 94 12 20 9B 11 20 7F 11 20 0D 13
1E80     CE 00 1E 10 EF 20 2B 15 60 AD 03 10 4A E9 02 20
1E90     81 11 AD 01 1E C9 01 D0 05 A9 49 18 90 02 A9 4F
1EA0     20 9B 11 A9 02 20 81 11 AD 07 10 20 9B 11 A9 02
1EB0     20 81 11 AD 06 12 20 A3 11 AD 05 12 20 A3 11 60
1EC0     06 03 3E 3C 10 7F 51 00 20 E0 12 CD C6 1E D0 17
1ED0     48 20 E0 12 CD C6 1E D0 04 68 68 68 60 8D C7 1E
1EE0     68 20 E7 1E AD C7 1E CD C1 1E D0 0B CE 01 1E 10
1EF0     05 A9 01 8D 01 1E 60 CD C2 1E D0 04 20 79 1F 60
1F00     CD C3 1E D0 04 20 87 1F 60 CD C5 1E D0 04 20 DD
1F10     1F 60 CD C4 1E D0 04 20 C5 1F 60 CD C0 1E D0 04
1F20     20 B4 1F 60 AE 01 1E F0 04 20 34 1F 60 20 2D 13
1F30     20 83 17 60 48 20 12 15 AD 53 15 48 AD 52 15 48
1F40     AD 55 15 48 AD 54 15 48 20 67 16 20 83 17 30 11
1F50     20 E2 18 AD 54 15 D0 04 CE 55 15 CE 54 15 20 D6
1F60     17 68 8D 54 15 68 8D 55 15 68 8D 52 15 68 8D 53
1F70     15 20 2B 15 68 20 2D 1F 60 20 94 12 C9 FF F0 04
1F80     20 83 17 60 A9 FF 60 38 AD 53 15 CD 06 12 90 0C
1F90     D0 10 AD 52 15 CD 05 12 F0 17 B0 06 20 1A 13 A9
1FA0     00 60 AD 52 15 8D 05 12 AD 53 15 8D 06 12 A9 00
1FB0     60 A9 FF 60 20 A0 17 A9 FF 20 2D 13 20 83 17 10
1FC0     F6 20 A0 17 60 20 A0 17 20 14 14 20 94 12 C9 FF
1FD0     F0 08 20 40 14 20 83 17 10 F1 4C 1A 14 20 12 15
1FE0     AD 53 15 48 AD 52 15 48 20 E2 18 20 83 17 20 67
1FF0     16 20 D6 17 68 8D 52 15 68 8D 53 15 20 2B 15 60
```

Appendix D11:

Extending the Visible Monitor

```
APPENDIX D11:        EXTENDING THE VISIBLE MONITOR

SEE CHAPTER 12 OF BEYOND GAMES: SYSTEM SOFTWARE FOR YOUR 6502 PERSONAL COMPUTER.



DUMPING $10B0-$10FF

        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F

10B0   C9 50 D0 09 AD 00 14 49 FF 8D 00 14 60 C9 55 D0
10C0   09 AD 02 14 49 FF 8D 02 14 60 C9 48 D0 0D AD 00
10D0   14 D0 04 20 57 15 60 20 AE 15 60 C9 4D D0 04 20
10E0   B4 17 60 C9 3F D0 0D AD 00 14 D0 04 20 09 19 60
10F0   20 26 19 60 C9 54 D0 04 20 02 1E 60 60 00 00 00
```

Appendix E1:

Screen Utilities

```
APPENDIX E1          SCREEN UTILITIES


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  4352 TO 4607
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 1000 DATA  4352, 32, 196, 17, 32, 43, 17, 174, 3, 4866
 1001 DATA  4360, 16, 172, 4, 16, 32, 19, 17, 32, 4668
 1002 DATA  4368, 211, 17, 96, 142, 42, 17, 152, 170, 5215
 1003 DATA  4376, 173, 6, 16, 172, 42, 17, 145, 0, 4947
 1004 DATA  4384, 136, 16, 251, 32, 118, 17, 202, 16, 5172
 1005 DATA  4392, 239, 96, 25, 162, 0, 160, 0, 24, 5098
 1006 DATA  4400, 144, 10, 173, 4, 16, 74, 168, 173, 5162
 1007 DATA  4408, 3, 16, 74, 170, 56, 236, 3, 16, 4982
 1008 DATA  4416, 144, 3, 174, 3, 16, 56, 204, 4, 5020
 1009 DATA  4424, 16, 144, 3, 172, 4, 16, 173, 0, 4952
 1010 DATA  4432, 16, 133, 0, 173, 1, 16, 133, 1, 4905
 1011 DATA  4440, 8, 216, 138, 24, 101, 0, 144, 3, 5074
 1012 DATA  4448, 230, 1, 24, 192, 0, 240, 11, 24, 5170
 1013 DATA  4456, 109, 2, 16, 144, 2, 230, 1, 136, 5096
 1014 DATA  4464, 208, 245, 133, 0, 40, 96, 173, 2, 5361
 1015 DATA  4472, 16, 24, 144, 5, 32, 155, 17, 169, 5034
 1016 DATA  4480, 1, 8, 216, 24, 101, 0, 144, 2, 4976
 1017 DATA  4488, 230, 1, 133, 0, 56, 173, 5, 16, 5102
 1018 DATA  4496, 197, 1, 176, 5, 173, 1, 16, 133, 5198
 1019 DATA  4504, 1, 40, 96, 32, 17, 16, 160, 0, 4866
 1020 DATA  4512, 145, 0, 96, 72, 74, 74, 74, 74, 5121
 1021 DATA  4520, 32, 182, 17, 32, 124, 17, 104, 32, 5060
 1022 DATA  4528, 182, 17, 32, 124, 17, 96, 8, 216, 5220
 1023 DATA  4536, 41, 15, 201, 10, 48, 2, 105, 6, 4964
 1024 DATA  4544, 105, 48, 40, 96, 104, 170, 104, 168, 5379
 1025 DATA  4552, 165, 1, 72, 165, 0, 72, 152, 72, 5251
 1026 DATA  4560, 138, 72, 96, 104, 170, 104, 168, 104, 5516
 1027 DATA  4568, 133, 0, 104, 133, 1, 152, 72, 138, 5301
 1028 DATA  4576, 72, 96, 0, 0, 0, 0, 0, 0, 4744
 1029 DATA  4584, 0, 0, 0, 0, 0, 0, 0, 0, 4584
 1030 DATA  4592, 0, 0, 0, 0, 0, 0, 0, 0, 4592
 1031 DATA  4600, 0, 0, 0, 0, 0, 0, 0, 0, 4600
 1032 END

OK
```

Appendix E2:

Visible Monitor (Top Level and Display Subroutines)

```
APPENDIX E2       VISIBLE MONITOR (TOP LEVEL & DISPLAY SUBS)


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  4608 TO 4831
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 1100 DATA  4608, 0, 12, 0, 0, 49, 177, 252, 8, 5106
 1101 DATA  4616, 216, 32, 18, 18, 32, 227, 18, 24, 5201
 1102 DATA  4624, 144, 246, 32, 196, 17, 32, 37, 18, 5346
 1103 DATA  4632, 32, 52, 18, 32, 92, 18, 32, 175, 5083
 1104 DATA  4640, 18, 32, 211, 17, 96, 162, 2, 160, 5338
 1105 DATA  4648, 2, 32, 60, 17, 162, 25, 160, 3, 5109
 1106 DATA  4656, 32, 19, 17, 96, 162, 13, 160, 2, 5157
 1107 DATA  4664, 32, 60, 17, 160, 0, 140, 81, 18, 5172
 1108 DATA  4672, 185, 82, 18, 32, 124, 17, 238, 81, 5449
 1109 DATA  4680, 18, 172, 81, 18, 192, 10, 208, 240, 5619
 1110 DATA  4688, 96, 10, 65, 32, 32, 88, 32, 32, 5075
 1111 DATA  4696, 89, 32, 32, 80, 162, 2, 160, 3, 5256
 1112 DATA  4704, 32, 60, 17, 173, 6, 18, 32, 163, 5205
 1113 DATA  4712, 17, 173, 5, 18, 32, 163, 17, 32, 5169
 1114 DATA  4720, 127, 17, 32, 148, 18, 72, 32, 163, 5329
 1115 DATA  4728, 17, 32, 127, 17, 104, 32, 124, 17, 5198
 1116 DATA  4736, 32, 127, 17, 162, 0, 189, 1, 18, 5282
 1117 DATA  4744, 32, 163, 17, 32, 127, 17, 232, 224, 5588
 1118 DATA  4752, 4, 208, 242, 96, 165, 2, 72, 166, 5707
 1119 DATA  4760, 3, 173, 5, 18, 133, 2, 173, 6, 5273
 1120 DATA  4768, 18, 133, 3, 160, 0, 177, 2, 168, 5429
 1121 DATA  4776, 104, 133, 2, 134, 3, 152, 96, 162, 5562
 1122 DATA  4784, 2, 160, 4, 32, 60, 17, 172, 0, 5231
 1123 DATA  4792, 18, 56, 192, 7, 144, 5, 160, 0, 5374
 1124 DATA  4800, 140, 0, 18, 185, 205, 18, 168, 173, 5707
 1125 DATA  4808, 7, 16, 145, 0, 96, 3, 6, 8, 5089
```

```
1126 DATA  4816, 11, 14, 17, 20, 0, 0, 0, 0, 4878
1127 DATA  4824, 0, 0, 0, 0, 0, 0, 0, 0, 4824
1128 END
```

Appendix E3:

Visible Monitor (Update Subroutine)

```
APPENDIX E3         VISIBLE MONITOR (UPDATE SUBROUTINE)


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  4832 TO 5119
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 1200 DATA  4832, 108, 8, 16, 32, 224, 18, 201, 62, 5501
 1201 DATA  4840, 208, 16, 238, 0, 18, 173, 0, 18, 5511
 1202 DATA  4848, 201, 7, 208, 5, 169, 0, 141, 0, 5579
 1203 DATA  4856, 18, 96, 201, 60, 208, 11, 206, 0, 5656
 1204 DATA  4864, 18, 16, 5, 169, 6, 141, 0, 18, 5237
 1205 DATA  4872, 96, 201, 32, 208, 9, 238, 5, 18, 5679
 1206 DATA  4880, 208, 3, 238, 6, 18, 96, 201, 13, 5663
 1207 DATA  4888, 208, 12, 173, 5, 18, 208, 3, 206, 5721
 1208 DATA  4896, 6, 18, 206, 5, 18, 96, 174, 0, 5419
 1209 DATA  4904, 18, 224, 2, 208, 27, 168, 165, 0, 5716
 1210 DATA  4912, 72, 166, 1, 173, 5, 18, 133, 0, 5480
 1211 DATA  4920, 173, 6. 18, 133, 1, 152, 160, 0, 5563
 1212 DATA  4928, 145, 0, 134, 1, 104, 133, 0, 96, 5541
 1213 DATA  4936, 201, 71, 208, 35, 172, 3, 18, 174, 5818
 1214 DATA  4944, 2, 18, 173, 4, 18, 72, 173, 1, 5405
 1215 DATA  4952, 18, 40, 32, 108, 19, 8, 141, 1, 5319
 1216 DATA  4960, 18, 142, 2, 18, 140, 3, 18, 104, 5405
 1217 DATA  4968. 141, 4, 18, 96, 109, 5, 18, 72, 5430
 1218 DATA  4976, 32, 213, 19, 48, 75, 168, 104, 152, 5787
 1219 DATA  4984, 174, 0, 18, 208, 20, 162. 3, 24, 5593
 1220 DATA  4992. 14, 5, 18. 46, 6, 18, 202, 16, 5317
 1221 DATA  5000. 246, 152, 13, 5, 18, 141, 5, 18, 5598
 1222 DATA  5008, 96, 224, 1, 208, 24, 41, 15, 72, 5689
 1223 DATA  5016, 32, 148, 18, 10. 10, 10, 10, 41, 5295
 1224 DATA  5024, 240, 141, 172, 19, 104, 13, 172. 19, 5904
 1225 DATA  5032, 32, 45, 19, 95, 16, 202, 202, 202, 5846
 1226 DATA  5040, 160, 3, 24, 30, 1, 18, 136, 16, 5428
 1227 DATA  5048, 249, 29, 1, 18, 157, 1, 18, 96, 5617
 1228 DATA  5056, 104, 201, 127, 208, 4, 32, 0, 17, 5749
```

```
1229 DATA  5064, 96, 201, 81, 208, 4, 104, 104, 40, 5902
1230 DATA  5072, 96, 32, 16, 16, 96, 56, 233, 48, 5665
1231 DATA  5080, 144, 15, 201, 10, 144, 14, 233, 7, 5848
1232 DATA  5088, 201, 16, 176, 5, 56, 201, 10, 176, 5929
1233 DATA  5096, 3, 169, 255, 96, 162, 0, 96, 0, 5877
1234 DATA  5104, 0, 0, 0, 0, 0, 0, 0, 0, 5104
1235 DATA  5112, 0, 0, 0, 0, 0, 0, 0, 0, 5112
1236 END
```

Appendix E4:

Print Utilities

```
APPENDIX E4         PRINT UTILITIES


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  5120 TO 5455
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


1300 DATA  5120, 0, 255, 0, 0, 0, 0, 0, 0, 5375
1301 DATA  5128, 169, 255, 141, 1, 20, 96, 169, 0, 5979
1302 DATA  5136, 141, 1, 20, 96, 169, 255, 141, 0, 5959
1303 DATA  5144, 20, 96, 169, 0, 141, 0, 20, 96, 5686
1304 DATA  5152, 169, 255, 141, 2, 20, 96, 169, 0, 6004
1305 DATA  5160, 141, 2, 20, 96, 32, 8, 20, 32, 5511
1306 DATA  5168, 20, 20, 32, 32, 20, 96, 32, 14, 5434
1307 DATA  5176, 20, 32, 26, 20, 32, 38, 20, 96, 5460
1308 DATA  5184, 201, 0, 240, 36, 141, 3, 20, 173, 5998
1309 DATA  5192, 1, 20, 240, 6, 173, 3, 20, 32, 5687
1310 DATA  5200, 105, 20, 173, 0, 20, 240, 6, 173, 5937
1311 DATA  5208, 3, 20, 32, 108, 20, 173, 2, 20, 5586
1312 DATA  5216, 240, 6, 173, 3, 20, 32, 111, 20, 5821
1313 DATA  5224, 96, 108, 10, 16, 108, 12, 16, 108, 5698
1314 DATA  5232, 14, 15, 169, 13, 32, 64, 20, 169, 5729
1315 DATA  5240, 10, 32, 64, 20, 96, 169, 32, 32, 5695
1316 DATA  5248, 64, 20, 96, 72, 74, 74, 74, 74, 5796
1317 DATA  5256, 32, 182, 17, 32, 64, 20, 104, 32, 5739
1318 DATA  5264, 182, 17, 32, 64, 20, 96, 169, 32, 5876
1319 DATA  5272, 142, 4, 20, 72, 174, 4, 20, 240, 5948
1320 DATA  5280, 10, 206, 4, 20, 32, 64, 20, 104, 5740
1321 DATA  5288, 24, 144, 240, 104, 96, 142, 4, 20, 6062
1322 DATA  5296, 174, 4, 20, 240, 9, 206, 4, 20, 5973
1323 DATA  5304, 32, 114, 20, 24, 144, 242, 96, 142, 6118
1324 DATA  5312, 5, 20, 181, 1, 72, 181, 0, 72, 5844
1325 DATA  5320, 174, 5, 20, 161, 0, 201, 255, 240, 6376
1326 DATA  5328, 12, 246, 0, 208, 2, 246, 1, 32, 6075
1327 DATA  5336, 64, 20, 24, 144, 235, 104, 149, 0, 6076
1328 DATA  5344, 104, 149, 1, 96, 104, 170, 104, 168, 6240
```

```
1329 DATA  5352, 32, 18, 21, 142, 5, 18, 140, 6, 5734
1330 DATA  5360, 18, 32, 13, 19, 32, 13, 19, 32, 5538
1331 DATA  5368, 148, 18, 201, 255, 240, 6, 32, 64, 6332
1332 DATA  5376, 20, 24, 144, 240, 174, 5, 18, 172, 6173
1333 DATA  5384, 6, 18, 32, 43, 21, 152, 72, 138, 5866
1334 DATA  5392, 72, 96, 104, 141, 6, 20, 104, 141, 6076
1335 DATA  5400, 7, 20, 173, 6, 18, 72, 173, 5, 5874
1336 DATA  5408, 18, 72, 173, 7, 20, 72, 173, 6, 5949
1337 DATA  5416, 20, 72, 96, 104, 141, 6, 20, 104, 5979
1338 DATA  5424, 141, 7, 20, 104, 141, 5, 18, 104, 5964
1339 DATA  5432, 141, 6, 18, 173, 7, 20, 72, 173, 6042
1340 DATA  5440, 6, 20, 72, 96, 0, 0, 0, 0, 5634
1341 DATA  5448, 0, 0, 0, 0, 0, 0, 0, 0, 5448
1342 END
```

Appendix E5:

Two Hexdump Tools

```
APPENDIX E5        TWO HEXDUMP TOOLS


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  5456 TO 6063
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 1400 DATA  5456, 0, 4, 0, 0, 255, 255, 0, 32, 6002
 1401 DATA  5464, 8, 20, 173, 81, 21, 141, 80, 21, 6009
 1402 DATA  5472, 173, 5, 18, 41, 248, 141, 5, 18, 6121
 1403 DATA  5480, 32, 114, 20, 32, 114, 20, 32, 161, 6005
 1404 DATA  5488, 21, 32, 114, 20, 32, 125, 20, 32, 5884
 1405 DATA  5496, 154, 21, 32, 13, 19, 173, 5, 18, 5931
 1406 DATA  5504, 41, 7, 208, 240, 32, 114, 20, 173, 6339
 1407 DATA  5512, 5, 18, 41, 15, 208, 3, 32, 114, 5948
 1408 DATA  5520, 20, 206, 80, 21, 208, 216, 32, 14, 6317
 1409 DATA  5528, 20, 96, 32, 148, 18, 32, 131, 20, 6025
 1410 DATA  5536, 96, 173, 6, 18, 32, 131, 20, 173, 6185
 1411 DATA  5544, 5, 18, 32, 131, 20, 96, 32, 201, 6079
 1412 DATA  5552, 21, 32, 233, 21, 32, 160, 23, 32, 6106
 1413 DATA  5560, 20, 20, 32, 235, 22, 32, 66, 23, 6010
 1414 DATA  5568, 16, 251, 32, 114, 20, 32, 26, 20, 6079
 1415 DATA  5576, 96, 32, 0, 17, 32, 8, 20, 32, 5813
 1416 DATA  5584, 228, 20, 127, 13, 80, 82, 73, 78, 6285
 1417 DATA  5592, 84, 73, 78, 71, 32, 72, 69, 88, 6159
 1418 DATA  5600, 68, 85, 77, 80, 13, 10, 10, 255, 6198
 1419 DATA  5608, 96, 32, 8, 20, 32, 228, 20, 127, 6171
 1420 DATA  5616, 13, 10, 83, 69, 84, 32, 83, 84, 6074
 1421 DATA  5624, 65, 82, 84, 73, 78, 71, 32, 65, 6174
 1422 DATA  5632, 68, 68, 82, 69, 83, 83, 32, 65, 6182
 1423 DATA  5640, 78, 68, 32, 80, 82, 69, 83, 83, 6215
 1424 DATA  5648, 32, 34, 81, 34, 46, 255, 32, 7, 6169
 1425 DATA  5656, 18, 32, 103, 22, 32, 8, 20, 32, 5923
 1426 DATA  5664, 228, 20, 127, 13, 10, 83, 69, 84, 6298
 1427 DATA  5672, 32, 69, 78, 68, 32, 65, 68, 68, 6152
 1428 DATA  5680, 82, 69, 83, 83, 32, 65, 78, 68, 6240
```

```
1429 DATA  5688, 32, 80, 82, 69, 83, 83, 32, 34, 6183
1430 DATA  5696, 81, 34, 46, 255, 32, 7, 18, 56, 6225
1431 DATA  5704, 173, 6, 18, 205, 83, 21, 144, 36, 6390
1432 DATA  5712, 208, 8, 173, 5, 18, 205, 82, 21, 6432
1433 DATA  5720, 144, 26, 173, 6, 18, 141, 85, 21, 6334
1434 DATA  5728, 173, 5, 18, 141, 84, 21, 96, 173, 6439
1435 DATA  5736, 6, 18, 141, 83, 21, 173, 5, 18, 6201
1436 DATA  5744, 141, 82, 21, 96, 32, 228, 20, 127, 6491
1437 DATA  5752, 13, 10, 10, 10, 32, 69, 82, 82, 6060
1438 DATA  5760, 79, 82, 33, 33, 33, 32, 69, 78, 6199
1439 DATA  5768, 68, 32, 65, 68, 68, 82, 69, 83, 6303
1440 DATA  5776, 83, 32, 76, 69, 83, 83, 32, 84, 6318
1441 DATA  5784, 72, 65, 78, 32, 83, 84, 65, 82, 6345
1442 DATA  5792, 84, 32, 65, 68, 68, 82, 69, 83, 6343
1443 DATA  5800, 83, 44, 32, 87, 72, 73, 67, 72, 6330
1444 DATA  5808, 32, 73, 83, 32, 255, 32, 187, 22, 6524
1445 DATA  5816, 76, 28, 22, 169, 36, 32, 64, 20, 6263
1446 DATA  5824, 173, 83, 21, 32, 131, 20, 173, 82, 6539
1447 DATA  5832, 21, 32, 131, 20, 96, 169, 36, 32, 6369
1448 DATA  5840, 64, 20, 173, 85, 21, 32, 131, 20, 6386
1449 DATA  5848, 173, 64, 21, 32, 131, 20, 96, 32, 6437
1450 DATA  5856, 187, 22, 169, 45, 32, 64, 20, 32, 6427
1451 DATA  5864, 205, 22, 96, 32, 228, 20, 127, 13, 6607
1452 DATA  5872, 10, 10, 68, 85, 77, 80, 73, 78, 6353
1453 DATA  5880, 71, 32, 255, 32, 223, 22, 32, 114, 6661
1454 DATA  5888, 20, 32, 228, 20, 127, 10, 10, 32, 6367
1455 DATA  5896, 32, 32, 32, 32, 32, 32, 32, 48, 6168
1456 DATA  5904, 32, 32, 49, 32, 32, 50, 32, 32, 6195
1457 DATA  5912, 51, 32, 32, 52, 32, 32, 53, 32, 6228
1458 DATA  5920, 32, 54, 32, 32, 55, 32, 32, 56, 6245
1459 DATA  5928, 32, 32, 57, 32, 32, 65, 32, 32, 6242
1460 DATA  5936, 66, 32, 32, 67, 32, 32, 68, 32, 6297
1461 DATA  5944, 32, 69, 32, 32, 70, 13, 10, 10, 6212
1462 DATA  5952, 255, 96, 32, 114, 20, 173, 5, 18, 6665
1463 DATA  5960, 72, 41, 15, 141, 86, 21, 104, 41, 6481
1464 DATA  5968, 240, 141, 5, 18, 32, 161, 21, 162, 6748
1465 DATA  5976, 3, 32, 150, 20, 173, 86, 21, 240, 6701
1466 DATA  5984, 13, 162, 3, 32, 150, 20, 32, 13, 6409
1467 DATA  5992, 19, 206, 86, 21, 208, 243, 32, 154, 6961
1468 DATA  6000, 21, 32, 125, 20, 32, 131, 23, 48, 6432
1469 DATA  6008, 9, 173, 5, 18, 41, 15, 201, 0, 6470
1470 DATA  6016, 208, 236, 96, 56, 173, 6, 18, 205, 7014
1471 DATA  6024, 85, 21, 144, 11, 208, 15, 56, 173, 6737
1472 DATA  6032, 5, 18, 205, 84, 21, 176, 6, 32, 6579
1473 DATA  6040, 13, 19, 169, 0, 96, 169, 255, 96, 6857
1474 DATA  6048, 173, 82, 21, 141, 5, 18, 173, 83, 6744
1475 DATA  6056, 21, 141, 6, 18, 96, 0, 0, 0, 6338
1476 END
```

Appendix E6:

Table-Driven Disassembler (Top Level and Utility Subroutines)

```
APPENDIX E6        DISASSEMBLER (TOP LEVEL & UTILITY SUBS)


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  6400 TO 6719
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 1500 DATA  6400, 5, 0, 0, 0, 0, 0, 0, 0, 6405
 1501 DATA  6408, 16, 32, 8, 20, 173, 0, 25, 141, 6823
 1502 DATA  6416, 1, 25, 169, 255, 141, 84, 21, 141, 7253
 1503 DATA  6424, 85, 21, 32, 114, 20, 32, 125, 25, 6878
 1504 DATA  6432, 206, 1, 25, 208, 248, 96, 32, 26, 7274
 1505 DATA  6440, 20, 32, 8, 20, 32, 228, 20, 127, 6927
 1506 DATA  6448, 13, 10, 32, 32, 32, 32, 32, 80, 6711
 1507 DATA  6456, 82, 73, 78, 84, 73, 78, 71, 32, 7027
 1508 DATA  6464, 68, 73, 83, 65, 83, 83, 69, 77, 7065
 1509 DATA  6472, 66, 76, 69, 82, 46, 13, 10, 255, 7089
 1510 DATA  6480, 32, 233, 21, 32, 20, 20, 32, 228, 7098
 1511 DATA  6488, 20, 127, 13, 10, 68, 73, 83, 65, 6947
 1512 DATA  6496, 83, 83, 69, 77, 66, 76, 73, 78, 7101
 1513 DATA  6504, 71, 32, 255, 32, 223, 22, 32, 160, 7331
 1514 DATA  6512, 23, 32, 114, 20, 32, 125, 25, 16, 6899
 1515 DATA  6520, 251, 32, 26, 20, 96, 32, 148, 18, 7143
 1516 DATA  6528, 72, 32, 146, 25, 32, 125, 20, 104, 7084
 1517 DATA  6536, 32, 175, 25, 32, 1, 26, 32, 131, 6990
 1518 DATA  6544, 23, 96, 162, 3, 142, 2, 25, 170, 7167
 1519 DATA  6552, 189, 0, 28, 170, 189, 80, 27, 142, 7377
 1520 DATA  6560, 3, 25, 32, 64, 20, 174, 3, 25, 6906
 1521 DATA  6568, 232, 206, 2, 25, 208, 238, 96, 170, 7745
 1522 DATA  6576, 189, 0, 29, 170, 32, 184, 25, 96, 7301
 1523 DATA  6584, 189, 27, 27, 141, 4, 25, 232, 189, 7418
 1524 DATA  6592, 27, 27, 141, 5, 25, 108, 4, 25, 6954
 1525 DATA  6600, 32, 13, 19, 32, 154, 21, 96, 32, 6999
```

```
1526 DATA  6608, 13, 19, 32, 148, 18, 72, 32, 13, 6955
1527 DATA  6616, 19, 32, 154, 21, 104, 32, 131, 20, 7129
1528 DATA  6624, 96, 169, 40, 208, 2, 169, 41, 32, 7381
1529 DATA  6632, 64, 20, 96, 169, 44, 32, 64, 20, 7141
1530 DATA  6640, 169, 88, 32, 64, 20, 96, 169, 44, 7322
1531 DATA  6648, 32, 64, 20, 169, 89, 32, 64, 20, 7138
1532 DATA  6656, 96, 141, 7, 25, 142, 6, 25, 202, 7300
1533 DATA  6664, 48, 6, 32, 26, 19, 202, 16, 250, 7263
1534 DATA  6672, 8, 216, 56, 173, 8, 25, 233, 4, 7395
1535 DATA  6680, 237, 7, 25, 40, 170, 32, 150, 20, 7361
1536 DATA  6688, 32, 161, 21, 32, 125, 20, 32, 154, 7265
1537 DATA  6696, 21, 32, 13, 19, 206, 6, 25, 16, 7034
1538 DATA  6704, 242, 32, 26, 19, 32, 114, 20, 96, 7285
1539 DATA  6712, 0, 0, 0, 0, 0, 0, 0, 0, 6712
1540 END
```

Appendix E7:

Table-Driven Disassembler (Addressing Mode Subroutines)

```
APPENDIX E7        DISASSEMBLER (ADDRESSING MODE SUBROUTINES)


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  6720 TO 6991
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 1600 DATA  6720, 32, 207, 25. 162. 2, 169, 4, 96, 7417
 1601 DATA  6728, 32, 64, 26, 32, 235, 25, 162, 2, 7306
 1602 DATA  6736, 169, 6, 96, 32, 64, 26, 32, 246, 7407
 1603 DATA  6744, 25, 162, 2, 169, 6, 96, 169, 65, 7438
 1604 DATA  6752, 32, 64, 20, 162, 0, 169, 1, 96, 7296
 1605 DATA  6760, 162, 0, 169, 0, 96, 169, 35, 32, 7423
 1606 DATA  6768, 64, 20, 169, 36, 32, 64, 20, 32, 7205
 1607 DATA  6776, 200, 25, 162, 1, 169, 4, 96, 32, 7465
 1608 DATA  6784, 225, 25, 32, 64, 26, 32, 229, 25, 7442
 1609 DATA  6792, 169, 6, 162, 2, 96, 32, 225, 25, 7509
 1610 DATA  6800. 32, 232, 26, 32, 229, 25, 162, 1, 7539
 1611 DATA  6808, 169, 8, 96, 32, 225, 25, 32, 219, 7614
 1612 DATA  6816, 26, 32. 229, 25. 32, 246, 25, 162, 7593
 1613 DATA  6824, 1, 169. 8, 96, 32, 13, 19, 32, 7194
 1614 DATA  6832, 18, 21. 32. 148, 18, 72, 32, 13, 7186
 1615 DATA  6840, 19, 104, 201, 0, 16, 3, 206, 6, 7395
 1616 DATA  6848. 18, 8, 216, 24, 109. 5, 18, 144, 7390
 1617 DATA  6856, 3, 238, 6, 18, 141, 5, 18, 40, 7325
 1618 DATA  6864, 32, 161, 21, 32, 43, 21, 162, 1, 7337
 1619 DATA  6872, 169, 4, 96, 169, 0, 32, 131. 20, 7493
 1620 DATA  6880, 32, 200, 25, 162, 1, 169. 4, 96, 7569
 1621 DATA  6888, 32, 219, 26, 32, 235, 25, 162, 1, 7620
 1622 DATA  6896, 169, 6, 96, 32, 219, 26, 32, 246, 7722
 1623 DATA  6904, 25, 162, 1, 169. 6, 96, 104, 104, 7571
 1624 DATA  6912, 104, 104, 32, 131, 23, 48, 13, 32, 7399
 1625 DATA  6920, 148, 18, 201, 255, 240, 6, 32, 64, 7884
```

```
1626 DATA  6928, 20, 24, 144, 238, 32, 114, 20, 32, 7552
1627 DATA  6936, 131, 23, 56, 104, 26, 94, 26, 109, 7545
1628 DATA  6944, 26, 219, 26, 232, 26, 243, 26, 64, 7806
1629 DATA  6952, 26, 72, 26, 83, 26, 104, 26, 172, 7487
1630 DATA  6960, 26, 141, 26, 155, 26, 127, 26, 254, 7741
1631 DATA  6968, 26, 0, 0, 0, 0, 0, 0, 0, 6994
1632 DATA  6976, 0, 0, 0, 0, 0, 0, 0, 0, 6976
1633 DATA  6984, 0, 0, 0, 0, 0, 0, 0, 0, 6984
1634 END
```

Appendix E8:

Table-Driven Disassembler (Tables)

```
APPENDIX E8        DISASSEMBLER (TABLES)


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  6992 TO 7679
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 1700 DATA  6992, 127, 66, 65, 68, 65, 68, 67, 65, 7583
 1701 DATA  7000, 78, 68, 65, 83, 76, 66, 67, 67, 7570
 1702 DATA  7008, 66, 67, 83, 66, 69, 81, 66, 73, 7579
 1703 DATA  7016, 84, 66, 77, 73, 66, 78, 69, 66, 7595
 1704 DATA  7024, 80, 76, 66, 82, 75, 66, 86, 67, 7622
 1705 DATA  7032, 66, 86, 83, 67, 76, 67, 67, 76, 7620
 1706 DATA  7040, 68, 67, 76, 73, 67, 76, 86, 67, 7620
 1707 DATA  7048, 77, 80, 67, 80, 88, 67, 80, 89, 7676
 1708 DATA  7056, 68, 69, 67, 68, 69, 88, 68, 69, 7622
 1709 DATA  7064, 89, 69, 79, 82, 73, 78, 67, 73, 7674
 1710 DATA  7072, 78, 88, 73, 78, 89, 74, 77, 80, 7709
 1711 DATA  7080, 74, 83, 82, 76, 68, 65, 76, 68, 7672
 1712 DATA  7088, 88, 76, 68, 89, 76, 83, 82, 78, 7728
 1713 DATA  7096, 79, 80, 79, 82, 65, 80, 72, 65, 7698
 1714 DATA  7104, 80, 72, 80, 80, 76, 65, 80, 76, 7713
 1715 DATA  7112, 80, 82, 79, 76, 82, 79, 82, 82, 7754
 1716 DATA  7120, 84, 73, 82, 84, 83, 83, 66, 67, 7742
 1717 DATA  7128, 83, 69, 67, 83, 69, 68, 83, 69, 7719
 1718 DATA  7136, 73, 83, 84, 65, 83, 84, 88, 83, 7779
 1719 DATA  7144, 84, 89, 84, 65, 88, 84, 65, 89, 7792
 1720 DATA  7152, 84, 83, 88, 84, 88, 65, 84, 88, 7816
 1721 DATA  7160, 83, 84, 89, 65, 84, 69, 88, 255, 7977
 1722 DATA  7168, 34, 106, 1, 1, 1, 106, 10, 1, 7428
 1723 DATA  7176, 112, 106, 10, 1, 1, 106, 10, 1, 7523
 1724 DATA  7184, 31, 106, 1, 1, 1, 106, 10, 1, 7441
 1725 DATA  7192, 43, 106, 1, 1, 1, 106, 10, 1, 7461
 1726 DATA  7200, 88, 7, 1, 1, 22, 7, 121, 1, 7448
 1727 DATA  7208, 118, 7, 121, 1, 22, 7, 121, 1, 7606
 1728 DATA  7216, 25, 7, 1, 1, 1, 7, 121, 1, 7380
```

```
1729 DATA 7224, 136, 7, 1, 1, 1, 7, 121, 1, 7499
1730 DATA 7232, 127, 73, 1, 1, 1, 73, 100, 1, 7609
1731 DATA 7240, 109, 73, 100, 1, 85, 73, 100, 1, 7782
1732 DATA 7248, 37, 73, 1, 1, 1, 73, 100, 1, 7535
1733 DATA 7256, 49, 73, 1, 1, 1, 73, 100, 1, 7555
1734 DATA 7264, 130, 4, 1, 1, 1, 4, 124, 1, 7530
1735 DATA 7272, 115, 4, 124, 1, 85, 4, 124, 1, 7730
1736 DATA 7280, 40, 4, 1, 1, 1, 4, 124, 1, 7456
1737 DATA 7288, 142, 4, 1, 1, 1, 4, 124, 172, 7737
1738 DATA 7296, 1, 145, 1, 1, 151, 145, 148, 1, 7889
1739 DATA 7304, 70, 1, 163, 1, 151, 145, 148, 1, 7984
1740 DATA 7312, 13, 145, 1, 1, 151, 145, 148, 1, 7917
1741 DATA 7320, 169, 145, 163, 1, 1, 145, 1, 1, 7946
1742 DATA 7328, 97, 91, 94, 1, 97, 91, 94, 1, 7894
1743 DATA 7336, 157, 91, 154, 1, 97, 91, 94, 1, 8022
1744 DATA 7344, 16, 91, 1, 1, 97, 91, 94, 1, 7736
1745 DATA 7352, 52, 91, 158, 1, 97, 91, 94, 1, 7937
1746 DATA 7360, 61, 55, 1, 1, 61, 55, 64, 1, 7659
1747 DATA 7368, 82, 55, 67, 1, 61, 55, 64, 1, 7754
1748 DATA 7376, 28, 55, 1, 1, 1, 55, 64, 1, 7582
1749 DATA 7384, 46, 55, 1, 1, 1, 55, 64, 1, 7608
1750 DATA 7392, 58, 133, 1, 1, 58, 133, 76, 1, 7853
1751 DATA 7400, 79, 133, 103, 1, 58, 133, 76, 1, 7984
1752 DATA 7408, 19, 133, 1, 1, 1, 133, 76, 1, 7773
1753 DATA 7416, 139, 133, 1, 1, 1, 133, 76, 1, 7901
1754 DATA 7424, 18, 22, 0, 0, 0, 6, 6, 0, 7476
1755 DATA 7432, 18, 4, 2, 0, 0, 12, 12, 0, 7480
1756 DATA 7440, 20, 24, 0, 0, 0, 14, 14, 0, 7512
1757 DATA 7448, 18, 16, 0, 0, 0, 22, 22, 0, 7526
1758 DATA 7456, 12, 22, 0, 0, 6, 6, 6, 0, 7508
1759 DATA 7464, 18, 4, 2, 0, 12, 12, 12, 0, 7524
1760 DATA 7472, 20, 24, 0, 0, 0, 8, 8, 0, 7532
1761 DATA 7480, 18, 16, 0, 0, 0, 14, 14, 0, 7542
1762 DATA 7488, 18, 22, 0, 0, 0, 6, 6, 0, 7540
1763 DATA 7496, 18, 12, 2, 0, 12, 12, 12, 0, 7564
1764 DATA 7504, 20, 24, 0, 0, 0, 8, 8, 0, 7564
1765 DATA 7512, 18, 16, 0, 0, 0, 14, 14, 0, 7574
1766 DATA 7520, 18, 22, 0, 0, 0, 6, 6, 0, 7572
1767 DATA 7528, 18, 4, 2, 0, 26, 12, 12, 0, 7602
1768 DATA 7536, 20, 24, 0, 0, 0, 8, 8, 0, 7596
1769 DATA 7544, 18, 16, 0, 0, 0, 14, 14, 28, 7634
1770 DATA 7552, 0, 22, 0, 0, 6, 6, 6, 0, 7592
1771 DATA 7560, 18, 0, 18, 0, 12, 12, 12, 0, 7632
1772 DATA 7568, 20, 24, 0, 0, 8, 8, 10, 0, 7638
1773 DATA 7576, 18, 16, 18, 0, 0, 14, 0, 0, 7642
1774 DATA 7584, 4, 22, 4, 0, 6, 6, 6, 0, 7632
1775 DATA 7592, 18, 4, 18, 0, 12, 12, 12, 0, 7668
1776 DATA 7600, 20, 24, 0, 0, 8, 8, 10, 0, 7670
1777 DATA 7608, 20, 16, 18, 0, 14, 14, 16, 0, 7706
1778 DATA 7616, 4, 22, 0, 0, 6, 6, 6, 0, 7660
1779 DATA 7624, 18, 4, 18, 0, 12, 12, 12, 0, 7700
1780 DATA 7632, 20, 24, 0, 0, 0, 8, 8, 0, 7692
1781 DATA 7640, 18, 16, 0, 0, 0, 14, 14, 0, 7702
1782 DATA 7648, 4, 22, 0, 0, 6, 6, 6, 0, 7692
1783 DATA 7656, 18, 4, 18, 0, 12, 12, 12, 0, 7732
1784 DATA 7664, 20, 24, 0, 0, 0, 8, 8, 0, 7724
1785 DATA 7672, 18, 16, 0, 0, 0, 14, 14, 0, 7734
1786 END
```

Appendix E9:

Move Utilities

```
APPENDIX E9        MOVE UTILITIES


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  6064 TO 6399
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 1800 DATA  6064, 0, 0, 0, 0, 32, 8, 20, 32, 6156
 1801 DATA  6072, 228, 20, 127, 13, 10, 32, 32, 32, 6566
 1802 DATA  6080, 32, 32, 77, 79, 86, 69, 32, 84, 6571
 1803 DATA  6088, 79, 79, 76, 46, 13, 10, 10, 255, 6656
 1804 DATA  6096, 32, 233, 21, 32, 185, 24, 174, 85, 6882
 1805 DATA  6104, 21, 56, 173, 84, 21, 237, 82, 21, 6799
 1806 DATA  6112, 141, 176, 23, 176, 2, 202, 56, 138, 7026
 1807 DATA  6120, 237, 83, 21, 141, 177, 23, 176, 3, 6981
 1808 DATA  6128, 169, 0, 96, 160, 3, 185, 0, 0, 6741
 1809 DATA  6136, 72, 136, 16, 249, 56, 173, 83, 21, 6942
 1810 DATA  6144, 205, 179, 23, 144, 64, 208, 24, 173, 7164
 1811 DATA  6152, 82, 21, 205, 178, 23, 144, 54, 208, 7067
 1812 DATA  6160, 14, 160, 0, 104, 153, 0, 0, 200, 6791
 1813 DATA  6168, 192, 4, 208, 247, 169, 255, 96, 32, 7371
 1814 DATA  6176, 164, 24, 160, 0, 174, 177, 23, 240, 7138
 1815 DATA  6184, 14, 177, 0, 145, 2, 200, 208, 249, 7179
 1816 DATA  6192, 230, 1, 230, 3, 202, 208, 242, 136, 7444
 1817 DATA  6200, 200, 177, 0, 145, 2, 204, 176, 23, 7127
 1818 DATA  6208, 208, 246, 76, 17, 24, 173, 177, 23, 7152
 1819 DATA  6216, 240, 72, 172, 177, 23, 173, 176, 23, 7272
 1820 DATA  6224, 56, 233, 255, 176, 1, 136, 170, 132, 7383
 1821 DATA  6232, 3, 138, 24, 109, 82, 21, 133, 0, 6742
 1822 DATA  6240, 144, 1, 200, 152, 109, 83, 21, 133, 7083
 1823 DATA  6248, 1, 138, 24, 109, 178, 23, 133, 2, 6856
 1824 DATA  6256, 144, 2, 230, 3, 165, 3, 109, 179, 7091
 1825 DATA  6264, 23, 133, 3, 174, 177, 23, 160, 255, 7212
 1826 DATA  6272, 177, 0, 145, 2, 136, 208, 249, 177, 7366
 1827 DATA  6280, 0, 145, 2, 198, 1, 198, 3, 202, 7029
 1828 DATA  6288, 208, 236, 32, 164, 24, 172, 176, 23, 7323
```

```
1829 DATA  6296, 177, 0, 145, 2, 136, 192, 255, 208, 7411
1830 DATA  6304, 247, 76, 17, 24, 173, 82, 21, 133, 7077
1831 DATA  6312, 0, 173, 83, 21, 133, 1, 173, 178, 7074
1832 DATA  6320, 23, 133, 2, 173, 179, 23, 133, 3, 6989
1833 DATA  6328, 96, 32, 8, 20, 32, 228, 20, 127, 6891
1834 DATA  6336, 13, 10, 83, 69, 84, 32, 68, 69, 6764
1835 DATA  6344, 83, 84, 73, 78, 65, 84, 73, 79, 6963
1836 DATA  6352, 78, 32, 65, 78, 68, 32, 80, 82, 6867
1837 DATA  6360, 69, 83, 83, 32, 81, 46, 255, 32, 7041
1838 DATA  6368, 7, 18, 173, 5, 18, 141, 178, 23, 6931
1839 DATA  6376, 173, 6, 18, 141, 179, 23, 96, 0, 7012
1840 DATA  6384, 0, 0, 0, 0, 0, 0, 0, 0, 6384
1841 DATA  6392, 0, 0, 0, 0, 0, 0, 0, 0, 6392
1842 END
```

Appendix E10:

Simple Text Editor

```
APPENDIX E10        A SIMPLE TEXT EDITOR


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  7680 TO 8191
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


1900 DATA  7680, 255, 1, 32, 15, 30, 32, 55, 30, 8130
1901 DATA  7688, 32, 200, 30, 24, 24, 144, 246, 32, 8420
1902 DATA  7696, 8, 20, 32, 228, 20, 127, 13, 10, 8154
1903 DATA  7704, 10, 83, 69, 84, 32, 85, 80, 32, 8179
1904 DATA  7712, 69, 68, 73, 84, 32, 66, 85, 70, 8259
1905 DATA  7720, 70, 69, 82, 46, 13, 10, 10, 255, 8275
1906 DATA  7728, 32, 233, 21, 32, 160, 23, 96, 32, 8357
1907 DATA  7736, 196, 17, 32, 43, 17, 174, 3, 16, 8234
1908 DATA  7744, 160, 3, 32, 19, 17, 32, 43, 17, 8067
1909 DATA  7752, 32, 118, 17, 32, 196, 17, 32, 94, 8290
1910 DATA  7760, 30, 32, 211, 17, 32, 118, 17, 32, 8249
1911 DATA  7768, 137, 30, 32, 211, 17, 96, 32, 18, 8341
1912 DATA  7776, 21, 173, 3, 16, 74, 170, 202, 202, 8637
1913 DATA  7784, 32, 26, 19, 202, 16, 250, 173, 3, 8505
1914 DATA  7792, 16, 141, 0, 30, 32, 148, 18, 32, 8209
1915 DATA  7800, 155, 17, 32, 127, 17, 32, 13, 19, 8212
1916 DATA  7808, 206, 0, 30, 16, 239, 32, 43, 21, 8395
1917 DATA  7816, 96, 173, 3, 16, 74, 233, 2, 32, 8445
1918 DATA  7824, 129, 17, 173, 1, 30, 201, 1, 208, 8584
1919 DATA  7832, 5, 169, 73, 24, 144, 2, 169, 79, 8497
1920 DATA  7840, 32, 155, 17, 169, 2, 32, 129, 17, 8393
1921 DATA  7648, 173, 7, 16, 32, 155, 17, 169, 2, 8419
1922 DATA  7856, 32, 129, 17, 173, 6, 18, 32, 163, 8426
1923 DATA  7864, 17, 173, 5, 18, 32, 163, 17, 96, 8385
1924 DATA  7872, 6, 3, 62, 60, 16, 127, 81, 0, 8227
1925 DATA  7880, 32, 224, 18, 205, 198, 30, 208, 23, 8818
1926 DATA  7888, 72, 32, 224, 18, 205, 198, 30, 208, 8875
1927 DATA  7896, 4, 104, 104, 104, 96. 141, 199, 30, 8678
1928 DATA  7904, 104, 32. 231, 30, 173, 199, 30, 205, 8908
```

```
1929 DATA  7912, 193, 30, 208, 11, 206, 1, 30, 16, 8607
1930 DATA  7920, 5, 169, 1, 141, 1, 30, 96, 205, 8568
1931 DATA  7928, 194, 30, 208, 4, 32, 121, 31, 96, 8644
1932 DATA  7936, 205, 195, 30, 208, 4, 32, 135, 31, 8776
1933 DATA  7944. 96, 205, 197, 30, 208, 4, 32, 221, 8937
1934 DATA  7952, 31, 96, 205, 196, 30, 208, 4, 32, 8754
1935 DATA  7960, 197, 31, 96, 205, 192, 30, 208, 4, 8923
1936 DATA  7968, 32, 180, 31, 96, 174, 1, 30, 240, 8752
1937 DATA  7976, 4, 32, 52, 31, 96, 32, 45, 19, 8287
1938 DATA  7984, 32, 131, 23, 96, 72, 32, 18, 21, 8409
1939 DATA  7992. 173, 83, 21, 72, 173, 82, 21, 72, 8669
1940 DATA  8000, 173, 85, 21, 72, 173, 84, 21, 72, 8701
1941 DATA  8008, 32, 103, 22, 32, 131, 23, 48, 17, 8416
1942 DATA  8016, 32, 226, 24, 173, 84, 21, 208, 4, 8788
1943 DATA  8024, 206, 85, 21, 206, 84, 21, 32, 214, 8893
1944 DATA  8032, 23, 104, 141, 84, 21, 104, 141, 85, 8735
1945 DATA  8040, 21, 104, 141, 82, 21, 104, 141, 83, 8737
1946 DATA  8048, 21, 32, 43, 21, 104, 32, 45, 31, 8377
1947 DATA  8056, 96, 32, 148, 18, 201, 255, 240, 4, 9050
1948 DATA  8064, 32, 131, 23, 96, 169, 255, 96, 56, 8922
1949 DATA  8072, 173, 83, 21, 205, 6, 18, 144, 12, 8734
1950 DATA  8080, 208, 16, 173, 82, 21, 205, 5, 18, 8808
1951 DATA  8088, 240, 23, 176, 6, 32, 26, 19, 169, 8779
1952 DATA  8096, 0, 96, 173, 82, 21, 141, 5, 18, 8632
1953 DATA  8104, 173, 83, 21, 141, 6, 18, 169, 0, 8715
1954 DATA  8112, 96, 169, 255, 96, 32, 160, 23, 169, 9112
1955 DATA  8120, 255, 32, 45, 19, 32, 131, 23, 16, 8673
1956 DATA  8128, 246, 32, 160, 23, 96, 32, 160, 23, 8900
1957 DATA  8136, 32, 20, 20, 32, 148, 18, 201, 255, 8862
1958 DATA  8144, 240, 8, 32, 64, 20, 32, 131, 23, 8694
1959 DATA  8152, 16, 241, 76, 26, 20, 32, 18, 21, 8602
1960 DATA  8160, 173, 83, 21, 72, 173, 82, 21, 72, 8857
1961 DATA  8168, 32, 226, 24, 32, 131, 23, 32, 103, 8771
1962 DATA  8176, 22, 32, 214, 23, 104, 141, 82, 21, 8815
1963 DATA  8184, 104, 141, 83, 21, 32, 43, 21, 96, 8725
1964 END
```

Appendix E11:
Extending the Visible Monitor

```
APPENDIX E11        EXTENDING THE VISIBLE MONITOR


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  4272 TO 4351
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 2000 DATA  4272, 201, 80, 208, 9, 173, 0, 20, 73, 5036
 2001 DATA  4280, 255, 141, 0, 20, 96, 201, 85, 208, 5286
 2002 DATA  4288, 9, 173, 2, 20, 73, 255, 141, 2, 4963
 2003 DATA  4296, 20, 96, 201, 72, 208, 13, 173, 0, 5079
 2004 DATA  4304, 20, 208, 4, 32, 87, 21, 96, 32, 4804
 2005 DATA  4312, 174, 21, 96, 201, 77, 208, 4, 32, 5125
 2006 DATA  4320, 180, 23, 96, 201, 63, 208, 13, 173, 5277
 2007 DATA  4328, 0, 20, 208, 4, 32, 9, 25, 96, 4722
 2008 DATA  4336, 32, 38, 25, 96, 201, 84, 208, 4, 5024
 2009 DATA  4344, 32, 2, 30, 96, 96, 0, 0, 0, 4600
 2010 END
```

Appendix E12:

System Data Block for the Ohio Scientific C-1P

```
APPENDIX E12      SYSTEM DATA BLOCK FOR OSI C1P


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  4096 TO 4119
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


2100 DATA  4096, 101, 208, 32, 24, 24, 211, 32, 16, 4744
2101 DATA  4104, 237, 254, 45, 191, 177, 252, 15, 16, 5292
2102 DATA  4112, 96, 96, 0, 0, 0, 0, 0, 0, 4304
2103 END

OK
```

Appendix E13:

System Data Block for the PET 2001

```
APPENDIX E13     SYSTEM DATA BLOCK FOR THE PET 2001


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  4096 TO 4151
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 2100 DATA  4096, 0, 128, 40, 39, 24, 131, 32, 30, 4520
 2101 DATA  4104, 42, 16, 210, 255, 16, 16, 16, 16, 4691
 2102 DATA  4112, 96, 41, 127, 56, 201, 64, 144, 17, 4858
 2103 DATA  4120, 201, 96, 144, 10, 162, 14, 141, 76, 4964
 2104 DATA  4128, 232, 233, 32, 24, 144, 3, 56, 233, 5085
 2105 DATA  4136, 64, 96, 32, 228, 255, 41, 127, 240, 5219
 2106 DATA  4144, 249, 96, 0, 0, 0, 0, 0, 0, 4489
 2107 END

OK
```

Appendix E14:

System Data Block for the Apple II

```
APPENDIX E14      SYSTEM DATA BLOCK FOR THE APPLE II


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  4096 TO 4127
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 2100 DATA  4096, 0, 4, 128, 39, 7, 7, 160, 222, 4663
 2101 DATA  4104, 20, 16, 26, 16, 16, 16, 16, 16, 4246
 2102 DATA  4112, 96, 9, 128, 96, 32, 12, 253, 41, 4779
 2103 DATA  4120, 127, 96, 9, 128, 32, 253, 251, 96, 5112
 2104 END

OK
```

Appendix E15:

System Data Block for the Atari 800

```
APPENDIX E15     SYSTEM DATA BLOCK FOR THE ATARI 800


THE FOLLOWING DATA STATEMENTS
CONTAIN DECIMAL OBJECT CODE AND
CHECKSUMS FOR MEMORY FROM  3712 TO 4223
SUITABLE FOR LOADING WITH
THE BASIC OBJECT CODE LOADER.


 2100 DATA  3712, 32, 196, 17, 173, 179, 23, 72, 173, 4577
 2101 DATA  3720, 178, 23, 72, 173, 85, 21, 72, 173, 4517
 2102 DATA  3728, 84, 21, 72, 173, 83, 21, 72, 173, 4427
 2103 DATA  3736, 82, 21, 72, 32, 43, 17, 165, 0, 4168
 2104 DATA  3744, 141, 178, 23, 165, 1, 141, 179, 23, 4595
 2105 DATA  3752, 32, 118, 17, 165, 0, 141, 82, 21, 4328
 2106 DATA  3760, 165, 1, 141, 83, 21, 174, 3, 16, 4364
 2107 DATA  3768, 172, 4, 16, 32, 60, 17, 165, 0, 4234
 2108 DATA  3776, 141, 84, 21, 165, 1, 141, 85, 21, 4435
 2109 DATA  3784, 32, 214, 23, 172, 4, 16, 162, 0, 4407
 2110 DATA  3792, 32, 60, 17, 174, 3, 16, 160, 1, 4255
 2111 DATA  3800, 32, 19, 17, 104, 141, 82, 21, 104, 4320
 2112 DATA  3808. 141, 83, 21, 104, 141, 84, 21, 104, 4507
 2113 DATA  3816, 141, 85, 21, 104, 141, 178, 23, 104, 4613
 2114 DATA  3824, 141, 179, 23, 32, 211, 17, 96, 0, 4523
 2115 DATA  3832, 0, 0, 0, 0, 0, 0, 0, 0, 3832
 2116 DATA  3840, 108, 106, 59, 0, 0, 107, 43, 42, 4305
 2117 DATA  3848, 111, 0, 112, 117, 13, 105, 45, 61, 4412
 2118 DATA  3856, 118, 0, 99, 0, 0, 98, 120, 122, 4413
 2119 DATA  3864, 52, 0, 51, 54, 27, 53, 50, 49, 4200
 2120 DATA  3872, 44, 32, 46, 110, 0, 109, 47, 0, 4260
 2121 DATA  3880, 114, 0, 101, 121, 9, 116, 119, 113. 4573
 2122 DATA  3888, 57, 0, 48, 55, 8, 56, 60, 62, 4234
 2123 DATA  3896, 102, 104, 100, 0, 0, 103, 115, 97, 4517
 2124 DATA  3904, 76, 74, 58, 0, 0, 75, 91, 94, 4372
 2125 DATA  3912, 79, 0, 80, 85, 13, 73, 45, 61, 4348
 2126 DATA  3920, 86, 0, 67, 0, 0, 66, 88, 90, 4317
 2127 DATA  3928, 52, 0, 51, 54, 27, 37, 34, 33, 4216
 2128 DATA  3936. 90, 32, 93, 78, 0, 77, 63, 0, 4369
```

```
2129 DATA  3944, 82, 0, 69, 89, 9, 84, 87, 81, 4445
2130 DATA  3952, 40, 0, 41, 39, 127, 64, 0, 0, 4263
2131 DATA  3960, 70, 72, 68, 0, 0, 71, 83, 65, 4389
2132 DATA  3968, 0, 0, 0, 0, 0, 0, 0, 0, 3968
2133 DATA  3976, 0, 0, 16, 0, 0, 0, 0, 0, 3992
2134 DATA  3984, 0, 0, 3, 0, 0, 0, 0, 0, 3987
2135 DATA  3992, 0, 0, 0, 0, 0, 0, 0, 0, 3992
2136 DATA  4000, 0, 0, 0, 0, 0, 0, 0, 0, 4000
2137 DATA  4008, 0, 0, 0, 0, 0, 0, 0, 0, 4008
2138 DATA  4016, 0, 0, 0, 0, 0, 0, 0, 0, 4016
2139 DATA  4024, 6, 0, 0, 0, 0, 0, 0, 0, 4030
2140 DATA  4032, 0, 0, 0, 0, 0, 0, 0, 0, 4032
2141 DATA  4040, 0, 0, 0, 0, 0, 0, 0, 0, 4040
2142 DATA  4048, 0, 0, 0, 0, 0, 0, 0, 0, 4048
2143 DATA  4056, 0, 0, 0, 0, 0, 0, 0, 0, 4056
2144 DATA  4064, 0, 0, 0, 0, 0, 0, 0, 0, 4064
2145 DATA  4072, 0, 0, 0, 0, 0, 0, 0, 0, 4072
2146 DATA  4080, 0, 0, 0, 0, 0, 0, 0, 0, 4080
2147 DATA  4088, 0, 0, 0, 0, 0, 0, 0, 0, 4088
2148 DATA  4096, 66, 124, 40, 39, 23, 127, 0, 123, 4638
2149 DATA  4104, 40, 16, 54, 16, 16, 16, 16, 16, 4294
2150 DATA  4112, 96, 41, 127, 56, 201, 32, 144, 8, 4817
2151 DATA  4120, 201, 96, 144, 8, 201, 123, 144, 7, 5044
2152 DATA  4128, 173, 6, 16, 96, 56, 233, 32, 96, 4836
2153 DATA  4136, 173, 252, 2, 201, 255, 240, 249, 168, 5676
2154 DATA  4144, 185, 0, 15, 96, 0, 0, 201, 13, 4654
2155 DATA  4152, 208, 6, 169, 0, 141, 53, 16, 96, 4841
2156 DATA  4160, 201, 10, 208, 3, 76, 128, 14, 141, 4941
2157 DATA  4168, 52, 16, 32, 196, 17, 172, 4, 16, 4673
2158 DATA  4176, 174, 53, 16, 32, 60, 17, 173, 52, 4753
2159 DATA  4184, 16, 32, 124, 17, 238, 53, 16, 173, 4853
2160 DATA  4192, 53, 16, 205, 3, 16, 208, 6, 32, 4731
2161 DATA  4200, 58, 16, 32, 128, 14, 32, 211, 17, 4708
2162 DATA  4208, 96, 0, 0, 0, 0, 0, 0, 0, 4304
2163 DATA  4216, 0, 0, 0, 0, 0, 0, 0, 0, 4216
2164 END

OK
```

Index

Software

Beyond Games: Systems Software for Your 6502 Personal Computer

By Ken Skier

Use your 6502 personal computer for more than games! Learn how it works and how to make it work for you. This book, for Apple, Atari, Ohio Scientific and PET computer owners who know little or nothing about bits, bytes, hardware, and software, presents a guided tour of your computer. Beginning with basic concepts such as *what is memory?* and *what is a program?*, **Beyond Games** moves through a fast but surprisingly complete course in assembly language programming. Having mastered these fundamentals, the reader is introduced to many useful subroutines and programming tools, such as screen utilities, print utilities, a machine language monitor, a hexadecimal dump tool, a move tool, a disassembler, and a simple, screen-based text editor.

About the Author

Ken Skier, systems analyst for Wang Laboratories, Inc, designs software for word processing and other applications concerning the office of the future. A Massachusetts Institute of Technology graduate, he co-founded the M.I.T. Writing Program, where he teaches science fiction writing. He lives in Cambridge, Massachusetts, with his wife Cynthia and a nameless white cat.

0-07-057860-5