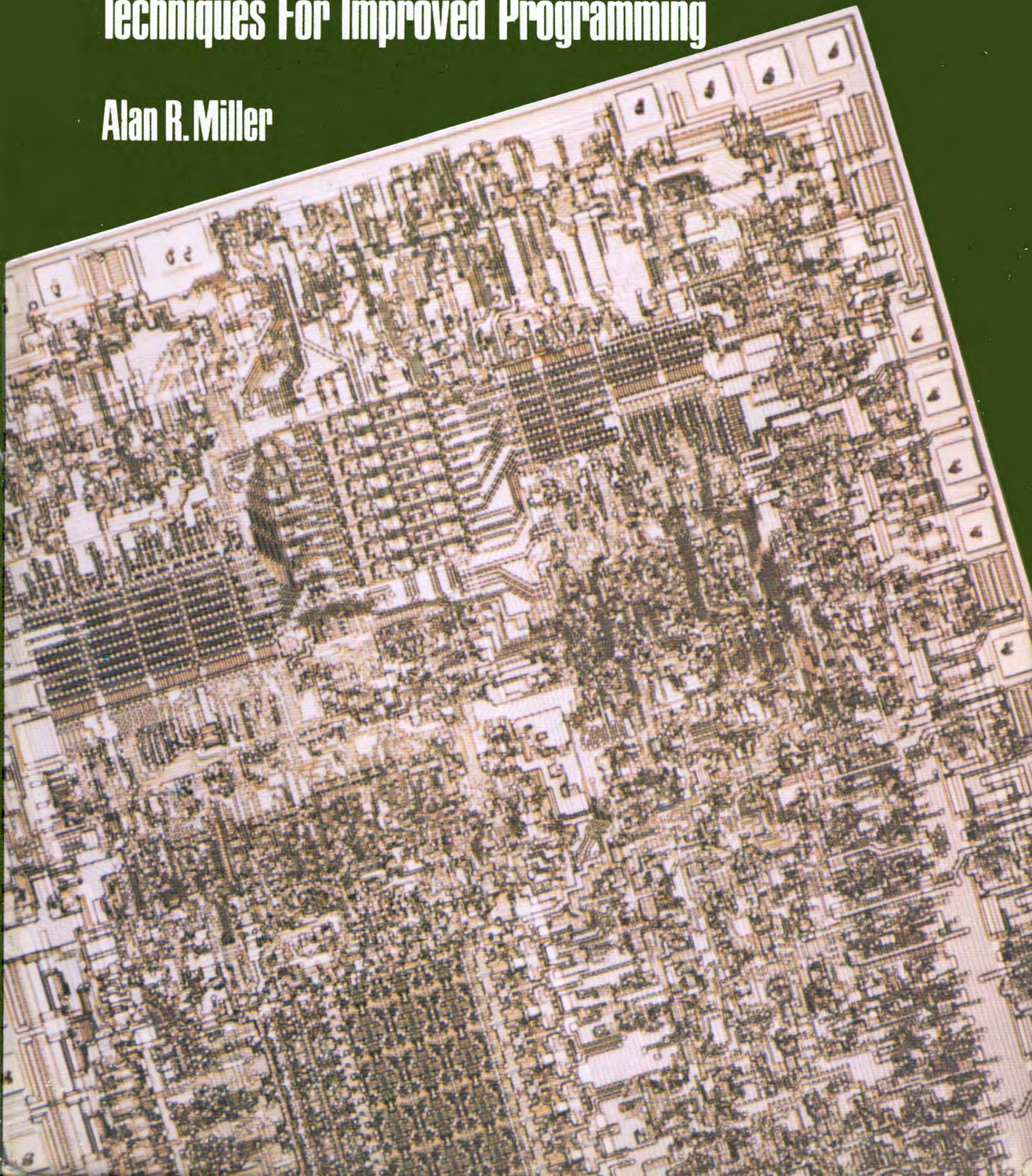


8080/Z80 Assembly Language

Techniques For Improved Programming

Alan R. Miller



THE 8080/Z-80 ASSEMBLY LANGUAGE TECHNIQUES FOR IMPROVED PROGRAMMING

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Preface

On first thought, it might seem strange that another book on the 8080 and Z-80 should appear at this time. Z-80 CPU cards generally became available in 1977 and the 8080 CPU is even older. But the Z-80 computer seems to become more popular with time. For example, the TRS-80 Model II announced recently by Radio Shack, and Heath's H-89 both use the CPU. High-level languages such as Pascal, APL, BASIC, FORTRAN, and C are now run on the 8080 and Z-80. Furthermore, Microsoft has available a Z-80 CPU card that can be easily inserted into the Apple II computer. There should be an increasing interest in the 8080 and Z-80 CPUs in the coming years, and I believe, a great increase in the number of 8080 and Z-80 programmers. So, there is a growing need for a book that covers programming for the 8080 and Z-80 assembly languages.

The combination of 8080 and Z-80 programming concepts into a single work is quite natural. The Z-80 CPU is upward compatible from the 8080 so that all commercially available 8080 software will run on the Z-80. Furthermore, 8080 assemblers, such as ASM provided with CP/M, can be used to create programs that will run on either an 8080 system or a Z-80 system.

The purpose of this book is twofold. First, I want to provide a single reference source for both 8080 and Z-80 assembly language programmers. The appendixes are designed with this goal in mind. They begin with the ASCII character set and a 64K memory map. These two appendixes are as useful to those using higher level languages as they are to assembly language programmers.

The 8080 and Z-80 instruction sets are listed both alphabetically and numerically in the next four appendixes. This is followed by a cross reference between the 8080 and the Z-80 mnemonics. An appendix describing each instruction in detail then follows. Common acronyms are identified

next in Appendix I, and some undocumented Z-80 instructions are discussed in the final appendix. Collectively, the appendixes contain all of the reference material needed to write 8080 or Z-80 assembly language programs.

The second purpose of this work is to demonstrate some useful techniques of assembly language programming. As an editor for Interface Age, I have seen numerous examples of inefficient or improper programming. General principles of assembly language programming are discussed in Chapters One through Five; specific programming examples are given in Chapters Five through Ten. The reader can actually assemble the programs and try them out.

The organization and operation of the 8080 and Z-80 CPUs is covered in Chapter One. This includes a discussion of the general-purpose registers, the flag registers, logical operations, branching, double-register operations, rotation and shifting. The concepts of hexadecimal, octal, and binary numbers, one's and two's complement arithmetic, and the use of logical operations are presented in Chapter Two.

Stack operations with PUSH, POP, CALL and RET commands and the passing of data between calling program and subroutine are given in Chapter Three. Chapter Four is devoted to input and output techniques, including an interrupt-driven keyboard routine and a telephone transmission program. Assembler macros are discussed in Chapter Five. Examples show how to generate Z-80 instructions with an 8080 macro assembler, and how to emulate Z-80 instructions on an 8080 CPU.

The reader can develop a small, powerful monitor in Chapter Six using the top-down programming method. The monitor contains the usual commands of dump, load, and go. In addition, there is a memory test, a routine to search for one or two hex bytes or ASCII characters, a routine to replace all occurrences of one byte with another, and a routine to perform input and output through any port.

In Chapter Seven the monitor is converted to Z-80 instructions and some additional features are added. Assembly-language subroutines for interconverting between binary numbers and ASCII characters coded in one of the common number bases are given in Chapter Eight. These routines perform all of the input and output through the system monitor developed in Chapter Six. Paper tape and magnetic tape routines are given in Chapter Nine. This method of data transfer is still very popular. I frequently am asked to read information on paper tape into our Z-80 computer so that it can be transmitted over the telephone line to our campus Dec-20 computer.

CP/M is currently the most popular 8080/Z-80 operating system. Chapter Ten demonstrates how assembly language programs can utilize CP/M for all input and output by presenting three programs. One of these programs allows the user to branch to any address from the system level. Nevertheless, the use of CP/M is not the subject of this book. More information on the use of the CP/M operating system can be obtained from *Using CP/M: A Self-Teaching Guide* by Judi Fernandez and Ruth Ashley (John Wiley and Sons, Inc., 1980).

The assembly language programs in this book have all been assembled on an Altair 8800, with an Ithaca Z-80 CPU card and North Star double-density disks. The Lifeboat 2.0 version of CP/M was used as the operating system. The system monitor given in Chapter Six was additionally programmed to run on a TRS-80 Model II, using a Lifeboat 2.2 version CP/M operating system. The alternate version of the input and output routines was used in this case. The Digital Research assembler MAC was used for the 8080 instructions and the Microsoft assembler MACRO-80 was used for the Z-80 code. All of the assembly listings have been reproduced directly from the original computer printouts. The manuscript was created and edited with MicroPro's Word-Master and formatted with Organic Software's Textwriter.

Thanks to Heidi for typing the manuscript. Also, I should like to acknowledge the programmers at Microsoft, Digital Research, and Lifeboat Associates for the many things they have taught me about programming.

Alan R. Miller
June 1980

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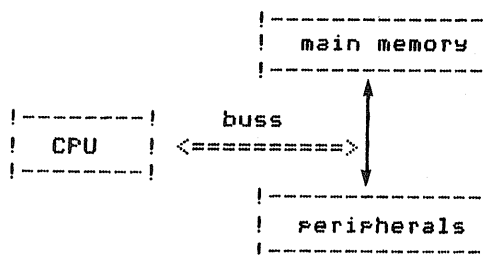
CHAPTER ONE

Introduction

There was a time when computers were gigantic machines containing racks upon racks of vacuum tubes. The invention of the transistor and the development of the integrated circuit (IC) changed all that. Today, it is possible to place tens of thousands of transistors on a single “chip” of silicon that is smaller than a quarter of an inch square. As a result of this technology, computers have become smaller and cheaper.

Computers are commonly classified into three categories, based on size and capability. The largest are known as *main frame computers*, the middle-sized ones are called *minicomputers*, and the smallest are termed *microcomputers*. A computer consists of three parts: the *central processing unit* (CPU), the *main memory*, and the *peripherals*.

The CPU directs the activities of the computer by interpreting a set of *instructions* called *operation codes*, or *op codes* for short. These instructions are located in the main memory. The memory is also used for the storage of data.



The CPU communicates with the user through such peripherals as the console, the printer, the disks, and so on. There are several electrical lines which are used to connect the CPU to the memory and to the peripherals. These lines are collectively known as the *buss*, or *bus*.

The CPU contains a set of *registers*, which are internal memory locations used for data storage and manipulation. One of these is a special register

called the *accumulator*. It receives the results of certain CPU operations. The CPU will also have a *status* register to indicate the nature of a previous operation, e.g., whether the result is zero or negative or positive. It will also indicate whether a carry or a borrow occurred during the operation.

Additional registers are used for auxiliary storage. They may contain general information such as a number that is about to be added to the accumulator. Alternately, a register may contain a number that refers to an *address* in the main memory. The value is called a *memory pointer* in this case. A special portion of main memory may be set aside for storing data. This area is called a *stack*. A special register called a *stack pointer* refers to this region. Another register, the *program counter*, tells the CPU where to find the next instruction in memory.

Computer operations are controlled by a computer *program*. Those programs which are used to solve engineering and physics problems are called *application* programs. On the other hand, computer programs which deal with the operation of the computer's own peripherals are known as *systems* programs.

The instruction set used by the CPU can be very large and difficult to use. Consequently, symbolic programming languages are commonly used instead. An application program may be written in a language such as BASIC, FORTRAN, or Pascal. This is called a *source* program. Then a separate processor program called a *compiler* or an *interpreter* is used to convert the user's source program into an *object* program that corresponds to the instructions needed by the computer.

A microcomputer's instruction set is relatively small compared to that of a larger computer. But even so, it is more convenient to write systems programs in a symbolic language called *assembly language*, rather than in the machine language of the computer. A processor program, called an *assembler*, is then utilized to translate the source program into the corresponding instructions of the computer. A major difference between assembly language and *higher-level* languages such as Pascal is that each line of an assembly language program represents one computer instruction. By contrast, one line of a Pascal source program might represent many computer instructions.

A line of an assembly language program can contain up to four elements: the *label*, the *mnemonic*, one or two *operands*, and a comment.

Label	Mnemonic	Operand	Comment
START:	CALL	FIRST	;initialize data

The label, which is usually terminated by a colon, is used to transfer control from one portion of the source program to another. The mnemonic represents the desired CPU instruction. The operand might reference a CPU register, a memory location, or simply a constant. Finally, a comment, preceded by a semicolon, can be used to explain the instruction. The comment, of course, is ignored by the assembler.

The remainder of this chapter is devoted to a general discussion of some of the features of the 8080 and Z-80 CPUs. The complete instruction sets

for these CPUs are listed in the appendix. Specific details of each instruction are given in Appendix H. If you are already familiar with these instruction sets, then you might want to go on to the next chapter.

THE 8080 CPU

The 8080 CPU is an integrated circuit that has 40 pins (legs). It requires three power supply voltages—12 V, 5 V, and -5 V, and a two-phase clock that runs at 2 Megahertz (MHz). There is an accumulator, a flag register, six general-purpose registers, a stack pointer, and a program counter. The accumulator is sometimes known as register A. The flag register is usually called the PSW (the letters being an acronym for *program status word*). The general-purpose registers are designated by the letters B, C, D, E, H, and L. Sometimes the registers are paired into 16-bit double registers known as BC, DE, and HL. The accumulator and flag register may also be paired. There are 78 different instruction types that produce a total of 245 different op codes.

Accumulator (Register A)	!-----!-----!	Flag Register (PSW)
	! 8 bits ! 8 bits !	
Register B	!-----!-----!	Register C
	! 8 bits ! 8 bits !	
Register D	!-----!-----!	Register E
	! 8 bits ! 8 bits !	
Register H	!-----!-----!	Register L
	! 8 bits ! 8 bits !	
Stack Pointer	!-----!	
	! 16 bits !	
Program Counter	!-----!	
	! 16 bits !	

Figure 1.1. The 8080 CPU registers.

Some of the 8080 instructions explicitly refer to the accumulator or to one of the general-purpose registers (B, C, D, E, H, and L).

mnemonic	operand	comment
INR	A	increment accumulator
DCR	B	decrement register B
MOV	H,D	move contents of D to H
MVI	C,4	put value of 4 into C

When there are two operands, data moves from the right operand (the *source*) into the left operand (the *destination*). There are additional 8080 commands that implicitly refer to the accumulator.

mnemonic	operand	comment
RAR		rotate accumulator right
RAL		rotate accumulator left
IN	0	input a byte to A from port 0
OUT	1	output a byte from A to port 1
ANI	7	logical AND with A and 7
ORI	3	logical OR with A and 3

For certain 8-bit operations, the accumulator is implicitly one of the source registers and will contain the result of the operation.

mnemonic	operand	comment
ADD	C	# add C to A
SUB	D	# subtract D from A
ANA	H	# logical AND of A with H
ORA	B	# logical OR of A and B

Other instructions refer to coupled pairs of 8-bit registers. These extended operations treat the BC, the DE, and the HL register pairs as 16-bit entities. Sometimes the stack pointer and program counter are included in these instructions. The X symbol in the mnemonic refers to these extended 16-bit operations.

mnemonic	operand	comment
INX	H	# increment HL register pair
DCX	SP	# decrement stack pointer
LXI	D,0	# load zero into DE pair

Additional instructions deal specifically with the HL register pair. The following two instructions move two bytes of data between memory and the HL double register.

mnemonic	operand	comment
LHLD	3	# addr 3, 4 to L and H
SHLD	3	# L,H to addr 3, 4

The LHLD instruction copies the value at memory location 3 into the L register and the value at location 4 into the H register. The SHLD operation reverses the process.

The XCHG operation interchanges the 16-bit HL register pair with the 16-bit DE register pair.

XCHG	!-----! ! HL register ! !-----!	<==>	!-----! ! DE register ! !-----!
SPHL	!-----! ! HL register ! !-----!	==>	!-----! ! stack pointer ! !-----!
PCHL	!-----! ! HL register ! !-----!	==>	!-----! ! program ! counter !-----!

The SPHL command copies the HL register into the stack pointer register. The PCHL instruction copies the HL register pair into the program counter register.

There are several instructions that perform double-register addition. The number in one of the 16-bit registers is added to the number in HL. The sum appears in the HL register pair.

```
DAD    D      ;add DE to HL
DAD    SP     ;stack pointer + HL
```

THE MEMORY REGISTER

There is another 8-bit register for the 8080 that is not shown in Figure 1.1. It is located in main memory. The 16-bit address contained in HL defines the location of this memory register, i.e., HL is a memory pointer. The instruction

```
MOV    M,E    ;move E to memory
```

will copy the contents of register E into the memory location pointed to by the HL register pair. The instruction

```
INR    M      ;increment memory
```

will increment this byte in memory.

THE FLAG REGISTER

Four bits of the PSW register can be used to control program flow. The bits or *flags* are used in conjunction with conditional jump, conditional call, and conditional return instructions. We say that a flag is *set* if it has a value of 1 or is *reset* if it has a value of zero.

The CPU sets the sign flag (S) if the result of a previous operation is positive; the flag is reset if the result is negative. The CPU sets a second flag, the zero flag (Z), if the result is zero; it is reset if not zero. A third flag, the carry flag (C), is set if there is a carry on addition or borrow on subtraction; it is reset otherwise. A fourth flag, the parity flag (P), indicates the parity of the result. Parity is even if there is an even number of ones (or zeros) and odd otherwise.



Figure 1.2. The PSW (flag) register.

The use of the flag register can be demonstrated with a simple routine. Suppose that a group of instructions is to be executed eight times. The following code will do this.

```
      MVI      B,8      ;put 8 into B
LOOP:  . . .
      DCR      B        ;decrement B
      JNZ      LOOP     ;loop if not zero
```

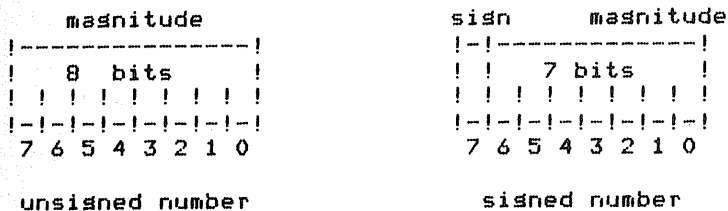
The B register is initialized to the value of 8. The DCR B instruction near the end of the loop decrements the B register each time the loop is executed. This will reset the zero flag on each of the first seven passes through the loop since B has not reached zero. The following conditional jump instruction, JNZ LOOP, causes the CPU to return to the line labeled LOOP in this case.

On the eighth pass through the loop the original value of 8 in the B register will have been decremented to zero. Now the zero flag will be set and the conditional jump instruction will not cause a branch. The instruction immediately following the jump will be executed instead.

FLAGS AND ARITHMETIC OPERATIONS

The results of addition and subtraction operations can be characterized from the PSW flags. Three of the flags are of interest here: the carry flag, the zero flag, and the sign flag. If the sum of two numbers exceeds 255 (1 less than 2 to the eighth power), then the result is too large to fit into the 8-bit accumulator. The carry flag will be set to reflect this overflow. During subtraction, the carry flag is set when a larger number is subtracted from a smaller one. In this case, the flag becomes an indication that borrowing has taken place.

Sometimes all eight bits of a register or memory location are used to represent a number. This is then an *unsigned* number. At other times it is convenient to utilize only the low-order seven bits (bits 0-6) for the magnitude of a number. The remaining high-order bit (bit 7) is then used to indicate the sign.



Numbers represented in this way are known as *signed* numbers. A 0 in bit 7 means that the number is positive and a 1 means that the number is negative. An 8-bit signed number can range in magnitude from -128 to 127, whereas an unsigned 8-bit number can range from 0 to 255.

The sign flag is set after certain operations if the value of bit 7 is 1 and it is reset if bit 7 is 0. If the sum of two numbers is exactly 256, the result in the 8-bit accumulator will be a zero. This occurs because 256 is 1 greater than the largest 8-bit number (255). The zero flag will be set in this case. In addition, the carry flag will be set because there is an overflow. The parity

flag will be set, since there is an even number of ones. (Zero is an even number.) Finally, the sign flag will be reset because bit 7 is a zero.

FLAGS AND LOGICAL OPERATIONS

In the case of arithmetic operations such as addition and subtraction, there can be a carry or borrow from one bit to another. But the logical operations AND, OR, and XOR (exclusive OR) operate on each bit separately; there is never a carry from one bit to the next. These logical operations, therefore, always reset the carry flag. The zero and parity flags, however, will be set or reset according to the result of the particular operation. We will discuss logical operations more fully in Chapter 2.

A value in the accumulator can be compared to a value in another register or to the byte immediately following the instruction byte in memory. The CPU performs the comparison by subtracting the value of the operand from the value in the accumulator. In the case of a regular subtraction, the difference is placed in the accumulator. For example, the arithmetic instruction

```
SUB    C
```

subtracts the value in register C from the accumulator and places the difference into the accumulator. The logical comparison operation

```
CMF    C
```

also subtracts the value in register C from the value in the accumulator. However, unlike the regular subtraction operation, the difference in this case is not actually saved. The flags, of course, will reflect the result of the operation. If the value in C is equal to the value in the accumulator the difference between them will be zero. In this case the zero flag is set indicating the equality. The carry flag will be reset since there was no borrow during the subtraction.

If the two values are not equal, then A is either larger or smaller. If A is larger, the comparison operation will reset the carry flag (and, of course, the zero flag). If A is smaller, then the carry flag will be set, because a larger number has been subtracted from a smaller one. Thus, if the carry flag has been set after a comparison, then the value originally in the accumulator must have been smaller than the value with which it was compared.

The following instructions can be used to determine if the value in register C is less than, greater than, or equal to the value in the accumulator.

```
CMF    C      ; subtract A from C
JZ     ZERO   ; if A equals C
JC     LESS   ; if A less than C
. . .      ; if A greater than C
```

The comparison instruction is executed first. This operation subtracts the value of C from the value in the accumulator. If the two numbers are equal, then their difference is zero. In this case, the zero flag is set and the JZ instruction causes a branch to the label ZERO. Otherwise, the next instruction is executed. Another possibility is that the value in C is greater than the value in the accumulator. The subtraction in this case requires a borrow so the carry (borrow) flag is set. The JC instruction then causes a branch to the label LESS. The last possibility is that the value in the accumulator is larger than that in register C. For this case, both the zero and the carry flags are reset, and the program continues.

INCREMENT, DECREMENT, AND ROTATE INSTRUCTIONS

The 8-bit increment and decrement instructions present an interesting case. Mathematically, the increment operation simply adds 1 to the current value in a register. Likewise, the decrement operation subtracts 1 from the present value. Thus, the two instructions

```
INR    A    and
ADI    1
```

both increase the value in the accumulator by 1 and the operations

```
DCR    A    and
SUI    1
```

both decrease the value in the accumulator by 1. The zero, parity, and sign flags correctly reflect the result in all cases.

The carry flag, however, responds differently for the two cases. The flag correctly reflects the result of the operation in the case of addition, but it is unaffected in the case of an increment or decrement operation. Thus, if you need to increment or decrement a value without disturbing the carry flag, then you should use the INR or DCR instructions. On the other hand, if you need to know whether a carry or borrow occurred during an increment or decrement, then use an add or subtract operation.

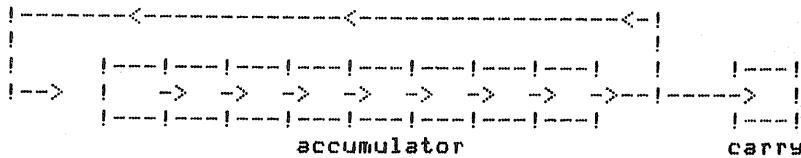
The instructions following the label GETCH in Listing 6.1 (in Chapter 6) are used to set ASCII characters from the console input buffer. As each character is obtained, the count of the remaining characters is decremented. When the count has been decremented past 0, then the routine is finished. Subtracting 1 from 0 requires a borrow so the carry flag should be set. But since the regular decrement operation doesn't alter the carry flag, the subtract instruction must be used instead.

ROTATION OF BITS IN THE ACCUMULATOR

There are four 8080 instructions that rotate the bits in the accumulator. The operations move each bit by one position. Two instructions rotate the bits to the right and two rotate them to the left. The right circular rotation

RRC

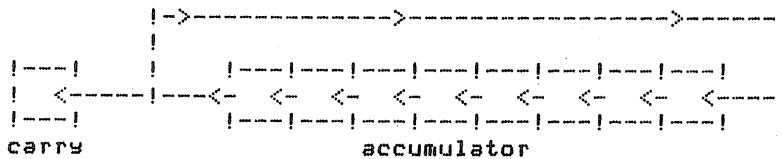
moves each bit one position to the right. The rightmost (low-order) bit is moved to the high-order bit and into the carry flag.



The left circular rotation

RLC

moves the bits the other way.

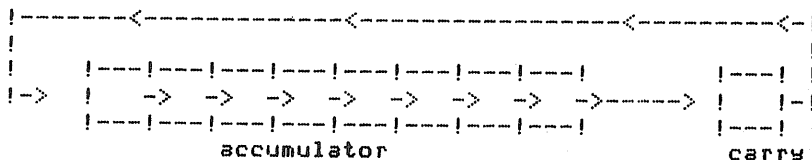


Each bit is moved one position to the left. The high-order bit goes to both the low-order bit and to the carry flag.

The rotate accumulator right instruction

RAR

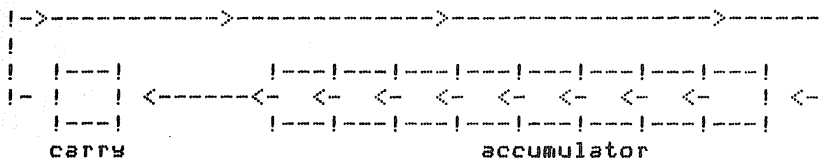
moves each bit one position to the right. But this time, the carry flag moves into the high-order bit and the low-order bit moves into the carry flag.



The instruction

RAL

moves each bit one position to the left. The carry flag moves into the low-order bit and the high-order bit moves into the carry flag.



FLAGS AND DOUBLE-REGISTER OPERATIONS

Double-register, or extended, operations involving HL, DE, and BC affect the flags very differently from the single-register operations. We saw that single-register increment and decrement operations did not alter the carry flag. The extended increment and decrement commands never alter any of the flags. This means that if a program is to loop until a double register has been decremented to zero, the following set of instructions will not work.

```

LOOP:  . . .
        . . .
        DCX    H        ;16-bit decrement
        JNZ    LOOP     ;if not zero

```

The proper procedure is to compare the two 8-bit halves with each other. This can be done by moving one of the registers to the accumulator.

```

MOV     A,L

```

Then the accumulator is compared to the other half by performing a logical OR. The result of this operation will set the zero flag only if both halves are zero. The complete operation looks like this.

```

LOOP:  . . .
        . . .
        DCX    H        ;16-bit decrement
        MOV    A,L      ;move L to A
        ORA    H        ;OR with H
        JNZ    LOOP     ;if not zero

```

The double-register add instruction correctly sets the carry flag if there is an overflow from the 16 bits, but zero, parity, and sign flags are not altered.

THE Z-80 CPU

The Z-80 CPU is a 40-pin IC just like the 8080. All of the 8080 instructions are common to the Z-80, thus we say the Z-80 is upward compatible from the 8080. In general, any program that runs on an 8080 will also run on a

Z-80. The one exception is that the 8080 parity flag is affected by arithmetic operations, while the Z-80 parity flag is not. Thus, one can use an 8080 assembler to generate 8080 code on a Z-80.

The Z-80 requires only a single 5-volt power supply and a single-phase clock that can run as fast as 6 MHz. There are 158 instruction types that give a very large number of total commands with all variations. These are given briefly in Appendixes E and F and in more detail in Appendix H. The Z-80 contains all of the 8080 general-purpose registers, plus an alternate set for easy interrupt processing. The alternate set is indicated with a prime symbol: A', B', and so on. Only one of the two general sets of registers can be used at any time, therefore, data cannot be transferred directly from one set to the other. There are also two 16-bit index registers called IX and IY, an 8-bit interrupt register (I), and an 8-bit refresh register (R).

Primary registers			Alternate registers		
A	8 bits	PSW	A'	8 bits	PSW'
B	8 bits	C	B'	8 bits	C'
D	8 bits	E	D'	8 bits	E'
H	8 bits	L	H'	8 bits	L'
SP	16 bits				
PC	16 bits				
Index Register X			16 bits		
Index Register Y			16 bits		
Interrupt Register I			8 bits		
Refresh Register R			8 bits		

Figure 1.3. The Z-80 CPU registers.

An operand for an assembly-language instruction may consist of a value that is used directly, or it may refer to a location that contains the value. For example, the command

```
LD    A,6
```

instructs the CPU to place the value of 6 into register A. Similarly, the instruction

```
LD    A,D
```

will move the contents of register D into register A. Alternately, the operand may be a pointer to another location. Thus the command

```
LD      A,(6)
```

will move the byte located at address 6 into the accumulator. Similarly, the instruction

```
LD      A,(HL)
```

tells the CPU to move the byte pointed to by the HL register into the accumulator. The Z-80 mnemonics clearly differentiate a pointer by means of the parentheses, whereas the corresponding 8080 mnemonics do not make such a clear distinction.

Z-80 RELATIVE JUMPS

Computer instructions are generally executed in order, one after the other. But it is sometimes necessary to branch out of the normal sequence of statements. Branching statements can be classified as either *conditional* or *unconditional*. An unconditional or absolute branch always causes the computer to execute instructions at a new location, out of the normal flow. Conditional branching, on the other hand, is based upon the condition of one of the flags.

Programs utilizing the Z-80 instruction set can be significantly shorter than those written with 8080 operation codes, especially if the relative jump instructions are used. Relative jumps are performed by branching forward or backward relative to the present position. Absolute jumps, on the other hand, are made to a specific memory location. Furthermore, there are both unconditional and conditional branch instructions. The absolute, unconditional jump op code and the conditional jump codes based on the state of the zero and parity flags are all three-byte instructions.

```
JP      ADDR1      ; unconditional jump
JP      Z,ADDR2     ; jump if zero flag set
JP      NZ,ADDR3    ; jump if zero flag reset
JP      C,ADDR4     ; jump if carry flag set
JP      NC,ADDR5    ; jump if carry flag reset
```

The above instructions are available on both the 8080 and the Z-80 CPUs. In addition, the Z-80 has a relative, unconditional jump and five relative, conditional jumps.

```
JR      ADDR      ; unconditional jump
JR      Z,ADDR6    ; zero
JR      NZ,ADDR7   ; not zero
JR      C,ADDR8    ; carry
JR      NC,ADDR9   ; not carry
DJNZ    ADDR10     ; decr, jump not zero
```

The relative jumps are only two bytes long as opposed to three bytes for the regular jumps, but the relative jump is limited to a displacement of less than 126 bytes forward or 128 bytes backward from the address of the current instruction. These numbers derive from the magnitude of the signed 8-bit displacement. Bit 7 is used for the sign of the number. A 0 in bit position 7 means a forward or positive displacement, a 1 in this bit position means a backward or negative displacement. The remaining seven bits are used for the magnitude of the jump.

Absolute jumps are specified with a 16-bit address that gives the new location. Relative jumps on the other hand are position-independent. The resulting code can be placed anywhere in memory. The last operation above, DJNZ, is a combination of two instructions. The B register is decremented. If the result is not zero, then there is a relative jump to the given argument ADDR10. This two-byte instruction requires four bytes on an 8080 CPU.

Z-80 DOUBLE-REGISTER OPERATIONS

While some of the Z-80 instructions appear to be shorter than their 8080 counterparts, they may not actually reduce the program size. Suppose, for example, that we want to move a block of data from one memory location to another. There is a single Z-80 instruction for accomplishing this task. The problem is that no verification is performed during the move. Thus, if there were no memory at the new location, or if the memory were defective, this fact would not immediately be discovered. If you want to check each location as the data are moved, then the Z-80 block-move instruction cannot be used.

A better way to move data is to define the beginning of the original memory block with HL and the end with DE. The BC register defines the beginning of the new block. We can work our way through the original block by incrementing HL and BC at each step along the way.

The end of the block can be detected when HL exceeds DE. We subtract the two 16-bit registers and observe the carry flag. The HL register pair will initially be less than the DE pair. Therefore, if we subtract DE from HL, we will set the carry (borrow) flag.

Eventually, the number in the HL register will equal the value in the DE pair. This time, the subtraction will not set the carry flag and the task will be completed. Since the 8080 doesn't have a 16-bit subtract instruction, the routine might look like this.

```

LOOP:  . . .          ; 8080 version
        . . .
        MOVE    A,L    ; GET L
        SUB     E      ; SUBTRACT E
        MOV     A,H    ; GET H
        SBB     D      ; SUBTRACT D AND BORROW
        JC      LOOP   ; IF NOT DONE
        RET          ; DONE

```


As long as HL is less than DE, the subtraction will set the carry flag and the loop will be repeated. But as soon as HL equals DE, the carry flag will be reset and the subroutine is finished.

The Z-80 has a 16-bit subtract instruction that can simplify the operation. But since the result of the subtraction is placed in the HL register pair rather than in the accumulator, the data originally present in HL will have to be saved somewhere else, say, on the stack. The Z-80 code is:

```
LOOP:  . . .      ; Z-80 version
        OR        A      ; RESET CARRY
        PUSH     HL      ; SAVE HL ON STACK
        SBC      HL,DE   ; SUBTRACT DE FROM HL
        POP      HL      ; RESTORE ORIGINAL HL PAIR
        JR       C,LOOP  ; IF NOT DONE
        RET
```

The necessary Z-80 instructions require just as many bytes as the corresponding 8080 code. And if the carry flag on the Z-80 has not been reset by a previous instruction, it will have to be reset at the beginning with a logical OR instruction. This latter problem occurs because the Z-80 16-bit subtraction includes the carry flag in its calculations.

Z-80 INPUT AND OUTPUT (I/O) INSTRUCTIONS

A useful pair of Z-80 instructions deals with input and output, i.e., the transfer of data between the CPU and peripherals such as the console, the printer, and the disk. The 8080 can only input and output data from the accumulator, and the address of the peripheral device must immediately follow the IN or OUT instruction in memory.

```
OUT    10
IN     11
```

This usually means that for *read-only memory* (ROM), there must be separate input and output routines for each peripheral.

In contrast, the Z-80 can input or output a byte from any of the general-purpose registers when the peripheral address is in the C register. In this case, it may be possible to use a single set of I/O routines for all peripherals. This approach is discussed more fully in Chapter 4.

SHIFTING BITS

The Z-80 CPU extends the four 8080 rotate instructions to the general-purpose registers B, C, D, E, H, and L. The memory byte referenced by HL, IX, and IY is also included.

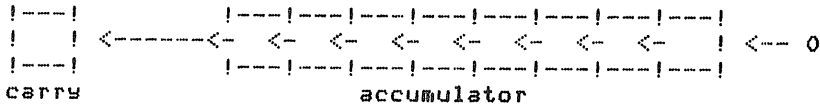
The Z-80 instruction set includes three shift operations. Shifts are similar to rotations since each bit moves one position and the bit that is

shifted out of the register is moved into the carry flag. The difference is in the bit that is shifted into the register.

The arithmetic shift left

SLA

shifts all bits to the left. A zero bit moves into the low-order bit.



The operation doubles the original 8-bit value. This operation can be performed on the accumulator of an 8080 by using an

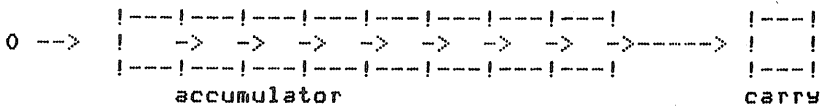
ADD A

instruction.

A logical shift right

SRL

is the inverse of the arithmetic shift left operation. Each bit shifts one position to the right. A zero bit is shifted into the high-order position.

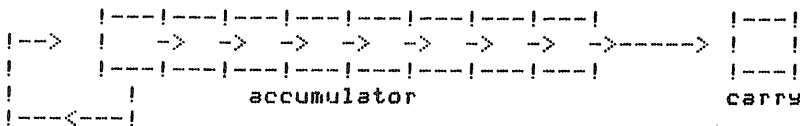


This operation halves the original 8-bit value. The carry flag is set if the original value was odd, that is, if there is a remainder from the division.

The arithmetic shift right

SRA

shifts each bit one position to the right, but the original high-order bit is unchanged.



This operation can be used to divide a signed number in half. The high-order bit, the sign bit, is unchanged. As with the logical shift right, the carry flag is set if the original number was odd.

CHAPTER TWO

Number Bases and Logical Operations

In this chapter we will consider how numbers are stored in a computer. We will also look at some of the operations that can be performed on these numbers. But first we will review the representation of numbers in general. When we write a number such as 245, we usually mean the quantity 5 plus 40 plus 200.

$$\begin{array}{rcll} 2 & 4 & 5 & \text{(decimal)} \\ \begin{array}{|l} \text{---} \\ \text{---} \\ \text{---} \end{array} & \begin{array}{|l} \text{---} \\ \text{---} \\ \text{---} \end{array} & \begin{array}{|l} \text{---} \\ \text{---} \\ \text{---} \end{array} & \begin{array}{l} 5 \times 1 = 5 \\ 4 \times 10 = 40 \text{ (4} \times \text{ the base)} \\ 2 \times 100 = 200 \text{ (2} \times \text{ the base squared)} \end{array} \\ & & & \underline{245} \text{ (decimal)} \end{array}$$

This is the ordinary decimal or base-10 representation of a number. The rightmost digit gives the number of units. The digit immediately to the left is the number of tens (the base). The next digit to the left is the number of 100s (the base squared).

In assembly language programs it is sometimes convenient to represent numbers with a base of 2, 8, or 16. In the octal, or base-8, system, for example, the number 245 is equivalent to the decimal number 165 (5 plus 32 plus 128).

$$\begin{array}{rcll} 2 & 4 & 5 & \text{(octal)} \\ \begin{array}{|l} \text{---} \\ \text{---} \\ \text{---} \end{array} & \begin{array}{|l} \text{---} \\ \text{---} \\ \text{---} \end{array} & \begin{array}{|l} \text{---} \\ \text{---} \\ \text{---} \end{array} & \begin{array}{l} 5 \times 1 = 5 \\ 4 \times 8 = 32 \text{ (4} \times \text{ the base)} \\ 2 \times 64 = 128 \text{ (2} \times \text{ the base squared)} \end{array} \\ & & & \underline{165} \text{ (decimal)} \end{array}$$

This example demonstrates how to convert numbers from other bases into the decimal representation by adding up the decimal equivalent of each digit.

In the binary, or base-2, system, only the digits 0 and 1 are used. The individual digits are called *bits*, an acronym for binary digits. The rightmost bit represents the units. The bit immediately to the left is the number of 2s (the base). The next bit to the left is the number of 4s (the base squared). We continue in this way through all of the bits. For example, the binary number

10100101

is equivalent to the decimal number 165. The conversion is obtained in the following way.

1	0	1	0	0	1	0	1	(binary)
								$1 \times 1 = 1$
								$0 \times 2 = 0$
								$1 \times 4 = 4$
								$0 \times 8 = 0$
								$0 \times 16 = 0$
								$1 \times 32 = 32$
								$0 \times 64 = 0$
								$1 \times 128 = 128$
								<u>165 (decimal)</u>

We have seen that the decimal system utilizes ten different digits (0-9). The octal system, however, utilizes only eight digits (0-7), and the binary system uses only two (0-1). The hexadecimal, or base-16, system is also commonly used in computer programs. With this method, we need 16 different digits. The problem is that if we use all of the digits (0-9) from the decimal system, we will still be six digits short. The solution is to use the letters A through F to represent the digits beyond 9. Thus, the hexadecimal number A5 is equivalent to the decimal number 165. We can convert a hexadecimal number into decimal in the usual way if we remember that A stands for decimal 10, B for 11, and so on.

A	5	(hexadecimal)
		$5 \times 1 = 5$
		$10 \times 16 = 160$ (10 times the base)
		<u>165 (decimal)</u>

The first 16 integers of the decimal, binary, octal, and hexadecimal systems are shown in Table 2.1.

Table 2.2. The first 16 integers represented
in various number systems.

decimal	binary	octal	hex
0	0000	000	00
1	0001	001	01
2	0010	002	02
3	0011	003	03
4	0100	004	04
5	0101	005	05
6	0110	006	06
7	0111	007	07
8	1000	010	08
9	1001	011	09
10	1010	012	0A
11	1011	013	0B
12	1100	014	0C
13	1101	015	0D
14	1110	016	0E
15	1111	017	0F

Table 2.1 shows the common practice of displaying leading zeros on numbers expressed in bases other than 10. Thus we write 5 for a decimal number, but we may write 005 if it is an octal number or 05 if it is a hexadecimal number. We may explicitly represent the base by a suffix. In books, for example, we typically utilize a subscript in smaller size type. Thus we will write:

1010 ₂	(binary)
17 ₈	(octal)
17 ₁₀	(decimal)
17 ₁₆	(hexadecimal)

Alternately, we use suffixes of B, Q, D, and H to designate, respectively, binary, octal, decimal, or hexadecimal mode in computer programs where subscripts are not available.

1010B	(binary)
17Q	(octal)
17D	(decimal)
17H	(hexadecimal)

(The letter Q is used instead of an O for an octal number to avoid confusion with zero.)

Binary numbers such as

011001101111

can be difficult to read, so it is common practice to represent them in octal or hexadecimal form. Conversion to octal is easy if the bits are grouped by threes.

011	001	101	111	(binary)
3	1	5	7	(octal)

Grouping by fours facilitates the conversion to hexadecimal.

0110	0110	1111	(binary)
6	6	F	(hexadecimal)

NUMBER REPRESENTATION IN BINARY, BCD, AND ASCII

All information is ultimately stored in computers as a series of binary digits. There are, however, several different coding schemes for representing the original data. The simplest method is to use straight binary coding, as shown in Table 2.1. Notice that we might choose to represent a binary value in decimal, octal, or hexadecimal notation. The number itself is unchanged by this. The decimal number 12, for example, is stored as the binary number 1100.

A different method of representing data is called *binary coded decimal* (BCD). Actually, there are two types of BCD: unpacked and packed. With unpacked BCD, each byte contains a single decimal digit from 0 to 9. Packed BCD can have one or two decimal digits in each byte. Thus, a packed BCD number can range from 0 to 99. By comparison, an 8-bit binary number can range from 0 to 255. Table 2.2 shows the first 16 integers in BCD. The first column gives the decimal equivalent, the second column the corresponding bit pattern.

Table 2.2. The first 16 integers represented in decimal and binary-coded decimal (BCD).

decimal	BCD
0	0000 0000
1	0000 0001
2	0000 0010
3	0000 0011
4	0000 0100
5	0000 0101
6	0000 0110
7	0000 0111
8	0000 1000
9	0000 1001
10	0001 0000
11	0001 0001
12	0001 0010
13	0001 0011
14	0001 0100
15	0001 0101

Notice that the binary representation for the decimal numbers 0 through 9 is the same for both binary and for BCD.

A third method for encoding data is called ASCII. This scheme is commonly used with peripherals such as printers and video terminals. When the key labeled 2 of an ASCII console is pressed, the bit pattern

0011 0010

is generated. Table 2.3 gives the bit patterns for the ASCII digits 0-9 in binary and hexadecimal notation.

Table 2.3. The bit pattern for the ASCII digits 0-9.

digit	binary	hexadecimal
0	0011 0000	30
1	0011 0001	31
2	0011 0010	32
3	0011 0011	33
4	0011 0100	34
5	0011 0101	35
6	0011 0110	36
7	0011 0111	37
8	0011 1000	38
9	0011 1001	39

LOGICAL OPERATIONS

The fundamental operations of a computer involve electrical signals that can have only one of two values. The two voltage levels might be zero and 5 volts, for example, or they might be something else. The actual value is unimportant at this point. Instead, we refer to the two allowable states as TRUE and FALSE. The TRUE state is also called a logical 1, or high state, and the FALSE state is also known as a logical 0, or low state.

TRUE = 1 (high)
FALSE = 0 (low)

Computers store numbers in binary form as a series of 1s and 0s. These two possible values correspond to the two possible voltage levels of the electronic circuitry. We can therefore utilize the expressions TRUE and FALSE to describe the state of each bit.

The collection of transistors, resistors, and so forth that makes up the physical computer is called the *hardware*. The computer program used to direct the activities of the computer is termed the *software*. In this sense, the hardware and software are distinctly different. But sometimes we use these terms a little differently.

Consider, for example, one of the major differences between minicomputers and microcomputers. Minicomputers contain electronic circuitry for the multiplication of two numbers. Since microcomputers do not contain such circuitry, multiplication is performed instead by executing a special computer program. We say that minicomputers perform multiplication by hardware, but that microcomputers must do multiplication by software.

Hardware operations are performed by electronic devices called *gates*. The internal structure of the gate is unimportant if we are only interested in the logic of its operation. There are input signal lines that are sampled by the gate, and there is an output signal that is generated by the gate. When we consider the logical operations that are performed by a computer, we can imagine that they are accomplished either by hardware or by software. The answer is the same.

A common logical operation is the complement or inversion of a binary digit. The complement of 0 is 1 and the complement of 1 is 0. The hardware complement is performed with an inverter or NOT gate. The electronic symbol for this gate, shown in Figure 2.1, is a triangle with one apex to the right (usually) or to the left (sometimes). A small circle or triangle at this apex completes the symbol.

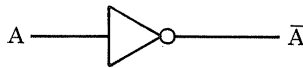


Figure 2.1. The electronic symbol for the NOT or inverter gate.

Letters of the alphabet are used to designate input or output signals. These binary signals can have one of two states, termed TRUE (1) or FALSE (0). The letter A with a bar over it (\bar{A}) represents the complement of A and is called NOT A. A truth table is used to summarize the possible states.

A	\bar{A}	or	A	\bar{A}
0	1		FALSE	TRUE
1	0		TRUE	FALSE

THE TWO'S COMPLEMENT

If each bit of an 8-bit byte is complemented, we produce a result that is termed the one's complement of the byte.

$$0000\ 1001 = 9$$

$$1111\ 0110 = \text{one's complement of } 9$$

Both the 8080 and the Z-80 CPUs provide an operation code for complementing the accumulator. A slightly different operation is the two's complement. It is obtained by incrementing (adding 1 to) the one's complement of a number. For example:

$$0000\ 1001 = 9$$

$$\begin{array}{rcl} 1111\ 0110 & = & \text{one's complement of 9} \\ +\ 0000\ 0001 & & \text{add one} \\ \hline \end{array}$$

$$1111\ 0111 = \text{two's complement of 9}$$

It is interesting to note that the sum of a number and its two's complement is zero.

$$1010\ 1010 = 170$$

$$\begin{array}{rcl} 0101\ 0101 & = & \text{one's complement of 170} \\ +\ 0000\ 0001 & & \text{add one} \\ \hline \end{array}$$

$$0101\ 0110 = \text{two's complement of 170}$$

$$\begin{array}{rcl} 0101\ 0110 & = & \text{two's complement of 170} \\ +\ 1010\ 1010 & = & 170 \\ \hline \end{array}$$

$$0000\ 0000 \quad \text{sum}$$

Adding the two's complement of a number produces the same result as subtracting the number itself. For example, we can subtract 170 from 223 by adding the two's complement of 170. The result is the same.

$$\begin{array}{rcl} 1101\ 1111 & = & 223 \\ -\ 1010\ 1010 & = & 170 \\ \hline \end{array}$$

$$0011\ 0101 = 53$$

or

$$\begin{array}{rcl} 1101\ 1111 & = & 223 \\ +\ 0101\ 0110 & = & \text{2's complement of 170} \\ \hline \end{array}$$

$$0011\ 0101 = 53$$

The 8080 CPU can perform both addition and subtraction with 8-bit numbers and it can add 16-bit numbers, but there is no 16-bit subtraction operation. We can effectively perform a 16-bit subtraction, however, by adding the two's complement. Suppose that the HL register pair contains the decimal value 10,005 and we want to subtract 10,000 from it. The difference between 10,005 and 10,000 can be obtained by adding the two's complement. Consider the bit pattern for the number 10,000.

$$0010\ 0111\ 0001\ 0000 = 10,000$$

We first form the one's complement, then increment the result to form the two's complement.

$$\begin{array}{rcl}
 1101 & 1000 & 1110 & 1111 & = & \text{one's complement of 10,000} \\
 + & 0000 & 0000 & 0001 & & \text{add one} \\
 \hline
 1101 & 1000 & 1111 & 0000 & = & \text{two's complement of 10,000}
 \end{array}$$

Finally, we add this two's complement to the value in HL.

$$\begin{array}{rcl}
 0010 & 0111 & 0001 & 0101 & = & 10,005 \text{ in HL} \\
 + & 1101 & 1000 & 1111 & 0000 & = \text{two's complement of 10,000} \\
 \hline
 0000 & 0000 & 0000 & 0101 & & \text{difference (sum) is 5}
 \end{array}$$

When an assembler encounters a negative argument, it will automatically calculate the corresponding two's complement. Thus the 8080 expression

LXI = D, -10000

will place the bit pattern

1101 1000 1111 0000

in the DE register pair. The instruction

DAD D

will then effectively perform a 16-bit subtraction on the number in HL.

LOGICAL OR AND LOGICAL AND

In the previous section, we considered the logical operation of NOT. Two other important logical operations are OR and AND. Both of these operations reflect the usual English meaning. The logical OR of two bits results in a value of TRUE (1) if either or both the original values are TRUE. The result is FALSE otherwise. The logical AND of two values gives an answer of TRUE (1) if and only if both of the original values are TRUE. If either or both the original values are FALSE, then the answer is FALSE.

Equations of logical operations can be written using the appropriate symbols. Two OR operators are in common use: a plus symbol and a V-shaped symbol. The AND operator is either a dot or an inverted V. The schematic representations of the OR and AND gates are shown with their corresponding mathematical representations in Figure 2.2.



Figure 2.2. The OR and the AND gates.

The truth table is

A	B	(OR)	(AND)
		A+B	A·B
0	0	0	0
0	1	1	0
1	0	1	0
1	1	1	1

where zero means FALSE and 1 means TRUE. The origin of the + symbol for the OR operation and · symbol for the AND operation can be seen from the truth table. Logical operations are performed separately on each bit, and there is never a carry. The logical OR (sum) of A and B gives zero if both bits are zero, but 1 otherwise. (Binary digits can't be larger than 1.) The logical AND (product) of A and B gives zero if either or both bits are zero and unity otherwise.

SETTING A BIT WITH LOGICAL OR

Sometimes, we need to set one or more bits of the accumulator. We can use the logical OR operation for this purpose. From the truth table in the previous section, we can see that a logical OR of 1 with either a 0 or a 1 will give a result of 1.

A	B	A+B
1	0	1
1	1	1

Thus, a logical OR of any bit with a 1 will set that bit. On the other hand, a logical OR of 0 and another bit gives the result of that other bit.

A	B	A+B
0	0	0
0	1	1

In this case, the second bit is not changed.

Suppose that the accumulator contains a binary 5 and we want to convert it to an ASCII 5.

0000 0101 = binary 5
0011 0101 = ASCII 5

If we compare the two bit patterns, we can see that they are the same except for bits 4 and 5. These bits can be set by executing a logical OR with an ASCII zero.

```

      0000 0101 = binary 5
OR   0011 0000 = ASCII zero
-----
      0011 0101 = ASCII 5

```

The OR operation has set the bit corresponding to the location of the 1, but it has left the other bits unchanged.

A logical OR of a register with itself does not change the value.

```

      0101 1010 = 5A hex
OR   0101 1010 = 5A hex
-----
      0101 1010 = 5A hex

```

But this operation can be used to set the flags. In this example, the zero, carry, and sign flags are reset and the parity flag is set.

RESETTING A BIT WITH LOGICAL AND

A logical AND operation can be used to reset any particular bit of the accumulator; the truth table shows how. A logical AND of 0 and either a 0 or a 1 will always give a result of 0.

A	B	A·B
0	0	0
0	1	0

Thus, the bit is reset. On the other hand, a logical AND of 1 and another bit will give the value of the other bit.

A	B	A·B
1	0	0
1	1	1

Thus the AND instruction can be used to reset or “turn off” particular bits. This step is sometimes called a *masking* AND operation.

When the CPU reads an ASCII character from the console, it gets an 8-bit byte. But since the ASCII code contains only 7 bits, the high-order bit is not needed. The console-input routine typically resets this bit by performing a masking AND operation. Suppose that the console transmitted an ASCII 5 with the high-order bit set. The bit pattern looks like this.

```

1011 0101

```

The high-order bit can be reset with an AND operation.

```
      1011 0101 (original byte)
AND   0111 1111 (mask)
-----
      0011 0101 (ASCII 5)
```

LOGICAL EXCLUSIVE OR

The ordinary OR operation is sometimes called an inclusive-or operation to distinguish it from the exclusive OR (XOR) operation. For this latter operation, the result is TRUE only if the corresponding bits of both values are different. Either A or B must be TRUE, but not both. The XOR operation is represented by a plus symbol surrounded by a circle. The complement of the XOR is the exclusive NOR or XNOR. It can be used as a comparator. The hardware implementation is sometimes used in circuitry to enable memory boards. The result is TRUE if and only if both corresponding bits are identical. The result is FALSE otherwise. The truth table is:

A	B	$A \oplus B$	$\overline{A \oplus B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	0	1

The exclusive OR of a bit with itself will always be FALSE. Therefore the XOR of the accumulator with itself will set it to zero.

```
      0111 1100 = 7C hex
XOR   0111 1100 = 7C hex
-----
      0000 0000 = zero
```

The corresponding electronic symbols for the hardware implementation of the XOR and XNOR are shown in Figure 2.3.



Figure 2.3. The exclusive or (XOR) and comparator (XNOR) gates.

LOGICAL NAND AND NOR GATES

By combining an inverter gate in series with the AND and OR gates, a new set of gates is formed. The NOT AND gate is called a NAND gate; it is shown

in Figure 2.4. The NOT OR gate is known as a NOR gate; it is shown in Figure 2.5.

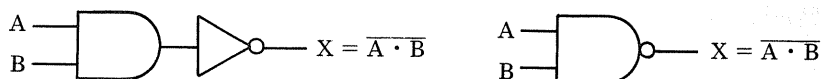


Figure 2.4. The NAND gate can be produced from an AND gate and a NOT gate.

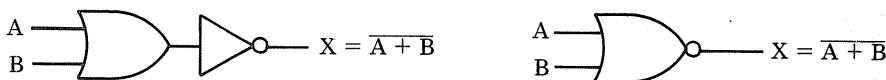


Figure 2.5. The NOR gate can be formed from the OR gate and the NOT gate.

From the truth table, it can be seen that the outputs of the NOR and NAND gates are the inverse of the corresponding OR and AND gates.

A	B	$\overline{A+B}$	$\overline{A \cdot B}$
0	0	1	1
0	1	0	1
1	0	0	1
1	1	0	0

If both inputs of the NOR gate are connected together, then the gate behaves like a NOT gate. The same is true for the NAND gate. This can be seen by comparing the first and last rows of the truth tables. In this way, two NOR gates can be combined serially to produce an OR gate. The result is a NOT NOT OR gate that is equivalent to an OR gate. This is shown in Figure 2.6. In a similar way, two NAND gates can be used to make an AND gate as shown in Figure 2.7. Since OR and AND gates cannot be similarly combined to produce the NOR and NAND gates, we will find that NAND and NOR gates are more common.



Figure 2.6. An OR gate is formed from two NOR gates.

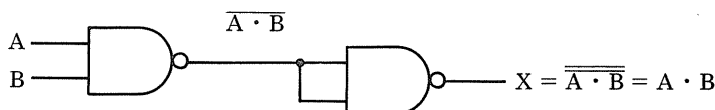


Figure 2.7. Two NAND gates are combined to produce an AND gate.

MAKING OTHER GATES

NOR and NAND gates are very versatile. NOR gates or NAND gates can be combined to produce all of the other gates. This can be seen from the following truth table.

A	B	\bar{A}	\bar{B}	$A+B$	$A \cdot B$	$\overline{A+B}$	$\overline{A \cdot B}$	$\overline{A+B}$	$\overline{A \cdot B}$
0	0	1	1	0	0	1	1	1	1
0	1	1	0	1	0	1	0	0	1
1	0	0	1	1	0	1	0	0	1
1	1	0	0	1	1	0	0	0	0

Notice that column 7 of the truth table has the same values as the last column. Similarly, columns 8 and 9 are identical. These relations follow De Morgan's theorem, which can be expressed mathematically as:

$$\overline{A+B} = \overline{A \cdot B} \quad \text{and} \\ \overline{A \cdot B} = \overline{A+B}$$

The corresponding digital gates are shown in Figures 2.8 and 2.9.

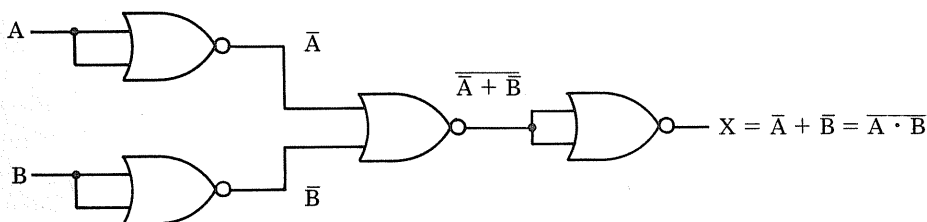


Figure 2.8. A NAND gate is formed from four NOR gates.

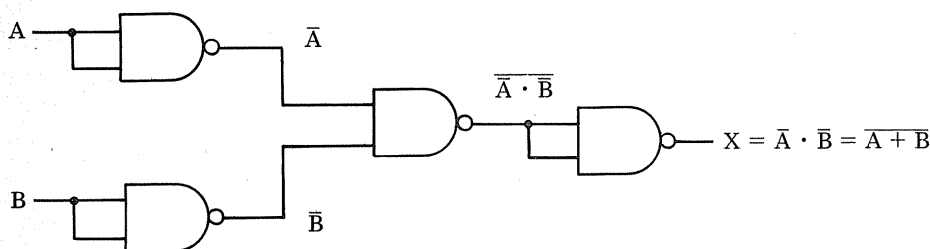


Figure 2.9. A NOR gate is obtained from four NAND gates.

The use of a small circle to represent inverted output brings up another approach to the understanding of digital logic gates. In the more commonly used system, the small circles are used only on the output side of the gate.

Another approach, however, is to always connect active-high outputs to active-high inputs, and active-low outputs to active-low inputs. For this latter system, NAND gates will sometimes appear as OR gates with inverted inputs, and NOR gates will sometimes appear as AND gates with inverted

inputs. According to De Morgan's theorem, the NAND gate is equivalent to the OR gate with inverted input signals. This is demonstrated in Figure 2.10. The circuit shown is logically the same as the one shown in Figure 2.9. Notice that the active-low outputs of the first NAND gates are connected to the active-low inputs of the next OR gate. That is, there are small circles on the outputs of the first gates and on the inputs of the second gate.

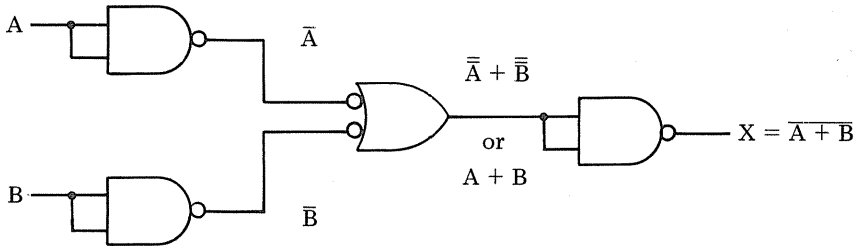


Figure 2.10. A NOR gate is produced from four NAND gates. The middle NAND gate is shown in its alternate representation.

CHAPTER THREE

The Stack

When main memory is used to store a collection of data, each member of the data set is individually accessible. This type of storage is termed *random access memory* (RAM). Magnetic tape storage, by contrast, is serial or *sequential access memory*. In this latter case, only one item of the set is available at any one time. There are two ways of storing and retrieving the items in a serial memory buffer: one is by means of a first-in, first-out (FIFO) buffer, and the other is by means of a last-in, first-out (LIFO) buffer. We can visualize the serial buffer as a long string of information. With the FIFO buffer, items are added at one end and removed from the other. This buffer is analogous to an escalator: the people who ride the escalator are like the data—those who get on first, get off first.

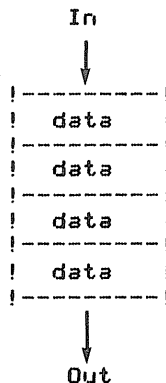


Figure 3.1. The first-in, first-out (FIFO) buffer.

With the LIFO buffer, on the other hand, the data are added and removed at the same place. This arrangement is analogous to a very long, narrow elevator. Those who get on first, have to wait until everyone else is

off before they can get off. It can be seen that magnetic tape is a FIFO medium.

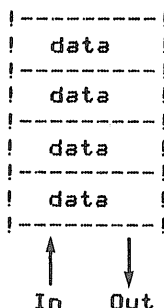


Figure 3.2. The last-in, first-out (LIFO) buffer.

Sometimes, a special area of main memory is designated as a LIFO buffer even though each member of the buffer is individually accessible. This region is known as a *stack*. As an example, Hewlett-Packard calculators utilize a very short LIFO stack, consisting of registers known by the letters Y, Z, and T. An item in any of the registers is individually accessible, yet the stack as a whole can be manipulated. As data is entered from the keyboard, it is placed into the X register. This information can then be transferred to the stack (register Y in this case) by pressing the ENTER key. We say that the contents of the X register are *pushed* onto the stack. Items can be retrieved from the stack and placed in the X register with the roll-down (R) key. We say that data are *popped* from the stack into the X register by this means. Another stack operation is performed by the EXCHANGE key which is used to swap the contents of the X and Y registers.

STORING DATA ON THE STACK

We have seen in the previous chapters that the 8080 and Z-80 microprocessors incorporate general-purpose registers for the storage of information. But these registers are limited in number. Consequently, a special area of main memory is designated for the additional storage of information. This area, called the stack, is implemented on the Z-80 and 8080 as a last-in, first-out serial buffer even though each item in the stack is individually accessible. One of the CPU registers, the stack pointer, references the current location in memory. This is the address of the most recently added item. The stack pointer is decremented as items are added and incremented as items are removed. The programmer may place the stack anywhere in memory by loading the stack pointer with the desired address. For example, the instruction

```
LD      SP,4000H      (Z-80)   or
LXI     SP,4000H      (8080)
```

initializes the stack to location 4000 hex.

Data can be placed on the stack with one of the PUSH operations. A command of

(Z-80)		(8080)
PUSH	HL	PUSH H

will move a copy of HL to the stack. Since main memory is addressed eight bits at a time, the PUSH operation is actually performed in two stages. The stack pointer is decremented, then the H register (the high half) is copied to the stack. The stack pointer is decremented a second time and the L register (the low half) is copied to the stack. The stack pointer register now contains the address of the low byte. Figure 3.3 demonstrates the action of a PUSH HL command. The region of memory devoted to the stack is shown with higher memory upward. The arrow represents the stack pointer.

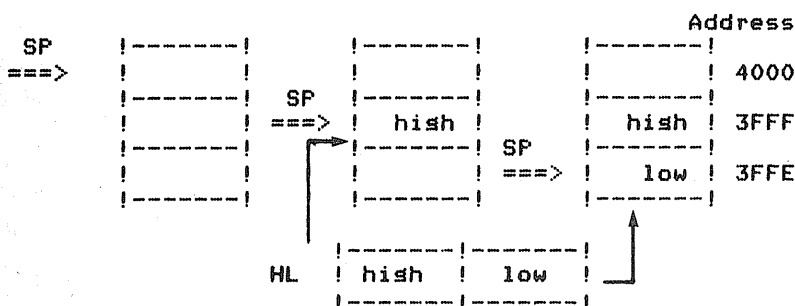


Figure 3.3. The HL register is pushed onto the stack.

The POP instruction reverses the PUSH process. For example, a POP DE command copies 16 bits from the stack into the DE register. Because the stack operates in a LIFO manner, the most recently added byte is removed first. This is placed into register E (the low half of the DE pair). The stack pointer is automatically incremented and the next byte is transferred from memory to register D (the high half). The stack pointer is then incremented a second time. Figure 3.4 demonstrates the operation. Notice that the data originally pushed onto the stack is still present.

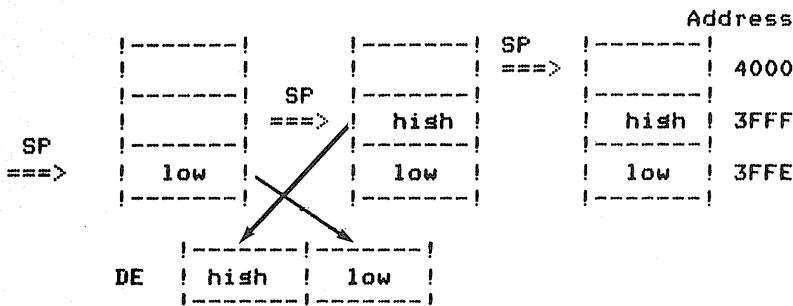


Figure 3.4. Two bytes are popped from the stack into DE.

It can be seen that the stack grows downward in memory as data are pushed into it, and it moves back up as data are popped off. For this reason, it is common practice to initialize the stack pointer to the top of usable memory. Actually, the stack pointer can start at one address above the top of memory since the stack pointer is always decremented before use.

If the general-purpose registers contain important information but they are needed for a calculation, it will be necessary to save the original data. This can be easily done by pushing the contents onto the stack. The registers are restored at the end of the calculation with the three corresponding POP commands. The operation goes like this.

```
PUSH    HL      ;save HL
PUSH    DE      ;save DE
PUSH    BC      ;save BC
. . .
. . .          ;do the calculation
. . .
POP     BC      ;restore BC
POP     DE      ;restore DE
POP     HL      ;restore HL
```

Notice that the order of the POP commands is reversed from that of the PUSH sequence. This is necessary because of the stack's LIFO operation.

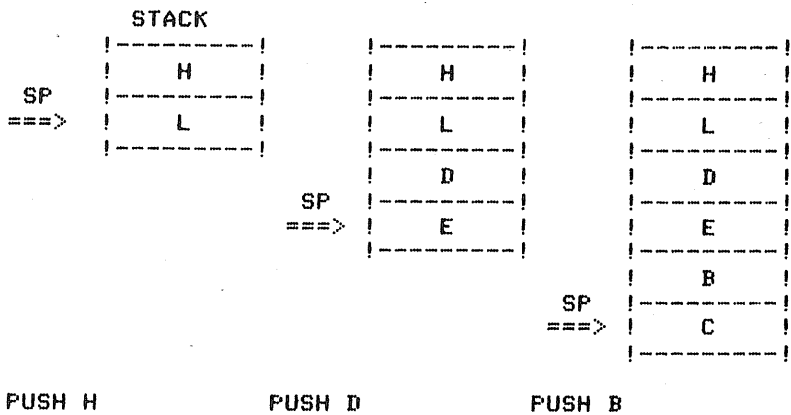


Figure 3.5. The contents of the general-purpose registers are saved on the stack.

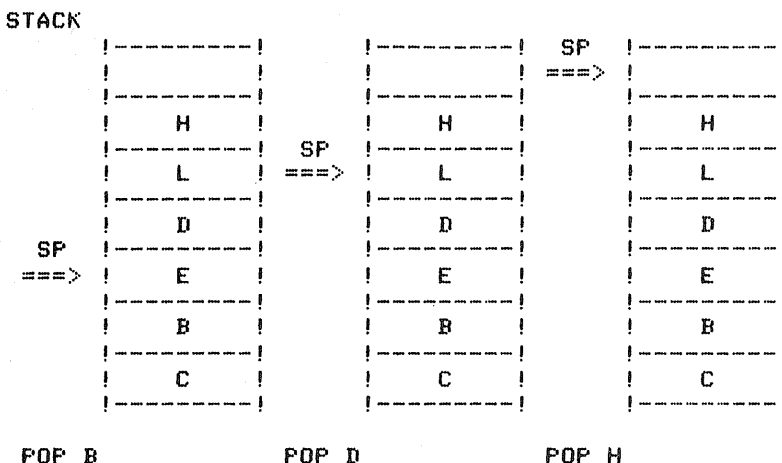


Figure 3.6. The original contents of the general-purpose registers are restored from the stack.

THE ACCUMULATOR AND PSW AS A DOUBLE REGISTER

The 8-bit accumulator and the 8-bit flag register are treated as a 16-bit double register for the PUSH AF and POP AF instructions. In this case, the accumulator is treated like the high byte since it is pushed onto the stack first. The flag register is pushed onto the stack second. Figure 3.7 demonstrates this.

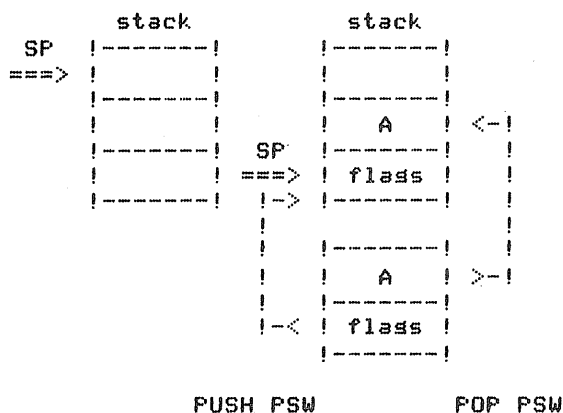


Figure 3.7. Contents of the accumulator and flag registers are pushed onto the stack.

Data can be moved from one register pair to another by using a PUSH/POP combination. For example, the two 8080 commands

```
PUSH H
POP D
```

will move H to D and L to E. This is not the most efficient way to accomplish the move, however. The sequence requires access to main memory and so is slower than the direct register moves

```
MOV D,H
MOV E,L
```

Z-80 INDEX REGISTERS

The Z-80 has two, 16-bit index registers that can participate in the PUSH and POP operations. However, the instructions each require two bytes compared to the other PUSH and POP instructions which only require one byte each. As a result, the execution time is slower than the other PUSH and POP instructions. There are no official instructions for moving data between the index registers and the general-purpose registers. This transfer can be performed, however, by use of the PUSH and POP commands. The two instructions

```
PUSH IX
POP BC
```

will copy the IX register into the BC register.

SUBROUTINE CALLS

We have seen that the PUSH instructions can be used by the programmer to store data on the stack. The 8080 and Z-80 CPUs use the stack for a second purpose: storing the return address when a subroutine is called. Subroutines are used to efficiently code a set of instructions needed at several different places in a computer program. A subroutine is called by using the assembly-language mnemonic CALL. At the end of the subroutine, indicated by the return statement, control is automatically returned to the calling program.

```
!-----!      Call      !-----!
! calling ! ----->      ! subroutine !
! program ! <-----      !-----!
!-----!      Return
```

The input and output routines which control the console may be needed at several locations in a program. Consequently, they are coded as

subroutines. The 8080 assembly language subroutine for the console might look like this.

```
OUTPUT: IN      STATUS  ; CHECK STATUS
        ANI     INMSK   ; INPUT MASK
        JZ      OUTPUT  ; NOT READY
        MOV     A,B      ; GET DATA
        OUT     DATA    ; SEND DATA
        RET          ; DONE
```

Data can be output from anywhere in a program by placing the byte in the B register and calling the output subroutine. The following examples of 8080 assembly language mnemonics show how a question mark and a colon can be printed by calling the console output routine.

```
WHAT:   MVI     B,'?'   ;OUTPUT A ?
        CALL    OUTPUT
        . . .
COLON:  MVI     B,':'    ;OUTPUT A COLON
        CALL    OUTPUT
        . . .
```

The above examples utilize the unconditional subroutine call and unconditional return instructions. Conditional call and return instructions are also available. These commands perform the appropriate call or return only if the referenced PSW flag is in the desired state. The four flags—zero, sign, carry, and parity—give rise to eight conditions.

zero
not zero
plus
minus
carry
not carry
parity even
parity odd

These instructions are discussed in more detail in Appendix H.

The stack provides the mechanism for subroutine operation. When a CALL instruction is encountered, the address immediately following the CALL statement is automatically pushed onto the stack. The subroutine address is then loaded into the program counter register. The program counter tells the CPU which instruction to execute next. Since a subroutine CALL uses the stack, the programmer must be sure that the stack is properly defined prior to a subroutine CALL. When a return instruction is subsequently encountered, the return address is popped off the stack and placed into the program counter. After return from a subroutine, program execution continues with the instruction following the CALL statement.

PASSING DATA IMPROPERLY TO A SUBROUTINE

Since the stack can be used for storing both data and subroutine return addresses, the programmer must ensure that there are no conflicts. First, there should normally be as many POP instructions as PUSH instructions. Second, one must be careful not to PUSH data onto the stack, CALL a subroutine, then POP data off the stack. The LIFO nature of the stack will cause trouble in this case.

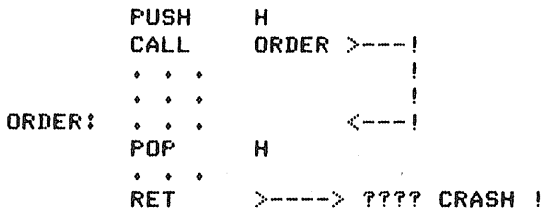


Figure 3.8 shows an example of improper mixing of data and the return address on the stack. Higher memory is upward and lower memory is downward. The arrow indicates the current stack pointer position.

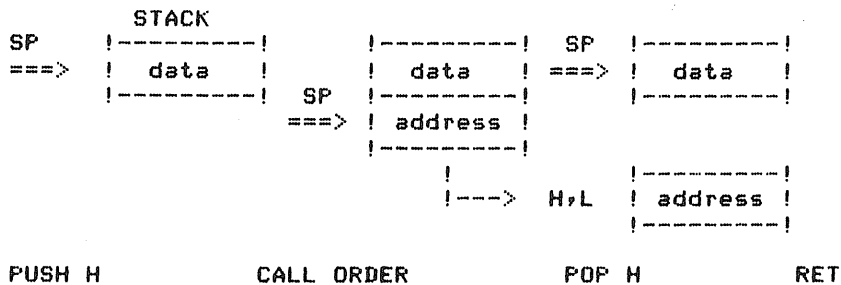


Figure 3.8. Improper mixing of data and the return address on the stack.

In this example, the data is first pushed onto the stack while in the main program. The return address is then pushed onto the stack next, when the CALL instruction is encountered. The POP instruction in the subroutine will actually load the HL register pair with the subroutine return address rather than the data that was expected. This occurs because the data was pushed onto the stack before the return address. Worse yet, the RET instruction will load the program counter with the data, rather than with a useful address. Strange things are likely to happen when the CPU attempts to execute instructions at an address defined by the data.

PASSING DATA PROPERLY TO A SUBROUTINE

This section demonstrates a proper way to pass data into a subroutine by using the stack. The task can be accomplished with the 8080 XTHL instruction

or the Z-80 EX (SP),HL instruction. This operation exchanges the HL register pair with the two bytes at the current stack position. The instruction is analogous to the X/Y EXCHANGE key on an HP calculator.

The method works in the following way. The data is pushed onto the stack while control is in the calling program. When the subroutine is called, the return address is pushed onto the stack, just after the data. A POP instruction, executed in the subroutine, delivers the return address to the HL register. Now, the XTHL instruction exchanges the HL register with the stack. The desired data is now in HL and the return address is on the stack. Finally, a return instruction will correctly return control to the calling program.

```

      PUSH    H      ; main program
      CALL    ORDER  ; call subroutine
      . . .
ORDER: . . .          ; start of subroutine
      POP     H      ; set return address
      XTHL                ; exchange with data
      . . .
      RET                ; return to main program

```

STACK	|-----|	SP	|-----|	SP	|-----|
	| data |	==>	| data |	==>	| address |
SP	|-----|		|-----|		|-----|
==>	| address |				

HL	|-----|	|-----|
	| address |	| data |
	-----	-----

CALL POP H XTHL RET

Figure 3.9. Proper mixing of data and return address on the stack.

It is important to note that the XTHL command only works with the HL register. There is no equivalent instruction for the DE or BC registers.

PASSING DATA BACK FROM A SUBROUTINE

A variation of the XTHL technique is also possible. Data can be pushed onto the stack from within a subroutine, then retrieved after returning to the calling program.

```

CALL    FETCH
POP     H          ;GET THE DATA
. . .
. . .
. . .
FETCH:  . . .
        LXI        H,DATA ;PUT IN H,L
        XTHL       ;SWITCH STACK
        PUSH       H      ;RET ADDR
        . . .
        RET

```

DATA in this case is predefined and is part of the LXI instruction.

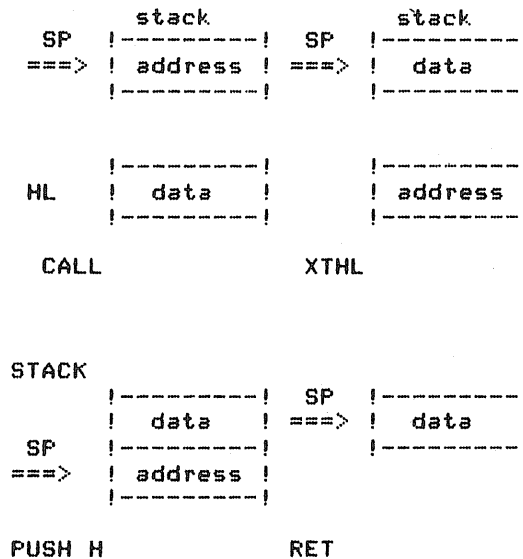


Figure 3.10. Using the stack to pass data back from a subroutine.

An extension of the XTHL technique allows additional data to be passed on the stack.

```
CALL    FETCH
POP     B      ;DATA 3
POP     D      ;DATA 2
POP     H      ;DATA 1
. . .
. . .
. . .
FETCH:  . . .
        LHLD    DATA1    ;DATA1 TO H,L
        XTHL    ;SWITCH STACK
        XCHG    ;STACK TO DE
        LHLD    DATA2    ;GET DATA2
        PUSH    H          ;PUT ON STACK
        LHLD    DATA3    ;GET DATA3
        PUSH    H          ;PUT ON STACK
        PUSH    D          ;RET ADDR TO STACK
        RET
```

In this example, the return address is first moved to the HL pair with the XTHL command. Then it is moved to the DE register pair with the XCHG instruction. Three sets of 16-bit data are obtained from the memory addresses pointed to by the arguments of the LHLD instructions DATA1, DATA2, and DATA3. The first set is placed on the stack with the XTHL command. Then the other two are pushed onto the stack. Next, the return address, previously saved in the DE register pair, is pushed onto the stack. A final RET instruction pops the return address from the stack into the program counter.

SETTING UP A NEW STACK

Sometimes it is desirable to save the current stack pointer and set up a new one. When this happens, the original stack pointer is restored at the conclusion of the task. The technique is particularly useful when one independent program is executed by another. The original stack pointer is saved in a memory location, then retrieved at the end of the program.

If the current program was reached through a subroutine call, the return address for the calling program should be the current address on the original stack. It is this address that must be saved.

There is a Z-80 instruction that allows the old stack pointer to be stored directly in main memory. The instruction looks like this.

```
; Z-80 VERSION
;
START: LD      (OLDSTK),SP ;save stack
        LD      SP,STACK  ;new stack
        . . .
        . . .
        LD      SP,(OLDSTK) ;set old stack
        RET      ;done
```

Now the calling program must put its own return address on the stack and get the address of CHEK into the program counter. The following example is a way to do this. Notice that program 1 does not enter program 2 with a CALL instruction. It uses instead the PCHL instruction which copies the contents of HL into the program counter.

```

      PUSH    H          ;SAVE H,L
      LXI     H,NEXT     ;RET ADDR
      PUSH    H          ;ONTO STACK
      LHLD    CHEK2
      PCHL    H          ;INTO PC
NEXT:  POP     H          ;ORIG H,L

```

CALLING ONE SUBROUTINE FROM ANOTHER

A subroutine called by a main program may in turn call another subroutine. When the first subroutine, SUB1, is called, the return address to the main program, MAINA, is pushed onto the stack. When the second subroutine, SUB2, is called, the return address SUB1A is next pushed onto the stack. After the second subroutine has been called, there will be two return addresses on the stack: one to get back to SUB1 from SUB2, and the other to get back to the main program from SUB1.

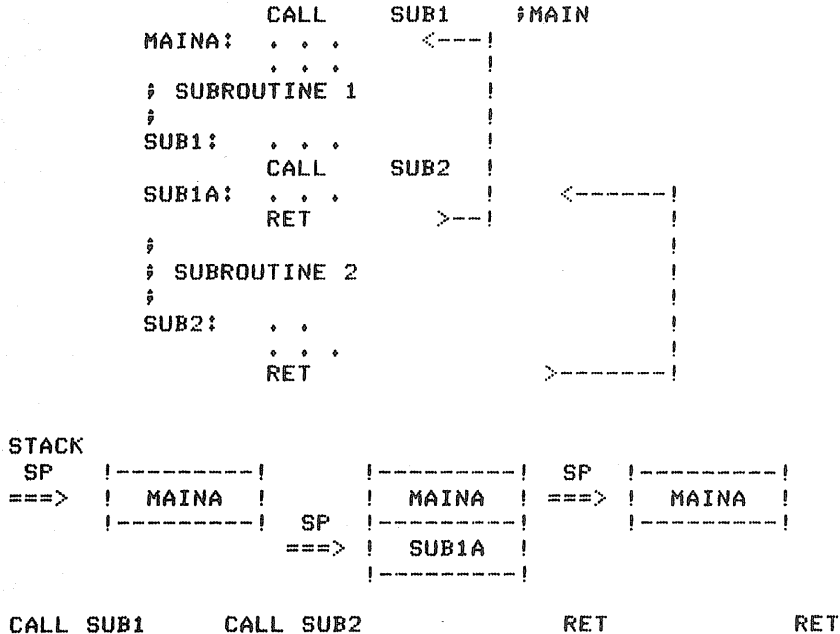


Figure 3.11. One subroutine calls another.

BYPASSING A SUBROUTINE ON RETURN

It may be that an operation in the second subroutine SUB2 makes it desirable to return directly to the main program from SUB2, bypassing SUB1. This is easily accomplished if the stack pointer is raised by two bytes before executing the return instruction. Of course, care should be taken to see if data has been pushed onto the stack after one or both return addresses were placed on the stack. The one-byte instruction to increment the stack pointer (INX SP) can be executed twice, to raise the stack pointer two bytes. Alternately, a one-byte POP command can be used if there is a free register pair available.

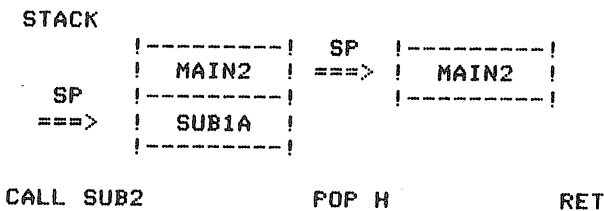
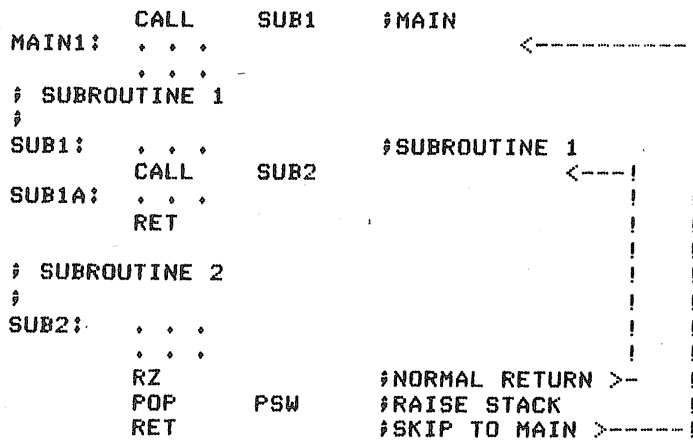


Figure 3.12. Skipping one level of subroutine during the return.

Suppose that an ordinary return from subroutine SUB2 back to subroutine SUB1 is desired if the zero flag is set to 1. On the other hand, an unusual return directly back to the main program is desired if the zero flag is reset to a value of zero. Here is a way to do this.



The POP PSW instruction raises the stack two bytes so that the final RET instruction delivers the return address of MAIN1 to the program counter. This effectively bypasses the intermediate subroutine.

A PUSH WITHOUT A POP

Near the beginning of the system monitor, explained in Chapter 6, there is a restart address called WARM. The program normally branches back to this point at the conclusion of each task. Thus the final instruction of each task could be:

```
JMP    WARM
```

A more efficient method, however, is to push this restart address WARM onto the stack at the beginning of the task. Then if the task does not terminate within a subroutine, a simple return instruction, rather than a jump, can be given at the end of the task. This causes a branch back to WARM.

```
WARM:  LXI    H,WARM    ;H,L = HERE  <-----!
        PUSH  H        ;ONTO STACK  !
        . . .          !
        JZ    OPORT    !
OPORT:  . . .          !
        RET             >-----!

```

This example is an exception to the rule that we should have a POP instruction for every PUSH. Here, there is a PUSH but no POP. Of course there is also a RET with no CALL. So everything is all right—or is it? What happens if termination occurs from a subroutine?

GETTING BACK FROM A SUBROUTINE

If a particular task terminates in a subroutine, then this subroutine's return address must be popped off the stack (or an INX SP instruction must be executed twice) before the return is issued.

```
WARM:  . . .          <-----!
        JZ    DUMP    !
DUMP:  . . .          !
        CALL  TSTOP    !
        . . .          !
TSTOP:  . . .          !
        RNC    ;NORMAL RETURN >--!
        POP   H        ;RAISE STACK !
        RET             ;TO WARM  >-----!

```

The stack pointer grows downward through memory during use. It is therefore common practice to place the stack as high as possible in available memory. But the system monitor may be located at the actual top of memory. In this case the stack can initially be placed lower in memory at the beginning of the monitor.

```
START:      LXI      SP, START
```

On the other hand, the monitor may be placed in read-only memory (ROM). In this case, the stack can be located at the actual top of read/write memory. (While both read/write memory and ROM are random-access memory—RAM, it is customary to refer to read/write memory as RAM and read-only memory as ROM. This convention will be followed here.)

AUTOMATIC STACK PLACEMENT

The placement of the stack at the top of RAM can be done automatically, so that the total amount of RAM can be changed without having to reprogram the PROM monitor. A short routine can test each block of memory starting at zero until it finds a location that can't be changed. The stack is then put at the beginning of this block. Remember, the stack pointer is always decremented before use; therefore, it can be initially defined as one location above usable memory.

The first part of the program is a memory search routine that starts at address zero. It moves the byte from that location into the accumulator, complements it, then moves the complemented byte back to the original location. A comparison is made to see if the memory location does indeed contain the complemented byte. If it does, the accumulator is complemented back to the original byte and returned to memory. Such an algorithm is often called a nondestructive memory test.

The first byte of each subsequent block of memory is checked in this way until a failure is found. This will usually reflect the top of usable memory, but of course, it could indicate defective memory. The following program will work properly if placed in read-only memory.

```

$
$ ROUTINE TO AUTOMATICALLY PLACE THE
$ STACK AT THE TOP OF MEMORY
$ 8080 CODE
$
NEXTP:  LXI      H,0      $FIRST ADDR
        MOV      A,M      $GET BYTE
        CMA      $COMPLEMENT
        MOV      M,A      $PUT IT BACK
        CMP      M      $COMPARE?
        JNZ      TOP      $NO, DONE
        CMA      $BACK TO ORIG
        MOV      M,A      $PUT IT BACK
        INR      H      $NEXT BLOCK
        JMP      NEXTP    $KEEP GOING
$
TOP:    SPHL      $SET STACK
        CALL     OUTHL    $PRINT IT
        . . .

```

This program might not work, however, if it is placed in read/write memory. The problem occurs because the routine is changing various locations in memory. If it happens to change its own instructions, then the results will be unpredictable.

The shortcomings of the previous program are solved with the following version. The improved version will operate properly no matter where it is placed. The stack will be placed at the top of contiguous RAM unless the routine itself is in that part of memory. In that case, the stack will be placed at the beginning of the program. The Z-80 version is shown, but the program can be run on an 8080 if two minor changes are made. The relative jump instruction must be changed to an absolute jump and the DJNZ instruction must be changed to the equivalent DCR B and JNZ combination.

```

;
; ROUTINE TO AUTOMATICALLY PLACE THE
; STACK AT THE TOP OF MEMORY
; FAILSAFE VERSION (Z-80 CODE)
;
START:  LD      HL,0      ;START CHECK AT 0
        LD      B,START  SHR 8
NEXTTP: LD      A,(HL)    ;GET BYTE
        CPL                     ;COMPLEMENT IT
        LD      (HL),A    ;PUT IT BACK
        CP      (HL)      ;DID IT GO?
        JR      Z,TOP     ;NO, DONE
        CPL                     ;BACK TO ORIG
        LD      (HL),A    ;RESTORE
        INC     H          ;NEXT BLOCK
        DJNZ    NEXTP     ;ARE WE HERE?
;
TOP:    LD      SP,HL     ;SET STACK
        . . .
```

The new version works in the following way. The B register initially contains the block number of the routine itself. The value in B is decremented as each successive block is checked. If the routine is in ROM, then the end of usable memory will be found, as in the previous version. The program will loop between the label NEXTP and the DJNZ NEXTP instruction. At some point, the CP (HL) instruction will reset the zero flag and the computer will jump to the address of TOP. The stack will then be placed at the top of RAM.

Alternately, if this routine is placed in the lower memory area, then the DJNZ instruction will decrement the B register all the way to zero. The zero flag will be set and the program will move on to TOP. Now the stack will be set to the beginning of the memory block that contains the program itself.

The START SHR 8 expression at the beginning of the routine instructs the assembler to calculate the high byte of the address of START and make it the second operand of the LD B instruction. It does this by shifting the

address of START by eight bits to the right, then taking the low-order eight bits of the result. Some assemblers allow an equivalent operand of

HIGH START

which is easier to comprehend. This automatic stack routine is incorporated into the system monitor explained in Chapter 6.

CHAPTER FOUR

Input and Output

Computers would not be very useful if they could not interact with the outside world. Commands and data are sent to the computer from the keyboard, magnetic tape, disk, and other peripherals. Results of computations are sent back from the computer to the printer, video terminal, tape unit, disk, and so on. Such input and output (I/O) transfers on a microcomputer are typically accomplished through special memory locations called *I/O ports*. One type of port is distinctly different from main memory. The other type of arrangement utilizes one of the regular main memory locations. The peripheral in this latter case is then said to use *memory-mapped* I/O. Each method has advantages and disadvantages. In either case, the I/O port will transfer eight bits, the natural word size for the 8080 and Z-80 CPUs.

MEMORY-MAPPED I/O

The I/O instructions on the 8080 microprocessor are rather limited compared to memory operations. There is a single IN and a single OUT instruction for transferring eight bits of data. In contrast, there is a much larger collection of memory operations available.

(8080 Mnemonics)		(Z-80 mnemonics)	
STA	80	LD	(80),A
LDA	81	LD	A,(81)
MOV	M,C	LD	(HL),C
STAX	D	LD	(DE),A
SHLD	84	LD	(84),HL

These additional instructions can be utilized with memory-mapped I/O, greatly increasing the versatility of the Z-80 and 8080 I/O operations.

The STA instruction stores the 8-bit accumulator value at the memory address specified by the operand. If this address corresponds to a memory-mapped port, then the byte is sent to the peripheral. The LDA command reverses the operation. It can be used to input a byte from a port. The MOV M,C instruction can be used to transfer a byte from the C register to the memory location designated by the HL register pair. The STAX D command moves a byte from the accumulator to the memory location designated by the DE register pair. The SHLD instruction opens a new dimension. Since this operation transfers 16 bits of data from the HL register pair directly into two consecutive memory locations, two adjacent ports can be simultaneously serviced.

The typical video console is a serial device that uses distinct ports. However, memory-mapped controller boards are commercially available. In this case, an ordinary TV set is then used for the video screen. There are also disk-controller boards that use memory-mapped operations to communicate with the disk drives. It is interesting to note that the Motorola 6600 CPU performs all of its I/O by memory mapping. There are no separate input or output instructions for this CPU.

DISTINCT DATA PORTS

Data ports may be designed to operate either in parallel or in serial fashion. Both the parallel and the serial I/O ports are connected to the computer through the system bus by a set of eight data lines. In addition, the parallel port is connected to the peripheral by another set of eight data lines. The serial port, by contrast, has only two data lines connecting it to the peripheral.

For some peripherals, such as a printer, data is transferred in only one direction. For others, such as the console and magnetic tape units, the peripheral is able to both send and receive data. In this latter case, there will be 16 data lines between the computer and the peripheral if a parallel port is used. Eight lines are used for sending data and eight are used for receiving data. The serial port, in contrast, will have three signal lines to the peripheral if there is two-way communication. One is for transmitting, one is for receiving, and the third is a common line for the other two.

There may be additional lines between the computer and the peripheral. One of these might indicate to the computer whether the terminal is operational. Another can be used to inform the terminal that the computer is ready. These extra lines are sometimes referred to as *handshake* lines.

The computer usually operates at a much higher speed than the peripherals. Consequently, there must be a mechanism for effectively slowing down the computer during I/O operations. For serial or parallel ports, this is typically accomplished by using two separate I/O ports for each peripheral device. One port is used for the data port and the other is used for the status port. Each of these two ports will have distinct addresses, one of the 256 values available to the 8080 or Z-80 CPU for this purpose. There are three

general methods of performing I/O through data ports: looping, polling, and interrupting.

LOOPING

Looping is the simplest method of performing I/O through separate ports, and it is the one that is most commonly employed in 8080 and Z-80 programs. The CPU performs output by sending a byte to the data port using the OUT instruction. The corresponding status port is then read with an IN instruction. One bit of the 8-bit status port reflects the condition of the corresponding peripheral.

When the CPU places a byte in the data register, using the OUT command, the output status bit of the status register is set. This may actually result in a logical 1 or a logical zero, depending on the port design. When the peripheral utilizes the byte that was placed into the data register, the output status bit of the status register is reset. These changes in the status bit are automatically handled by the I/O interface hardware. However, the programmer must include in the software the appropriate routines for monitoring the status bits.

As an example of the looping method, consider the following sub-routine:

```
COUT:  IN      10H      ;CHECK STATUS
        ANI     2       ;SELECT BIT
        JZ      COUT    ;NOT READY
        MOV     A,C      ;GET BYTE
        OUT     11H     ;SEND
        RET          ;DONE
```

This routine could be used to send a byte of data to the system console. The first instruction of the listing causes the CPU to read the 8-bit status port which has the address of 10 hex. The second instruction performs a masking AND operation to select the write-ready bit, bit 1. Remember that a logical AND with zero and anything else gives a result of zero. However, a logical AND with unity and a second logical value, gives the result of that second value.

Suppose that the output status is indicated by a logical 1 of bit 1, where bit 0 is the least-significant bit of the register. Then, a logical AND with the value in the status register and with the number 2 will result in a logical 1 if the peripheral is ready. If the device is not ready, however, the result is a logical 0.

	0101 0111	status	0101 0101
AND	0000 0010	= 2	0000 0010
	-----		-----
	0000 0000		0000 0010
	ready		not ready

Thus, the logical AND with the value of 2 in the status register gives a result of zero if bit 1 (the second bit) is 0. Otherwise, a nonzero result is obtained.

The third instruction in the looping example is a conditional jump. If the peripheral is not ready, the JZ instruction will cause the computer to loop repeatedly through the first three lines until the peripheral is ready for another byte. At this point, the write-ready bit, bit 1, will be a logical 1. Then the logical AND operation, the second instruction of the subroutine, produces the nonzero value of 2. The MOV instruction following the conditional jump will then be executed. The byte to be outputted is moved to the accumulator, and then sent to data port 11 hex by use of the OUT command.

When the byte to be output is actually sent to the data port, the write-ready flag is reset to a logical zero. The output routine may be immediately reentered for outputting another byte, but now the peripheral is not ready. Looping will occur again through the first three instructions of the output routine since the write-ready flag has been reset to zero.

The CPU clock may be operating at 2 or 4 MHz. This rate is thousands of times faster than the speed of a typical printer. Consequently, if the looping method is used, the CPU will be spending over 99 percent of its time simply looping through the first three lines of the output subroutine. The computer will be spinning its wheels, so to speak, waiting on the peripheral.

Because the CPU is operating so much faster than the peripherals, it can, in principle, service many peripherals simultaneously. A very simple but useful implementation of this idea is found on the CP/M* operating system. In the CP/M system,* console output is normally sent only to the console. This terminal is typically a high-speed video device. But if the user types a Control-P, then the list device is also turned on. Console output will now appear simultaneously at both the console and the line printer.

This technique can be easily observed if the console video accepts data much faster than the line printer. Normally, as data is sent only to the console, it appears rapidly on the video screen. But when the list device is turned on, the output appears much more slowly. The reason for the slow-down is that both peripherals are operating at the speed of the slower one, in this case the printer.

A subroutine for accomplishing such a dual output might look like this.

LOUT:	IN	LSTAT	#LIST STATUS
	ANI	2	#OUTPUT MASK
	JZ	LOUT	#LOOP UNTIL READY
	MOV	A,C	#GET THE BYTE
	OUT	LDATA	#SEND TO LIST
	OUT	CDATA	#AND CONSOLE
	RET		#DONE

*CP/M is a registered trademark of Digital Research, Inc., Pacific Grove, California.

This routine is not the one that is actually used in the CP/M system since, with our routine, the console will always display everything that is sent to the printer. This feature does not increase printing time as long as the console operates faster than the printer. Notice that there is no need to check the console status register. The output rate is set at the speed of the printer, and so the console, which operates so much faster, will always be ready if the printer is ready.

POLLING

One way to improve the performance, or throughput, of a CPU is with a technique known as polling. In this method, the CPU sends a byte to each of several different peripherals. Each peripheral operates at its full speed. Polling is more efficient than the looping method, and has been incorporated into several commercial 8080 software products. One product is a multiuser BASIC which can service up to four separate consoles. Each user can independently perform calculations using the same BASIC interpreter.

Another product that uses the polling technique is known as a *spooler*. The looping method is typically utilized for all output. In this case, all other activities must be halted while the printer is working. With a spooler program, however, things are different. When this program is incorporated into the system, the user can perform other tasks using the system console while a disk file is being printed.

In the polling method, the I/O routines are somewhat different from the corresponding routines of the looping method. The output-ready flag of the status register is checked periodically as with the looping method. But if the status flag indicates that the device is not ready, the CPU returns to perform some other task. Thus, the CPU does not waste time looping around the first three instructions of the input or output routine. A typical output routine using the polling method might look like this.

```
LOUT:  IN      LSTAT    ;CHECK STATUS
        ANI     LMASK    ;MASK FOR OUTPUT
        RZ
        MOV     A,C      ;GET THE BYTE
        OUT     LDATA    ;SEND IT
        RET
```

While the polling method is a great improvement over the looping method, there are still problems. For example, a decision must be made as to how often each status register will be polled. An even better method is to use hardware interrupts.

HARDWARE INTERRUPTS

The 8080 and Z-80 microprocessors incorporate a hardware interrupt system. This feature allows an external device, such as the system console or printer,

to interrupt the current task of the processor. When the CPU is interrupted, it suspends its current task, and calls on one of several memory locations set aside for this purpose. The CPU services the request of the interrupting peripheral, then it returns to its previous task.

In this method, the CPU does not have to be programmed to check the peripherals on a regular basis as with the method of polling; nor does it have to waste time in a loop. Instead, the peripheral interrupts the processor when it needs service. If several peripherals are able to interrupt the CPU, then there must be a method for prioritizing the requests. This ordering is accomplished through a vectored interrupt system. For example, if a lower-priority device has interrupted the CPU for service, this phase can also be interrupted by a peripheral with a higher priority. On the other hand, a device with a lower priority cannot interrupt a higher-priority service, but must wait its turn.

Usually, the highest-priority interrupt will be assigned to updating the system clock. If the computer misses a beat, then the time will be incorrect. The next lower priority could be assigned to disk transfer. The printer could have a low priority since it is a relatively slow device, and it won't matter if it must slow down every so often.

Suppose that the printer is operated by interrupts rather than by looping or polling. The computer sends a byte to the printer, then continues with another task. When the current byte has actually been printed, the printer interrupts the CPU for another byte. In the time between the printing of two bytes, the CPU can perform many other tasks.

The console keyboard is another peripheral that can be readily serviced by an interrupt system. In this case, each time the user presses a key, the CPU is interrupted from its current task. Of course, if the CPU is currently servicing a higher-priority interrupt, then the console keyboard request will have to wait.

Both the 8080 and the Z-80 allocate eight addresses that can be used for the interrupt service routines. These addresses can be called by the eight, one-byte RST instructions.

Z-80 mnemonic	8080 mnemonic	Instruction code		Call address
		hex	binary	
RST 00H	RST 0	C7	1100 0111	00H
RST 08H	RST 1	CF	1100 1111	08H
RST 10H	RST 2	D7	1101 0111	10H
RST 18H	RST 3	DF	1101 1111	18H
RST 20H	RST 4	E7	1110 0111	20H
RST 28H	RST 5	EF	1110 1111	28H
RST 30H	RST 6	F7	1111 0111	30H
RST 38H	RST 7	FF	1111 1111	38H

These instructions can be used as one-byte subroutine calls. As an example, suppose that the CPU executes an RST 5 instruction which corresponds to the instruction code EF hex. A subroutine call is then made to the corresponding address of 28 hex. The return address is pushed onto the stack,

just as for a regular subroutine call. Subsequent execution of a return instruction will cause the program flow to return to the instruction immediately following the RST 5 instruction.

Hardware interrupts operate by emulating the software RST call. When an interrupt occurs, the CPU automatically disables the interrupt flip-flop, thus further interrupts are prevented. Then a subroutine call is made to the corresponding call address. This is done by jamming the desired RST code onto the data bus. The simplest implementation is to use a single interrupting device and the RST 7 instruction. (A normal interrupt always performs an RST 7.) The interrupting peripheral momentarily changes the state of the interrupt-request bus line. For the S-100 bus, this would require that bus line 73 be pulled to a zero-voltage state from the usual 5-volt level. The CPU responds by automatically calling memory address 38 hex. The programmer will have previously placed the service routine at this location. The service routine will conclude with a command to re-enable the interrupt flip-flop. Then a return instruction will be executed.

The trouble with this simple approach is that the RST 7 call to location 38 hex interferes with system debuggers because they also use this address. Consequently, another interrupt level is more suitable. Unfortunately, a single interrupt system always calls the RST 7 location. One solution to this problem is to use a vectored interrupt board. A vectored interrupt board allows the user to select up to eight separate interrupt levels corresponding to the RST 0 to 7 instructions. The disadvantage of this approach is the cost, since a vectored interrupt board may sell for several hundred dollars.

However, there is a low-cost solution. If only one interrupt level is required, a single hardware interrupt can be converted from an RST 7 to some other level such as an RST 5 by using only two logic gates. The circuit shown in Figure 4.1 will make the needed translation. The output of the two-input NAND gate IC-1 goes low when both of the input lines are high. One of these inputs is SINTA, line 96 on the S-100 bus. It is a CPU status signal that indicates acknowledgment of the interrupt request. The other input is PDBIN, bus line 78. This signal indicates that the data bus is in the input mode.

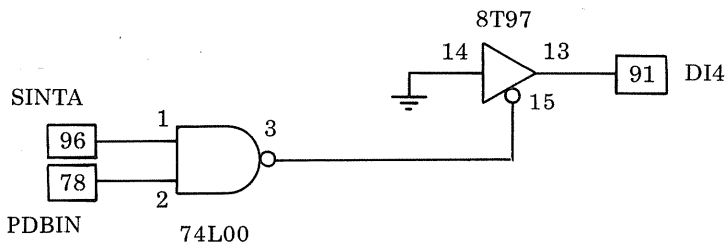


Figure 4.1. Circuit to convert an 8080 interrupt to an RST 5.

When the output of IC-1 goes low, it turns on the three-state buffer IC-2. This pulls the data-input bus line DI4 low. Since the remaining seven lines of the data-in bus are high, the CPU will see the value of

1110 1111

Notice that this is the bit pattern for the RST 5 instruction. The result is that the CPU executes an RST 5 instruction, by calling address 28 hex. The interrupt service routine, or a jump to it, is placed at this address.

AN INTERRUPT-DRIVEN KEYBOARD

We have seen that a printer operates considerably slower than a CPU. The console keyboard is even slower than the printer, especially if the operator is not an expert typist. Conversion to an interrupt-driven keyboard will considerably increase the effectiveness of a computer.

Characters entered on an interrupt-driven keyboard are temporarily stored in a memory buffer area. Each time a key is pressed on the console, the CPU is interrupted from its current task. The new byte is read and placed into the keyboard buffer. The computer then returns to its prior task. When the computer needs console input, it gets it from the input buffer, rather than from the console itself.

An interface program, utilizing a keyboard-interrupt approach, is shown in Listing 4.1. This program provides the necessary routines for interfacing the Lifeboat version of CP/M to a North Star disk system.* The portions of the program which specifically utilize the interrupt routines begin with a row of asterisks and end with a row of semicolons.

Computer pointer F400	Computer count F402	Keyboard count F403	Keyboard pointer F404	Buffer F406
-----------------------------	---------------------------	---------------------------	-----------------------------	----------------

Figure 4.2. The input buffer and pointers.

The layout of the memory buffer with its pointers is shown in Figure 4.2. The buffer area is arbitrarily chosen to start at the address of F400 hex. The location can be anywhere above the CP/M operating system. There is only one keyboard buffer, but there are two sets of pointers: one for the CPU and one for the keyboard. Two counters are also utilized; one shows how many characters have been entered from the keyboard and the other shows how many have been read by the computer. Since both sets of pointers grow larger, they need to be reset periodically. The two pointers are compared after each carriage return. If they are the same, then they are both reset to the beginning of the buffer.

Suppose that this interface program is incorporated into your system. CP/M might be printing something on the console video screen when a key on the console is pressed. A hardware interrupt will occur, causing the computer to stop its task and call address 28 hex (RST 5). A jump instruction at address 28 hex will transfer control to subroutine KEYBD. The keyboard

*Lifeboat Associates, 2248 Broadway, New York, N.Y. 10024.

Listing 4.1. Interrupt driven keyboard.

```

                                TITLE  'Interrupt CP/M BIOS'
                                ;
                                ; (Put today's date here)
                                ;
                                ; LIFEBOAT VERSION WITH OPTION FOR
                                ; EITHER SINGLE OR DOUBLE DENSITY
                                ;
                                ; TERMINAL DEVICES SUPPORTED:
                                ;
                                ;  CONSOLE      10 HEX  CON:
                                ;  LIST-       12 HEX  LST:
                                ;  PHONE MODEM  14 HEX  FUN:
                                ;
0000 = FALSE EQU 0
FFFF = TRUE EQU NOT FALSE
                                ;
FFFF = DOUBLE EQU TRUE ;DOUBLE DENSITY
FFFF = INTRM EQU TRUE ;INTERR VERSION
                                ;
                                IF DOUBLE
0036 = MSIZE EQU 54 ;DECIMAL K
D600 = BIOS EQU MSIZE*1024-200H
DB00 = USER EQU BIOS+500H
4900 = OFFSET EQU 1FOOH-BIOS
                                ELSE
                                MSIZE EQU 56
                                USER EQU MSIZE*1024-700H
                                ENDIF
0003 = IOBYTE EQU 3 ;I/O SETUP
000D = CR EQU 0DH ;CARRIAGE RET
000A = LF EQU 0AH ;LINEFEED
000C = FFEED EQU 12 ;FORMFEED
0003 = CTRC EQU 3 ;^C, KILL SCROLL
0004 = CTRD EQU 4 ;^D, EMPTY BUFFER
0011 = CTRQ EQU 17 ;^Q, SCROLL
0013 = CTRS EQU 19 ;^S, FREEZE SCROLL
                                ;
                                IF DOUBLE
                                ; PATCH DATE
D5B1 ORG BIOS-100H+0B1H
                                ELSE
D5B1 ORG USER-600H+0AFH
                                ENDIF
D5B1 2E4465 DB '.Jan 28,80' ;PATCH DATE
                                ;
DB00 ORG USER
                                ;
0010 = CSTAT EQU 10H ;CONSOLE STATUS
0011 = CDATA EQU CSTAT+1 ;CONSOLE DATA
0001 = CIMSK EQU 1 ;INPUT MASK
0002 = COMSK EQU 2 ;OUTPUT MASK
0012 = LSTAT EQU 12H ;LIST STATUS
0013 = LDATA EQU LSTAT+1 ;LIST DATA
0001 = LIMSK EQU 1 ;INPUT MASK
0002 = LOMSK EQU 2 ;OUTPUT MASK
0000 = LNULL EQU 0 ;LIST NULLS

```

```

0014 = MSTAT EQU 14H ;MODEM STATUS
0015 = MDATA EQU MSTAT+1 ;MODEM DATA
0040 = MIMSK EQU 40H ;INPUT MASK
0080 = MOMSK EQU 80H ;OUTPUT MASK
;
; INITIALIZE PORTS FOR COMPUTIME BOARD
;
00C4 = ADATA EQU 0C4H
00C5 = ACONT EQU ADATA+1
00C6 = BDATA EQU ADATA+2
00C7 = BCONT EQU ADATA+3
;
;*****
; IF INTRM ;INTERRUPTS
0095 = STOP EQU 95H ;SET FOR INTERR
;
; CONSOLE INPUT-BUFFER LOCATION
;
F400 = BUFFER EQU 0F400H ;INPUT BUFFER
F400 = CPNTR EQU BUFFER ;COMPUTER POINTER
F402 = CCNT EQU CPNTR+2 ;BUFFER COUNT
F403 = KCNT EQU CCNT+1 ;KEYBRD BUFF COUNT
F404 = KPNTR EQU KCNT+1 ;KEYBOARD POINTER
F406 = BUFF EQU KPNTR+2 ;INPUT BUFFER
0005 = LEV EQU 5 ;INTERR LEVEL
; ENDIF ;INTERRUPTS
;*****
;
START:
DB00 C315DB JMP INIT ;INITIALIZATION
DB03 C3ABDB JMP CONST ;CONSOLE STATUS
DB06 C3D3DB JMP CONIN ;CONSOLE INPUT
DB09 C312DC JMP CONOUT ;CONSOLE OUTPUT
DB0C C326DC JMP LOUT ;LIST OUTPUT
DB0F C348DC JMP PUNCH
DB12 C3D3DB JMP CONIN ;FOR READER
;
; INITIALIZATION ROUTINES
;
DB15 3E03 INIT: MVI A,3
DB17 D310 OUT CSTAT ;RESET
DB19 D312 OUT LSTAT ;INTERFACE
DB1B 3E15 MVI A,15H
DB1D D312 OUT LSTAT
;
; IF INTRM
DB1F 3E95 MVI A,STOP ;SET FOR INTERR.
; ENDIF
;
DB21 D310 OUT CSTAT ;INTERFACE
;
; COMPUTIME BOARD INITIALIZATION
;
DB23 AF XRA A ;GET A ZERO
DB24 D3C5 OUT ACONT
DB26 D3C7 OUT BCONT
DB28 3E70 MVI A,70H
DB2A D3C4 OUT ADATA

```

```

DB2C 3E77          MVI      A,77H
DB2E D3C6          OUT      BDATA
DB30 3E14          MVI      A,14H
DB32 D3C5          OUT      ACONT
DB34 3E04          MVI      A,4
DB36 D3C7          OUT      BCONT
; *****
; IF INTRM
;
; PATCH RST LOCATION TO JUMP TO KEYBD
;
DB38 F3            DI        ;DISABLE INTERRUPT
DB39 3EC3          MVI      A,0C3H ;JMP INSTR
DB3B 322800        STA      B*LEV ;PATCH RST
DB3E E5            PUSH     H
DB3F 215BDB        LXI      H,KEYBD ;INTERR ENTRY
DB42 222900        SHLD     B*LEV+1 ;JUMP HERE
DB45 2106F4        LXI      H,BUFF ;BUFFER ADDR
DB48 2204F4        SHLD     KPNTN ;RESET POINTERS
DB4B 2200F4        SHLD     CPNTN
DB4E 210000        LXI      H,0 ;2 ZEROS
DB51 2202F4        SHLD     CCNT ;ZERO THE COUNTS
DB54 E1            POP      H
DB55 FB            EI        ;RE-ENABLE INTERRUPT
; *****
; ENDIF INTERRUPTS
;
; INITIALIZE IOBYTE
;
DB56 AF            XRA      A ;RESET IOBYTE
DB57 320300        STA      IOBYTE
DB5A C9            RET
; *****
; IF INTRM
;
; INTERRUPT ENTRY FOR KEYBOARD INPUT
;
KEYBD: PUSH     PSW
DB5C DB10          IN       CSTAT ;CONSOLE STATUS
DB5E E601          ANI      CIMSK
DB60 CA92DB        JZ       KEY2 ;NOT READY
DB63 DB11          IN       CDATA ;GET DATA
DB65 E67F          ANI      7FH ;MASK PARITY
;
; CHECK FOR ^S, ^Q SCROLL CONTROL
;
DB67 FE13          CPI      CTRS ;^S
DB69 C27FDB        JNZ      KEY3 ;NO
DB6C DB10          IN       CSTAT ;CHECK KEYBOARD
DB6E E601          ANI      CIMSK ;READY?
DB70 CA6CDB        JZ       KEY4 ;LOOP UNTIL READY
DB73 DB11          IN       CDATA ;GET BYTE
DB75 E67F          ANI      7FH ;STRIP PARITY
DB77 FE11          CPI      CTRQ ;^Q?
DB79 C26CDB        JNZ      KEY4 ;NO
DB7C C392DB        JMP      KEY2
;

```



```

DBC6 AF          XRA      A           ;GET ZERO
DBC7 C9          RET

;
;
ELSE            ;NOT INTERRUPTS
IN              CSTAT   ;GET STATUS
ANI             CIMSK
RZ              ;NOT READY
ENDIF           ;INTERRUPTS

;
QUIT:           MVI      A,TRUE
BCA C9          RET               ;INPUT READY

;
; LIST READY FOR CONSOLE
;
LISST: IN        LSTAT
BCD E601         ANI       LIMSK
BCF C8           RZ         ;NOT READY
BBD 3EFF         MVI      A,TRUE
BBD2 C9          RET           ;READY

;
; CONSOLE INPUT
;
CONIN: LDA       IOBYTE
BD6 E602         ANI       2
BDB C206DC       JNZ      LIN    ;LIST INPUT

;
*****
IF              INTRM   ;INTERRUPTS

;
; GET INPUT FROM KEYBOARD BUFFER
; INSTEAD OF FROM CONSOLE
;
;
BDB E5           PUSH     H
BDC 2A02F4       CIN3:    LHLD CCNT   ;BOTH COUNTS
BDF 7C           MOV      A,H
BE0 95           SUB      L          ;SAME?
BE1 CADCD8       JZ       CIN3      ;KEEP TRYING
BE4 F3           DI        ;HOLD OFF
BE5 2102F4       LXI      H,CCNT    ;COMPUTER COUNT
BE8 34           INR       M         ;INCREMENT IT
BE9 2A00F4       LHLD     CPNTR     ;COMPUTER PNTR
BEC 7E           MOV      A,M       ;GET BYTE

;
; RESET BOTH POINTERS IF CARR RET FOUND
;
BED 23           INX       H         ;BUMP POINTER
BEE 2200F4       SHLD     CPNTR     ;SAVE IT
BF1 FE0D         CPI       CR       ;CARRIAGE RET?
BF3 C203DC       JNZ      CIN4      ;NO
BF6 2A02F4       LHLD     CCNT     ;GET BOTH COUNTS
BF9 7C           MOV      A,H
BFA 95           SUB      L         ;DIFFERENCE
BFB C201DC       JNZ      CIN5      ;NOT SAME

;
; RESET BOTH POINTERS TO ZERO

```



```

DBFE CD9BDB      CALL      RSETP
DC01 3E0D      CIN5:  MVI      A,CR      ;RESTORE CR
DC03 E1        CIN4:  POP       H
DC04 FB        EI          ;READY FOR MORE
DC05 C9        RET
                ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
                ELSE          ;NO INTERRUPTS
;
CIN2:  IN       CSTAT      ;CHECK STATUS
      ANI      CIMSK
      JZ       CIN2
      IN       CDATA      ;GET DATA
      ANI      7FH        ;MASK PARITY
      RET
      ENDIF          ;INTRM
;
; CONSOLE INPUT FROM LIST
;
DC06 DB12      LIN:  IN       LSTAT
DC08 E601      ANI      LIMSK
DC0A CA06DC    JZ       LIN
DC0D DB13      IN       LDATA
DC0F E67F      ANI      7FH
DC11 C9        RET
;
; CONSOLE OUTPUT
;
DC12 3A0300    CONOUT: LDA      IOBYTE  ;WHERE?
DC15 E603      ANI      3
DC17 B7        ORA      A
DC18 E22EDC    JPO      LIST
;
DC1B DB10      CONW:  IN       CSTAT      ;CHECK STATUS
DC1D E602      ANI      COMSK
DC1F CA1BDC    JZ       CONW
DC22 79        MOV      A,C          ;GET BYTE
DC23 D311      OUT      CDATA      ;SEND IT
DC25 C9        RET
;
; LIST OUTPUT
;
DC26 3A0300    LOUT:  LDA      IOBYTE
DC29 E640      ANI      40H          ;BIT 6
DC2B C21BDC    JNZ      CONW        ;CONSOLE OUT
;
DC2E DB12      LIST:  IN       LSTAT      ;CHECK STATUS
DC30 E602      ANI      LOMSK
DC32 CA2EDC    JZ       LIST
DC35 79        MOV      A,C          ;GET BYTE
DC36 D313      OUT      LDATA      ;SEND IT
;
      IF      LNULL > 0
;
; NULLS FOR LIST DEVICE
;

```

```

                                ANI      7FH
                                CPI      CR
                                JNZ      FORM
                                MVI      C,0
                                CALL     LIST      ;1 NULL
                                CALL     LIST      ;2 NULLS
                                CALL     LIST      ;3 NULLS
                                JMP      LIST      ;4 NULLS
                                ENDIF

                                ;
                                ; FORM: CPI FFEED ;FORMFEED?
                                ; RNZ ;NO
                                ;
                                ; EMULATE FORMFEED WITH 9 LINES
                                ;
                                DC3B C5          PUSH      B
                                DC3C 010A09      LXI      B,900H+LF
                                DC3F CD2EDC      LSKIP: CALL     LIST
                                DC42 05          DCR      B
                                DC43 C23FDC      JNZ      LSKIP
                                DC46 C1          POP      B
                                DC47 C9          RET

                                ;
                                ; PUNCH OUTPUT SENT TO MODEM
                                ;
                                DC48 79          PUNCH: MOV      A,C      ;GET BYTE
                                DC49 E67F        ANI      7FH
                                DC4B B7          ORA      A      ;NULL?
                                DC4C C8          RZ          ;DON'T SEND
                                DC4D FE0A        CPI      LF
                                DC4F C8          RZ          ;SKIP LINEFEED
                                DC50 CD69DC      CALL     MOUT      ;SEND
                                DC53 FE0D        CPI      CR
                                DC55 CA5EDC      JZ       MODCR      ;WAIT FOR CR
                                DC58 CD74DC      CALL     MIN      ;MODEM INPUT
                                DC5B D311        OUT      CDATA      ;SEND TO CONSOLE
                                DC5D C9          RET

                                ;
                                ; SEND <CR> TO MODEM, WAIT FOR ONE BACK
                                ;
                                DC5E CD74DC      MODCR: CALL     MIN
                                DC61 D311        OUT      CDATA      ;TO CONSOLE
                                DC63 FE0D        CPI      CR
                                DC65 C25EDC      JNZ      MODCR      ;KEEP TRYING
                                DC68 C9          RET

                                ;
                                ; MODEM OUTPUT
                                ;
                                DC69 DB14        MOUT: IN       MSTAT      ;CHECK STATUS
                                DC6B E680        ANI      MOMSK
                                DC6D CA69DC      JZ       MOUT
                                DC70 79          MOV      A,C      ;GET BYTE
                                DC71 D315        OUT      MDATA      ;SEND IT
                                DC73 C9          RET

                                ;
                                ; MODEM INPUT
                                ;

```

```

DC74 DB14      MIN:    IN      MSTAT    ;CHECK STATUS
DC76 E640                      ANI      MIMSK
DC78 CA74DC                      JZ      MIN
DC7B DB15                      IN      MDATA    ;GET BYTE
DC7D E67F                      ANI      7FH      ;MASK PARITY
DC7F C9                      RET

          ;
DC80 31322D                      DB      '1-28-80' ;VERSION
          ;
DC88                      END

```

symbol table

00C5 ACONT	00C4 ADATA	00C7 BCONT	00C6 BDATA
D400 BIOS	F400 BUFFER	F406 BUFF	F402 CCNT
0011 CDATA	0001 CIMSK	DBDC CIN3	DC03 CIN4
DC01 CIN5	0002 COMSK	DBD3 CONIN	DC12 CONOUT
DBAB CONST	DC1B CONW	F400 CPNTR	000B CR
0010 CSTAT	0003 CTRC	0004 CTRD	0011 CTRQ
0013 CTRS	FFFF DOUBLE	0000 FALSE	000C FFEED
DC38 FORM	DB15 INIT	FFFF INTRM	0003 IOBYTE
F403 KCNT	DB92 KEY2	DB7F KEY3	DB6C KEY4
DB91 KEY5	DB95 KEY6	DB5B KEYBD	F404 KPNTR
0013 LDATA	0005 LEV	000A LF	0001 LIMSK
DC06 LIN	DBC8 LISST	DC2E LIST	0000 LNULL
0002 LOMSK	DC26 LOUT	DC3F LSKIP	0012 LSTAT
0015 MDATA	0040 MIMSK	DC74 MIN	DC5E MODCR
0080 MOMSK	DC69 MOUT	0036 MSIZE	0014 MSTAT
4900 OFFSET	DC48 PUNCH	DBC8 QUIT	DB9B RSETP
DB00 START	0095 STOP	FFFF TRUE	DB00 USER

entry is read with an IN instruction. The byte is then placed into the keyboard buffer and the buffer pointer and buffer count are both incremented. The interrupt flip-flop is enabled with an EI instruction, then the computer returns to its previous task.

When the CPU needs another byte, it gets it from the keyboard buffer in memory, rather than from the keyboard itself. The instructions starting at subroutine CONIN perform this step. The separate buffer pointer and buffer count, maintained for the CPU, are both incremented.

The interrupt-driven keyboard can be utilized with most of the CP/M systems programs. For example, if a BASIC interpreter has been loaded and a source program has been entered, then the source program can first be listed, then executed by typing the following two lines.

```

LIST
RUN

```

The second command can be given immediately following the first, even though the first task has not been completed. The second command will not be displayed on the console, however, until the completion of the first task. Therefore, the operator must type carefully.

SCROLL CONTROL AND TASK ABORTION

Data can appear (scroll) too rapidly on a high-speed video screen. With the usual CP/M arrangement, the user can type a Control-S to freeze the video display. Typing any other character will cause scrolling to resume. The interrupt-driven routine given in Listing 4.1 incorporates its own scroll control. Typing a Control-S freezes the screen, just as with the usual CP/M setup. However, scrolling can only be resumed by typing a Control-Q. The two commands, Control-S and Control-Q, are treated distinctly; they are not placed into the input buffer, but are acted upon immediately.

CP/M tasks are normally aborted by typing any keyboard character. On the other hand, a Control-C is required in Microsoft BASIC, and a Control-E is used by Xitan BASIC for aborting the current task. This protocol has been altered so that characters can be entered into the keyboard buffer during a scroll operation. Nevertheless, it may be desirable to abort a task.

If no characters have been typed ahead, that is, if the computer is executing the latest command, then a Control-C command will abort the current operation. Alternatively, if there are characters waiting in the console-input buffer, then these must be flushed out by typing a Control-D. At this point, a Control-C can be typed to abort the task. This arrangement will work with most programs, including Microsoft BASIC and Tarbell BASIC. If you use Xitan BASIC, then you must change the abort command character in the interface routine from a Control-C to a Control-E.

An additional alteration is necessary for the Word-Master text editor. First of all, Word-Master buffers the keyboard buffer using software routines. Consequently, a hardware-interrupt system is unnecessary. Secondly, Word-Master uses Control-C and Control-D for system commands. Control-C is used to display the next screen and Control-D is used to move the cursor to the next word. If you want to use hardware interrupts with Word-Master, you must change the Control-C and Control-D commands in either the interface routine or in Word-Master.

DATA TRANSMISSION BY TELEPHONE

The process of transmitting information between a peripheral and the computer may be simple or it may be complex. If the system console is wired into the computer, or if the computer itself is built into the console, then the integrity of the transmitted data is not likely to be much of a problem. It may be, however, that the console is connected to the computer through a telephone line. The computer may be located across town or across the country. In any case, connection through a telephone line complicates things.

In a typical telephone arrangement, the data is sent from the console by modulating an acoustical carrier for transmission over the telephone line. The conversion is performed by an electronic device called a *modem* (the name is an abbreviation for MODulator-DEModulator). Two modems are required, one at each end of the telephone line. One converts the transmitted

signal to telephone frequencies, the other converts the signal back to the original data.

The modem may also have an *acoustical coupler*. This allows a standard telephone headset to be pressed into two rubber-lined openings in the modem, making a direct connection between the modem and the telephone line unnecessary.

There will usually be two data carrier signals at different frequencies. This allows simultaneous two-way, or *full duplex*, operation. The computer can transmit data to the console on one carrier while the console is transmitting data to the computer on the other carrier.

A microcomputer can produce a more effective link between a console and a large main-frame computer, especially if a relatively slow modem is utilized. A program can be developed using the microcomputer's editor, then the resulting file can be automatically transmitted to the larger computer. A subroutine that can be used to link a microcomputer to a large computer is given in Listing 4.2. This routine can be readily incorporated into the system monitor introduced in Chapter 6.

Listing 4.2 Connection to a large computer

```

;
; CONNECT TO ANOTHER COMPUTER
; THROUGH PHONE MODEM
; (Z-80 CODE)
;
0014      DSTAT   EQU      14H      ;STATUS
0015      DDATA   EQU      DSTAT+1
0040      DIMSK   EQU      40H      ;INPUT MASK
0080      DOMSK   EQU      80H      ;OUT MASK
;
0004      CTRD    EQU      4        ;^D, COPY
57A1      TYFLG   EQU      STACK+1 ;COPY FLAG
;
5BB3 AF      DEC:   XOR      A        ;ZERO
5BB4 32 57A1   LD      (TYFLG),A ;RESET COPY
5BB7 DB 14     DECIN:  IN      A,(DSTAT) ;READY?
5BB9 E6 40     AND     DIMSK
5BBB 28 13     JR      Z,ALTIN ;NO
5BBD 3A 57A1   LD      A,(TYFLG) ;COPY FLAG
5BC0 B7       OR      A        ;TO MEMORY?
5BC1 28 07     JR      Z,DIN5  ;NO
5BC3 CD 5BF1   CALL    DINPUT  ;GET BYTE
5BC6 77       LD      (HL),A    ;TO MEMORY
5BC7 23       INC     HL        ;POINTER
5BC8 18 03     JR      DEC2
;
5BCA CD 5BF1   DIN5:   CALL    DINPUT  ;GET BYTE
5BCD CD 5835   DEC2:   CALL    OUTT    ;TO CONSOLE
5BD0 CD 5827   ALTIN:  CALL    INSTAT  ;CONSOLE
5BD3 28 E2     JR      Z,DECIN  ;NOT READY
5BD5 CD 581A   CALL    INPUT2  ;CONSOLE
5BD8 FE 04     ALT2:   CP      CTRD   ;^D
5BDA 28 1A     JR      Z,DCOPY  ;SET FLAG

```

```

5BDC CD 5BE1    ALT5:  CALL    DECOU  ;TO DEC
5BDF 18 D6      JR      DECIN  ;DEC INPUT
;
; OUTPUT A BYTE TO DEC
;
5BE1 F5        DECOU:  PUSH    AF
5BE2 CD 5BEA    CALL    DORDY
5BE5 F1        POP      AF
5BE6 D3 15     OUT      (DDATA),A
5BE8 18 CD     JR      DECIN  ;NEXT
;
; DEC INPUT READY
;
5BEA DB 14     DORDY:  IN      A,(DSTAT)
5BEC E6 80     AND      DOMSK
5BEE 28 F1     JR      Z,DECOU
5BF0 C9       RET
;
; INPUT FROM DEC MODEM
;
5BF1 DB 15     DINPUT: IN      A,(DDATA)
5BF3 E6 7F     AND      DEL     ;MASK PARITY
5BF5 C9       RET
;
; SET DEC COPY FLAG. START COPYING
; INTO MEMORY AT 100 HEX
;
5BF6 21 0100   DCOPY:  LD      HL,100H
5BF9 3E 01     LD      A,1
5BFB 32 57A1    LD      (TYFLG),A
5BFE 18 B7     JR      DECIN
;
;
;
END          START

```

PARITY CHECKING

Parity checking provides a method of monitoring the integrity of data transmission. While there are several different schemes for digitally encoding the common characters, the ASCII method is frequently used for microcomputers. The ASCII code, shown in Appendix A, requires only seven bits for each character. Since each byte of data contains eight bits, there is one bit available for use as a check bit.

Consider the 7-bit pattern for the ASCII characters 2 and 3.

```

ASCII 2    011 0010
ASCII 3    011 0011

```

The value of 2 is encoded with four logical zero bits and three logical 1 bits. The value of 3 is encoded with three logical zero bits and four logical 1 bits. A parity check can be obtained by including an additional bit on the left (high-order) end.

There are two common methods of generating the parity bit. One encoding method is called *even parity*. In this case, a leading zero bit is added if there are an even number of logical ones among the other seven bits. On the other hand, the parity bit would be a logical 1 if there are an odd number of logical ones among the other seven bits. With even parity coding, the ASCII characters 2 and 3 would look like this.

```

2   1011 0010
3   0011 0011

```

Now the 8-bit representation of both the 2 and the 3 contains an even number of logical ones (and an even number of logical zeros).

An alternate approach is called *odd parity*. In this case, the operation is simply the inverse of even parity. The logic of the parity bit is chosen so that the resulting bit pattern contains an odd number of logical ones. Either even or odd parity encoding will provide a check on the integrity of the data transmission.

Suppose that during transmission of the character 2, the rightmost bit became inverted. The console sent the even-parity bit pattern

```
1011 0010
```

but the computer received the bit pattern

```
1011 0011
```

A parity check, performed at the computer, would be able to detect the fact that there was an error.

A typical console-input routine might look like this.

```

CONIN:  IN      CMASK    ;CHECK STATUS
        ANI     CIMSK    ;MASK FOR INPUT
        JZ      CONIN    ;LOOP UNTIL READY
        IN      CDATA    ;GET THE DATA
        ANI     7FH      ;REMOVE PARITY
        RET

```

The next to the last instruction in this subroutine performs a logical AND with 7F hex. This step is used to remove the high-order bit of the byte since it is not needed for ASCII data. Instead of ignoring this eighth bit, we could use it as a parity check. An input routine to perform a check for parity looks like the following list.


```
CONIN:  IN      CMASK  ;CHECK STATUS
        ANI     CIMSK  ;MASK FOR INPUT
        JZ      CONIN  ;LOOP UNTIL READY
        IN      CDATA  ;GET THE DATA
        ORA     A      ;SET PARITY FLAG
        JPO     PERROR ;PARITY ERROR
        ANI     7FH    ;REMOVE PARITY
        RET

;
; PARITY-ERROR MESSAGE
;
PERROR: . . .
```

This routine is essentially the same as the one given immediately before, but after the data register has been read by the computer, the parity of the byte is determined.

The ORA A instruction performs a logical OR of the accumulator with itself. A logical OR of any byte with itself will not change the byte. However, it does affect the status flags in this case. After the OR operation, the parity flag will be set according to the parity of the accumulator. If the parity is found to be odd, then an error is present. The JPO instruction causes a jump to the parity-error routine in this case. However, if the parity is found to be even, then the byte in the accumulator does not contain a parity error.

Notice that a parity check will not detect an even number of bit errors in a byte. There may be two, four, or six errors, and the parity check will not detect an error. This is not likely to be a practical problem, however, since the likelihood of two errors is much less than the likelihood of single errors.

ASCII computer terminals usually have the ability to automatically transmit an eighth parity bit with the data. Furthermore, there will typically be a user-selectable switch for choosing either even or odd parity. There may also be the additional choices of always resetting or always setting the parity bit. The input routine can check for odd parity if the JPO instruction is changed to a JPE instruction.

There are much more sophisticated methods of checking for transmission errors. One of these is the checksum approach discussed in Chapter 9. With this method, the transmitted data are added together. At regular intervals, the sum, or its complement, is transmitted along with the data. When the data are decoded, the data are added up again and compared to the checksum.

The Hamming error-correction code is even better than the checksum method. It not only detects errors, but can also correct them. In the end, however, it is wise to find out why errors occur, and to take the appropriate action to correct the problem. A dirty tape head, for example, can produce errors. Cleaning the head is better than relying on an error-correction scheme.

CHAPTER FIVE

Macros

Sophisticated assemblers incorporate a macro processor. A macro is used to define a set of instructions which are associated with the macro name. Then whenever the macro name appears in the source program, the assembler substitutes the corresponding instructions. This is called a *macro expansion*.

Suppose that we want to interchange the contents of two memory locations with the following instructions.

```
LDA    FIRST    #GET FIRST BYTE
PUSH   PSW      #SAVE
LDA    SECOND   #GET SECOND
STA    FIRST    #PUT INTO FIRST
POP    PSW      #GET FIRST
STA    SECOND   #PUT INTO SECOND
```

This set of instructions can be defined in a macro called SWAP.

```
SWAP    MACRO          #SWAP FIRST AND SECOND
        LDA    FIRST   #GET FIRST BYTE
        PUSH   PSW     #SAVE
        LDA    SECOND  #GET SECOND
        STA    FIRST   #PUT INTO FIRST
        POP    PSW     #GET FIRST
        STA    SECOND  #PUT INTO SECOND
        ENDM
```

The macro definition is placed near the top of the assembler source program. The first line defines the macro name; the last line terminates the definition. The name SWAP can now be used like an operation code. It is placed in the source program whenever the corresponding instructions are needed. When the assembler encounters the name SWAP, it substitutes the desired

instructions. The final binary code generated by the assembler is the same as it would be if the instructions had originally been entered into the source program.

Each time the macro name SWAP appears in the source program, the same set of instructions will be generated and the same two memory locations will be interchanged. The SWAP macro becomes more versatile if the memory locations can be changed. If the names of the memory locations are placed on the first line of the macro definition, they become dummy variables.

```
SWAP    MACRO    FIRST, SECOND
        LDA      FIRST    ;GET 1ST BYTE
        PUSH     PSW      ;SAVE
        LDA      SECOND   ;GET 2ND
        STA      FIRST    ;PUT INTO 1ST
        POP      PSW      ;GET 1ST
        STA      SECOND   ;PUT INTO 2ND
        ENDM
```

The actual parameters in the macro call are substituted for the dummy parameters at assembly time. The macro call

```
SWAP    HIGH, LOW
```

generates the assembly language instructions

```
LDA      HIGH    ;GET 1ST BYTE
PUSH     PSW      ;SAVE
LDA      LOW     ;GET 2ND
STA      HIGH    ;PUT INTO 1ST
POP      PSW      ;GET 1ST
STA      LOW     ;PUT INTO 2ND
```

The statement

```
SWAP    LEFT, RIGHT
```

will produce the instructions

```
LDA      LEFT    ;GET 1ST BYTE
PUSH     PSW      ;SAVE
LDA      RIGHT   ;GET 2ND
STA      LEFT    ;PUT INTO 1ST
POP      PSW      ;GET 1ST
STA      RIGHT   ;PUT INTO 2ND
```

The structure of macros can be much more complicated than the above examples. One macro can be nested inside another.

```

OUTER  MACRO
      . . .
      IF FAST
INNER  MACRO
      . . .
      ENDM                ;;INNER
      ENDF                ;;FAST
      ENDM                ;;OUTER

```

Conditional assembly directives can be used to create different versions. Comments in the macro definition which begin with a single semicolon are reproduced in the macro expansion along with the op codes. But if the comments are preceded by two consecutive semicolons, then they will appear only in the macro definition, not in the macro expansion.

GENERATING THREE OUTPUT ROUTINES WITH ONE MACRO

A subroutine can be used whenever a set of instructions is needed at several places in a program. But there are times when a similar but different group of instructions is needed. A subroutine cannot be used in this case. Consider the three 8080 output routines that follow. The first sends a byte to the console, the second sends a byte to the list device, and the third sends a byte to the phone modem.

```

COT:   IN      CSTAT
      ANI     COMSK
      JZ      COT
      MOV     A,C
      OUT     CDATA
      RET

;
LOT:   IN      LSTAT
      ANI     LOMSK
      JZ      LOT
      MOV     A,C
      OUT     LDATA
      RET

;
MOT:   IN      MSTAT
      ANI     MOMSK
      JNZ     MOT
      MOV     A,C
      OUT     MDATA
      RET

```

The structure of these three routines is very similar. Each begins by reading the appropriate status register. Then a logical AND is performed to select the output-ready bit. Looping occurs until the peripheral is ready. The byte is moved from the C register into the accumulator and sent to the appropriate peripheral. Finally, a return instruction is executed.

These three routines are slightly different, hence they cannot be replaced by a single subroutine. However, since they have similar structure they can be generated with a macro. The macro definition looks like this.

```
OUTPUT MACRO ?S,?Z    #OUTPUT ROUTINES
?S&OT: IN    ?S&STAT  #CHECK STATUS
      ANI    ?S&OMSK  #MASK FOR OUTPUT
      J?Z    ?S&OT    #NOT READY
      MOV    A,C      #GET BYTE
      OUT    ?S&DATA  #SEND IT
      RET
      ENDM
```

It would appear near the beginning of the source program. The macro name chosen is OUTPUT and the two dummy arguments are ?S and ?Z. Dummy arguments can have the same form as any other identifier. A question mark was chosen as the first character so that the dummy arguments would be easier to find in the macro definition. You must be careful not to use register names such as A, B, H, or L for dummy arguments if these register names also appear in the macro.

Each of the three output routines is generated by a one-line macro call.

```
      OUTPUT C,Z      #CONSOLE OUTPUT
#
      OUTPUT L,Z      #LIST OUTPUT
#
      OUTPUT M,NZ     #MODEM OUTPUT
```

Each line includes the appropriate parameters. At assembly time, the real arguments replace the dummy arguments of the macro. The ampersand character (&) is a concatenation operator. It separates a dummy argument from additional text. The macro processor substitutes the real parameter for the dummy argument, then joins it to the rest of the text. By this means the expression ?S&OT becomes LOT if the real argument is the letter L.

Macro assemblers may give the user three options for the assembly listing:

1. Show the macro call, the generated source line, and the resultant hex code.
2. Show the macro call and the hex code.
3. Show only the macro call.

If option 1 is chosen, then the above three macro calls to OUTPUT will produce the following.

necessary. Consider, for example, the Z-80 instruction that performs a two's complement on the accumulator. The Zilog mnemonic for this operation is NEG. A Z-80 assembler converts this mnemonic into the two hex bytes ED 44. With an 8080 macro assembler you can use the same mnemonic. Define the macro

```
NEG      MACRO    ; TWO'S COMPLEMENT
          DB      0EDH, 44H
          ENDM
```

Then, the macro call

```
NEG
```

is placed in the source program when the Z-80 NEG instruction is needed. The 8080 macro assembler will insert the desired hex bytes ED 44 at this point.

As another example, consider the Z-80 relative-jump instruction. This instruction can be implemented with a macro that uses the assembler's program counter, a dollar sign. The macro definition looks like this.

```
JR      ADDR      ;RELATIVE JUMP
          DB      18H, ADDR-$-1
          ENDM
```

The dummy parameter ADDR is the destination address of the jump. The macro call

```
JR      ERROR
```

will generate the correct Z-80 code. The first byte will be 18 hex. The second byte will be the required displacement for the jump.

The Z-80 instruction, DJNZ, can be generated in a similar way. This instruction decrements the B register and jumps relative to the address of the argument if the zero flag is not set. The macro definition is

```
DJNZ    MACRO    ADDR
          DB      10H, ADDR-$-1
          ENDM
```

and the macro call looks like

```
DJNZ    LOOP
```

This approach will work with most macro assemblers. There may be a problem, however, with the interpretation of the dollar sign. This symbol usually refers to the address of the beginning of the current instruction. But for some assemblers, it is interpreted as the address of the following instruction.

If your assembler uses the latter interpretation, you will have to change the macro accordingly. If in doubt, check the user manual.

Some Z-80 mnemonics are not compatible with the macro format. For example, the Z-80 instruction

```
PUSH    IX
```

cannot be generated with a macro called

```
PUSH    MACRO    REG
```

since PUSH is a regular 8080 mnemonic. One possibility is to name the macro PUSHIX instead.

```
PUSHIX  MACRO
        DB      0DDH,0E5H
        ENDM
```

Similar problems occur with the commands POP IX, ADD IX,BC, SUB (IX+dis), and SET. A format that is different from the Z-80 mnemonic must be chosen in each of these cases.

The Digital Research macro assembler has an added bonus. Frequently-used macros can be placed into a separate macro library and given the file extension of LIB. In fact, this assembler is supplied with a macro library called Z80.LIB that will generate all of the Z-80 instructions. The statement

```
MACLIB  Z80
```

is placed near the beginning of the regular source program. The assembler will then look in the file Z80.LIB for the required macros.

EMULATING Z-80 INSTRUCTIONS WITH AN 8080 CPU

The Z-80 CPU can execute many powerful instructions that are not available to the 8080. Some of these useful instructions are difficult to implement on an 8080, while others are simply combinations of regular 8080 instructions. The NEG instruction is one of the easiest to implement. The macro definition is

```
NEG      MACRO
        CMA
        INR    A
        ENDM
```

 ;8080 TWO'S COMPLEMENT
 ;1'S COMPLEMENT
 ;2'S COMPLEMENT

Now, whenever a two's complement is needed, the macro call

```
NEG
```

is placed into the program. The assembler generates the required 8080 mnemonics

```
CMA
INR    A
```

Another useful Z-80 operation is the arithmetic shift. This operation shifts all bits of a register one position to the left. The high-order bit is moved into carry, that is, the carry flag is set to a 1 if bit 7 was originally a value of 1. The carry flag is reset to zero if bit 7 was zero. A value of zero is placed into the low-order bit (bit zero).

The 8080 instruction ADD A, which adds the value in the accumulator to itself, performs the arithmetic shift left. But for the 8080, this is the only register which can perform the shift. The Z-80 has an additional instruction which allows this operation to be performed on any of the general-purpose, 8-bit registers or on the memory byte referenced by HL, IX, or IY.

The following macro will generate a set of 8080 instructions for the arithmetic shift left operation.

```
SLA      MACRO    REG      ;SHIFT LEFT ARITH
          MOV      A,REG    ;;GET BYTE
          ADD      A        ;;SHIFT LEFT
          MOV      REG,A    ;;PUT BACK
          ENDM
```

The byte is first moved to the accumulator. The next step is to add the accumulator to itself. This doubling operation performs the needed shift into carry. Then the result is returned to the original register. The value in register C can be doubled by inserting the macro call

```
SLA      C
```

This macro must be used with caution, since the accumulator will be changed during use. But the byte originally in the accumulator cannot be saved with a PUSH PSW instruction. The problem is that the subsequent POP PSW command will overlay the flag register, so that the carry result of the shift will be lost. One solution is to save the accumulator in memory.

```
SLA      MACRO    REG      ;SHIFT LEFT ARITH
          STA      SAVE    ;;SAVE A
          MOV      A,REG    ;;GET BYTE
          ADD      A        ;;SHIFT LEFT
          MOV      REG,A    ;;PUT BACK
          LDA      SAVE    ;;RESTORE A
          ENDM
```

THE REPEAT MACROS

There are times when several lines of identical or nearly identical lines of code are needed. Three repeat macros, REPT, IRP, and IRPC are provided for this purpose. The repeat macros differ from the regular macros in that they are placed directly into the source program where they are needed. The macro definition is the macro call. In the simplest form, an instruction or group of instructions can be replicated. The expression

```
REPT    4
RAR
ENDM
```

will generate the four lines

```
RAR
RAR
RAR
RAR
```

By using the SET directive, this operation can become more versatile. The SET instruction is like an EQU except that the value can be redefined. The lines

```
ADDR    SET    8000H
        REPT    4
ADDR    SET    ADDR+3
        DW      ADDR
        ENDM
```

will generate the code corresponding to

```
DW      8003H
DW      8006H
DW      8009H
DW      800CH
```

Such a series could refer to jump vectors that are spaced three bytes apart.

The repeat macro, combined with the conditional-assembly directive, can generate the required number of nulls after a carriage-return, line-feed pair. This will give the printer time to return to the left margin. Some printers need no nulls, whereas others may need as many as six or seven. The source code could be

```

$
$ OUTPUT TO LIST DEVICE
$
LOUT:  IN      LSTAT
      ANI     LMSK
      JZ      LOUT
      MOV     A,C      $GET DATA
      OUT     LDATA    $SEND BYTE
```

```

;
    IF      NULLS > 0
    ANI     7FH      ;REMOVE PARITY
    CPI     CR       ;CARRIAGE RETURN?
    RNZ     ;NO
    MVI     C,0      ;GET A NULL
;
    REPT    NULLS    ;HOW MANY?
    CALL    LOUT     ;SEND NULL
    ENDM
    ENDIF      ;NULLS
;
    RET

```

The first part is a typical output subroutine. A call is made with the byte in register C. When the output device is ready, the byte is moved from the C register to the accumulator. It is then sent to the printer. If no nulls are required, then the passage from

```

    IF      NULLS > 0
to
    ENDIF

```

is not assembled. On the other hand, if nulls are required, then this passage is assembled. If four nulls are needed, then the assembler will generate four lines of

```

    CALL    LOUT      ;SEND NULL

```

The list output routine calls itself to produce the required nulls. The identifier called NULLS must be previously set to the necessary number of nulls.

There are two other repeat macros called IRP and IRPC. A set of one-character message routines can be generated by using the indefinite repeat macro IRPC. This example will introduce something called a programming trick. Some people think that it is a horrible example of programming. Others think it is very clever. Its purpose is to save two bytes of instruction each time it is used. In addition, less branching is required.

Suppose that we need five different message routines that each produce a single character. The instructions might look like

```

CHARC: MVI    A,'C'
        JMP    OUTT
CHARM: MVI    A,'M'
        JMP    OUTT
CHARR: MVI    A,'R'
        JMP    OUTT
CHAR?: MVI    A,'?'
        JMP    OUTT
CHAR$: MVI    A,'$'
        JMP    OUTT
      . . .
OUTT:   <output routine>

```

If the B and C registers are not in use, we can shorten the above passage by replacing each line containing the instruction `JMP OUTT` with a line of `DB 1`.

```
CHARC: MVI    A,'C'
        DB    1
CHARM: MVI    A,'M'
        DB    1
CHARR: MVI    A,'R'
        DB    1
CHAR?: MVI    A,'?'
        DB    1
CHAR$: MVI    A,'$'
;
OUTT:  . . .
```

Let's see how this works. Suppose that a branch is made to the label `CHARC`. The accumulator is loaded with an ASCII letter C. The next byte, a `DB 1`, looks like the start of an `LXI B` instruction. The following two bytes, corresponding to the `MVI A,'M'` instruction, will be interpreted as the argument for the `LXI` instruction. That is, they will be considered as data. The same will hold for the other occurrences of `DB 1`. By this means, we have effectively shortened the code. We no longer need the `JMP` statements. Caution: a disassembler is not likely to interpret this passage correctly. It looks like there are labels pointing into the middle of the `LXI` instructions. Notice that the second version has subroutine `OUTT` positioned directly under the `CHAR$` routine, so that no `JMP` instruction is needed at this point.

The second version can be easily generated with the `IRPC` macro. Only five lines are needed in the source program.

```
        IRPC    X,CMPT?$
        DB      1      ;FAKE LXI B
CHAR&X: MVI     A,'&X'
        ENDM
```

The five different message routines are all generated with this single macro. One replication is made for each character of the second argument to `IRPC`.

PRINTING STRINGS WITH MACROS

Suppose that we want to send messages to the console from various points of a program. We could write a subroutine called `SENDM` for this purpose.

```
SENDM: LDAX    D      ;GET CHAR
        ORA    A      ;ZERO?
        RZ      ;YES
        INX    D      ;POINTER
        MOV    C,A
        CALL   OUTT    ;SENT
        JMP    SENDM   ;NEXT
```

The address of the message is loaded into the DE register and subroutine SENDM is called.

```
LXI    D,MESS1
CALL   SENDM
```

Subroutine SENDM prints a message by sending each character to the output subroutine OUTT. When a binary zero, used to indicate the end of the message, is found, SENDM returns to the calling program.

We can simplify the sending of messages by using a macro called PRINT. At each point we write

```
PRINT  <CHECKSUM ERROR>
. . .
PRINT  <END OF FILE>
. . .
PRINT  <OUTPUT TO LIST?>
```

The macro called PRINT will generate the message given in the argument. The message is enclosed in angle brackets because the blanks are part of the argument.

If subroutine SENDM were placed into the macro body, then one copy of SENDM would be inserted for each occurrence of the PRINT statement. But we don't need more than one copy of SENDM. On the other hand, if we don't include SENDM in the macro, there may not be any copies at all. What we need is a mechanism for inserting one, and only one, copy of SENDM regardless of how many times we give the PRINT command.

The solution is to write a double macro—one nested inside the other. Both macros will be given the same name. Subroutine SENDM will be part of the outer macro which will be expanded only once. The layout looks like this.

```
PRINT  MACRO    <message>  ;OUTER MACRO
. . .
[define SENDM]
. . .
PRINT  MACRO    <message>  ;INNER MACRO
. . .
[send message]
. . .
ENDM                      ;INNER MACRO
. . .
ENDM                      ;OUTER MACRO
```

The source program in Listing 5.1 demonstrates this technique. The outer macro PRINT has the argument ?TEXT, used for the first call to the macro. Subroutine SENDM is generated at this time. Additional macro calls to PRINT utilize the inner macro which has the argument ?TEXT2. Subroutine SENDM is not generated on these subsequent calls.

Listing 5.1. Source listing for a macro demonstration program.

```

;
PRINT    MACRO    ?TEXT
          LOCAL    AROUND
;
          JMP      AROUND    ;SENDM
;
; SUBROUTINE TO SEND A STRING TO
; THE CONSOLE. BINARY ZERO AT STRING END.
; D,E IS STRING POINTER.
;
SENDM:   LDAX     D        ;GET CHAR
          ORA     A        ;ZERO?
          RZ              ;YES
          INX     D        ;POINTER
          MOV     C,A
          CALL    OUTT     ;SENT
          JMP     SENDM    ;NEXT
;
AROUND:
;
; REDEFINE THE MACRO
;
PRINT    MACRO    ?TEXT2
          LOCAL    MSG,CONT
;
          PUSH    D        ;SAVE D,E
          LXI     D,MSG    ;POINT
          CALL    SENDM
          POP     D        ;RESTORE
          JMP     CONT     ;SKIP MESSAGE
;
MSG:
          DB      CR,LF,'&?TEXT2',0
;
CONT:    ENDM          ;INNER MACRO
          PRINT    <?TEXT>
          ENDM          ;OUTER MACRO
;
CSTAT    EQU      10H    ;CONSOLE STATUS
CDATA    EQU      CSTAT+1 ;CONSOLE DATA
CR        EQU      13    ;CARRIAGE RETURN
LF        EQU      10    ;LINE FEED
;
ORG       100H
START:
          PRINT    <CHECKSUM ERROR.>
;
          PRINT    <END OF FILE.>
;
          PRINT    <OUTPUT TO LIST?>
          JMP     0        ;RETURN TO CP/M
;
; SEND CHARACTER IN C TO THE CONSOLE
;

```



```
OUTT:  IN      CSTAT
      ANI      2
      JZ       OUTT
      MOV      A,C
      OUT      CDATA
      RET
;
      END
```

Subroutine SENDM is coded into the main flow of the program, that is, it is an inline routine. It is therefore necessary to jump around SENDM. Additionally, there must be a branch around each of the messages, since they too are coded inline. Labels for the required branches are uniquely generated in the macro by declaring the corresponding labels as LOCAL. The resulting assembly listing is given in Listing 5.2. The assembler places plus symbols between the address and the generated code of the assembly listing to designate those lines that were generated by macros. Thus, lines that contain plus symbols were not present in the original source listing.

Listing 5.2. Assembly listing for a macro demonstration program.

```
;
PRINT  MACRO  ?TEXT
      LOCAL  AROUND
;
      JMP    AROUND  ;SENDM
;
; SUBROUTINE TO SEND A STRING TO
; THE CONSOLE. BINARY ZERO AT STRING END.
; D,E IS STRING POINTER.
;
SENDM: LDAX   D      ;GET CHAR
      ORA    A      ;ZERO?
      RZ     ;YES
      INX    D      ;POINTER
      MOV    C,A
      CALL   OUTT    ;SENT
      JMP    SENDM   ;NEXT
;
AROUND:
;
; REDEFINE THE MACRO
;
PRINT  MACRO  ?TEXT2
      LOCAL  MSG,CONT
;
      PUSH   D      ;SAVE D,E
      LXI    D,MSG   ;POINT
      CALL   SENDM
      POP    D      ;RESTORE
      JMP    CONT    ;SKIP MESSAGE
;
MSG:    DB      CR,LF,'&?TEXT2',0
;
```

```

CONT:      ENDM          ;INNER MACRO
PRINT      <?TEXT>
ENDM       ;OUTER MACRO

;
CSTAT EQU 10H ;CONSOLE STATUS
0010 = CSTAT EQU CSTAT+1 ;CONSOLE DATA
0011 = CSTAT EQU CSTAT+1 ;CONSOLE DATA
000D = CR EQU 13 ;CARRIAGE RETURN
000A = LF EQU 10 ;LINE FEED
;
0100 ORG 100H
START:
PRINT <CHECKSUM ERROR.>
0100+C30E01 JMP ??0001 ;SENDM
0103+1A SENDM: LDAX D ;GET CHAR
0104+B7 ORA A ;ZERO?
0105+C8 RZ ;YES
0106+13 INX D ;POINTER
0107+4F MOV C,A
0108+CD6501 CALL OUTT ;SENT
010B+C30301 JMP SENDM ;NEXT
010E+D5 PUSH D ;SAVE D,E
010F+111901 LXI D,??0002 ;POINT
0112+CD0301 CALL SENDM
0115+D1 POP D ;RESTORE
0116+C32B01 JMP ??0003 ;SKIP MESSAGE
0119+0D0A434845 DB CR,LF,'CHECKSUM ERROR.',0
;
PRINT <END OF FILE.>
012B+D5 PUSH D ;SAVE D,E
012C+113601 LXI D,??0004 ;POINT
012F+CD0301 CALL SENDM
0132+D1 POP D ;RESTORE
0133+C34501 JMP ??0005 ;SKIP MESSAGE
0136+0D0A454E44 DB CR,LF,'END OF FILE.',0
;
PRINT <OUTPUT TO LIST?>
0145+D5 PUSH D ;SAVE D,E
0146+115001 LXI D,??0006 ;POINT
0149+CD0301 CALL SENDM
014C+D1 POP D ;RESTORE
014D+C36201 JMP ??0007 ;SKIP MESSAGE
0150+0D0A4F5554 DB CR,LF,'OUTPUT TO LIST?',0
0162 C30000 JMP 0 ;RETURN TO CP/M
;
; SEND CHARACTER IN C TO THE CONSOLE
;
0165 DB10 OUTT: IN CSTAT
0167 E602 ANI 2
0169 CA6501 JZ OUTT
016C 79 MOV A,C
016D D311 OUT CDATA
016F C9 RET
;
0170 END

```

If you are familiar with the operation of your assembler, type up the demonstration program and try it out. Branch to the beginning and three messages will appear at the console.

```
Checksum error
End of file
Output to list?
```

Assembler operation will be considered in the next chapter.

By constructing increasingly complicated macros, it is possible to develop some of the structure that is characteristic of higher-level languages such as Pascal. The common loop constructions

```
REPEAT
. . .
. . .
UNTIL <condition true>
```

and

```
LOOP
. . .
EXITIF <condition true>
. . .
ENDLOOP
```

can be realized with macros called REPEAT, UNTIL, and so on. The arguments to UNTIL and EXITIF will consist of three terms. The first and third will be numeric values. The middle term will represent a logical operation such as EQUALS or LESS THAN. The spelling of the logical operators in this case will have to be unusual, since the normal spellings

```
EQ
LT
GE
```

are already utilized by the macro assembler. Macros for all of the common structures are available commercially. Also, source programs for structured macros of this type may be given in the instruction manual for your macro assembler.

CHAPTER SIX

Development of a System Monitor

The best way to learn assembly language programming is to actually do it. Consequently, in this chapter you will develop a small but very powerful utility program called a *monitor*. There are many useful things that can be done with the monitor. There is a command to examine memory and another to change it. Other commands deal with memory blocks. These allow you to move a block from one location to another. Some of the features will duplicate those found in other programs, but other features, such as a search routine and a memory test routine, will be unique.

You will not program the entire monitor at one time. Instead, you will start with just the bare essentials. You will check the monitor after each major change to ensure that the new features have been added correctly. With this so-called top-down method, any error that develops is likely to be found in the most recently added instructions. As new features are incorporated, the monitor will increase in size until it reaches 1K bytes. This is a size that can be easily programmed into a single ROM. The monitor will then be immediately available as soon as the computer is turned on.

An editor and an assembler are required for the development of the monitor. In addition, a debugger will be helpful if you have problems along the way. Each phase of the development will require the same sequence of steps.

1. Generate an assembly language source file with the editor.
2. Assemble the source program to produce an object file.
3. Compare the hex code from your assembly listing to the listing given in this chapter.
4. Load the object program into memory.
5. Branch to the monitor and try it out.

The assembly listings given in this chapter are written with 8080 mnemonics. You can use an 8080 assembler for these programs whether you have an 8080 or a Z-80 CPU. The resulting code will run on both an 8080 and a Z-80 CPU. If you have only a Z-80 assembler, you will have to change the mnemonics. The cross-reference between the 8080 and Z-80 mnemonics, given in Appendix G, can be used to find the corresponding instructions. Alternately, you can define the 8080 mnemonics as macros.

PROGRAM DEVELOPMENT DETAILS

This section describes the details of program development. Skip to the next section if you are familiar with the operation of your editor and assembler. An editor is needed to create and alter the assembly language source file. If you have CP/M, you will have an editor called ED. Other editors, such as ED-80, EDIT80, and Word-Master, are separately available.

The session begins by giving the name of the editor and the name of the source program. The following discussion assumes that you have CP/M. If you have some other operating system, the approach will be similar, but the details may differ. Put the CP/M system diskette in drive A and a working diskette in drive B if you have more than one drive. Go to drive B with the command

```
A>B:
```

The response will be

```
B>
```

Type the name of the editor followed by the name of the monitor source program. The command line might look like this.

```
B>A:ED MON1.ASM
```

for the first version. The digit 1 in the filename refers to the version number. The file type is ASM for the Digital Research assemblers ASM and MAC. The file type should be chosen as MAC, however, if the Microsoft assembler is used.

As you type the source program, be careful to include only the instructions and the comments shown in Listing 6.1A. Do not type the resulting hex code that is also given at the beginning of each line. For example, the line that defines the parameter TOP, on the first page of the listing, should be typed as

```
TOP      EQU      24      ;MEMORY TOP, K BYTES
```

rather than as:

```
0018 = TOP      EQU      24      ;MEMORY TOP, K BYTES
```

Type a Control-I or tab to automatically generate the blank spaces between symbols.

Most of the assembly language symbols have five or fewer characters. This is acceptable to many assemblers. However, if your assembler only allows names to have a maximum of five characters, then several symbols will have to be shortened. The TITLE directive, on the first line, is another potential problem. The CP/M version is shown. The apostrophes should be removed if the Microsoft assembler is utilized. If the TITLE directive is not available on your assembler, place a semicolon at the beginning of this first line to convert it to a comment.

VERSION 1: THE INPUT AND OUTPUT ROUTINES

Refer to Listing 6.1A. This version will contain only the input and output routines. Generate an assembler source file with the system editor. The following variables will have to be tailored to your particular system.

TOP	(top of usable memory, decimal K)
HOME	(where to return when done)
CSTAT	(console input status address)
CDATA	(console input data address)
CSTATO	(console output status address)
CDATAO	(console output data address)
INMSK	(input-ready mask)
OMSK	(output-ready mask)
BACKUP	(console backspace character)

Normally, CSTATO will be the same as CSTAT, and CDATAO will be the same as CDATA. But if your console input address is different from your console output address, then each can be separately defined. Furthermore, the address of CDATA will typically have a value one larger or smaller than that of CSTAT.

Listing 6.1A. The beginning of a system monitor.

```

                                TITLE   '8080 system monitor, ver 1'
                                ;
                                ; (put today's date here)
                                ;
0018 = TOP      EQU      24      ;MEMORY TOP, K BYTES
5800 = ORGIN    EQU      (TOP-2)*1024 ;PROGRAM START
                                ;
5800 ORG      ORGIN
                                ;
                                ;
0000 = HOME     EQU      0        ;ABORT (VER 1-2)
                                ;HOME EQU ORGIN ;ABORT ADDRESS
0031 = VERS     EQU      '1'      ;VERSION NUMBER
57A0 = STACK    EQU      ORGIN-60H
0010 = CSTAT    EQU      10H      ;CONSOLE STATUS
0011 = CDATA    EQU      CSTAT+1  ;CONSOLE DATA
0010 = CSTAT0   EQU      CSTAT    ;CON OUT STATUS
0011 = CDATA0   EQU      CSTAT0+1 ;OUT DATA
0001 = INMSK    EQU      1        ;INPUT MASK
0002 = OMSK     EQU      2        ;OUTPUT MASK
                                ;
57A0 = PORTN    EQU      STACK    ;3 BYTES I/O
57A3 = IBUFF    EQU      STACK+3  ;BUFFER POINTER
57A5 = IBUFC    EQU      IBUFF+2  ;BUFFER COUNT
57A6 = IBUFF    EQU      IBUFF+3  ;INPUT BUFFER
                                ;
0008 = CTRH     EQU      8        ;^H BACKSPACE
0009 = TAB      EQU      9        ;^I
0011 = CTRQ     EQU      17       ;^Q
0013 = CTRS     EQU      19       ;^S
0018 = CTRX     EQU      24       ;^X, ABORT
0008 = BACKUP   EQU      CTRH     ;BACKUP CHAR
007F = DEL      EQU      127      ;RUBOUT
001B = ESC      EQU      27       ;ESCAPE
00F7 = APOS     EQU      (39-'0') AND OFFH
000D = CR       EQU      13       ;CARRIAGE RET
000A = LF       EQU      10       ;LINE FEED
00DB = INC      EQU      0DBH     ;IN OP CODE
00D3 = OUTC     EQU      0D3H     ;OUT OP CODE
00C9 = RETC     EQU      0C9H     ;RET OP CODE
                                ;
                                START:
5800 C34A58      JMP      COLD      ;COLD START
5803 C35358      RESTRT: JMP      WARM ;WARM START
                                ;
                                ; CONSOLE INPUT ROUTINE
                                ;
5806 CD1658      INPUTT: CALL     INSTAT ;CHECK STATUS
5809 CA0658      JZ        INPUTT ;NOT READY ***
580C DB11        INPUT2: IN       CDATA ;GET BYTE
580E E67F        ANI       DEL      ;
5810 FE18        CPI       CTRX    ;ABORT?
5812 CA0000      JZ        HOME     ;YES
5815 C9          RET
                                ;
                                ; GET CONSOLE-INPUT STATUS
                                ;

```

```

5816 DB10      INSTAT: IN      CSTAT
5818 E601              ANI      INMSK
581A C9              RET

;
;  CONSOLE OUTPUT ROUTINE
;
581B F5      OUTT:  PUSH      PSW
581C CD1658  OUT2:  CALL      INSTAT  ;INPUT?
581F CA3558              JZ      OUT4   ;NO ***
5822 CD0C58              CALL      INPUT2 ;GET INPUT
5825 FE13              CPI      CTR5   ;FREEZE?
5827 C21C58              JNZ      OUT2   ;NO

;
;  FREEZE OUTPUT UNTIL ^Q OR ^X
;
582A CD0658  OUT3:  CALL      INPUTT  ;INPUT?
582D FE11              CPI      CTRQ   ;RESUME?
582F C22A58              JNZ      OUT3   ;NO
5832 C31C58              JMP      OUT2

;
5835 DB10      OUT4:  IN      CSTATO  ;CHECK STATUS
5837 E602              ANI      OMSK
5839 CA1C58              JZ      OUT2   ;NOT READY ***
583C F1              POP      PSW
583D D311              OUT      CDATEO ;SEND DATA
583F C9              RET

;
5840 OD0A      SIGNON: DB      CR,LF
5842 205665      DB      ' Ver '
5847 3100      DW      VERS
5849 00      DB      0

;
;  CONTINUATION OF COLD START
;
584A 31A057      COLD:  LXI      SP,STACK
584D 114058      LXI      D,SIGNON ;MESSAGE
5850 CDE258      CALL      SENDM   ;SEND IT

;
;  WARM-START ENTRY
;
5853 215358      WARM:  LXI      H,WARM ;RETURN HERE
5856 E5              PUSH      H
5857 CD8658      CALL      CRLF   ;NEW LINE
585A CD7758      CALL      INPLN  ;CONSOLE LINE
585D CDCC58      CALL      GETCH  ;GET CHAR
5860 FE44      CPI      'D'     ;DUMP
5862 CA5358      JZ      WARM     ;(VER 1)
;
;      JZ      DUMP     ;HEX/ASCII (2)
5865 FE43      CPI      'C'     ;CALL
5867 CA5358      JZ      WARM     ;(VER 1-2)
;
;      JZ      CALLS   ;SUBROUTINE (3)
586A FE47      CPI      'G'     ;GO
586C CA5358      JZ      WARM     ;(VER 1-2)
;
;      JZ      GO      ;SOMEWHERE (3)
586F FE4C      CPI      'L'     ;LOAD
5871 CA5358      JZ      WARM     ;(VER 1-3)
;
;      JZ      LOAD    ;INTO MEMORY (4)
5874 C35358      JMP      WARM   ;TRY AGAIN
;

```



```

; INPUT A LINE FROM CONSOLE AND PUT IT
; INTO THE BUFFER. CARRIAGE RETURN ENDS
; THE LINE. RUBOUT OR ^H CORRECTS LAST
; LAST ENTRY. CONTROL-X RESTARTS LINE.
; OTHER CONTROL CHARACTERS ARE IGNORED
;
5877 3E3E      INPLN: MVI      A,'>'      #PROMPT
5879 CD1B58    CALL      OUTT
587C 21A657    INPL2: LXI      H,IBUFF    #BUFFER ADDR
587F 22A357    SHLD     IBUFF    #SAVE POINTER
5882 0E00      MVI      C,0          #COUNT
5884 CD0658    INPLI: CALL     INPUTT    #CONSOLE CHAR
5887 FE20      CPI      ' '         #CONTROL?
5889 DAA858    JC       INPLC      #YES
588C FE7F      CPI      DEL        #DELETE
588E CAC058    JZ       INPLB      #YES
5891 FE5B      CPI      'Z'+1      #UPPER CASE?
5893 DA9858    JC       INPL3      #YES
5896 E65F      ANI      5FH        #MAKE UPPER
5898 77        INPL3: MOV      M,A      #INTO BUFFER
5899 3E20      MVI      A,32        #BUFFER SIZE
589B B9        CMP      C           #FULL?
589C CA8458    JZ       INPLI      #YES, LOOP
589F 7E        MOV      A,M        #GET CHAR
58A0 23        INX      H          #INCR POINTER
58A1 0C        INR      C          #AND COUNT
58A2 CD1B58    INPLE: CALL     OUTT     #SHOW CHAR
58A5 C38458    JMP      INPLI      #NEXT CHAR
;
; PROCESS CONTROL CHARACTER
;
58AB FE08      INPLC: CPI      CTRH    #^H?
58AA CAC058    JZ       INPLB      #YES
58AD FE0D      CPI      CR         #RETURN?
58AF C28458    JNZ      INPLI      #NO, IGNORE
;
; END OF INPUT LINE
;
58B2 79        MOV      A,C         #COUNT
58B3 32A557    STA      IBUFC      #SAVE
;
; CARRIAGE-RETURN, LINE-FEED ROUTINE
;
58B6 3E0D      CRLF:  MVI      A,CR
58B8 CD1B58    CALL     OUTT        #SEND CR
58BB 3E0A      MVI      A,LF
58BD C31B58    JMP      OUTT        #SEND LF
;
; DELETE PRIOR CHARACTER IF ANY
;
58C0 79        INPLB: MOV      A,C         #CHAR COUNT
58C1 B7        ORA      A           #ZERO?
58C2 CA8458    JZ       INPLI      #YES
58C5 2B        DCX      H          #BACK POINTER
58C6 0D        DCR      C          #AND COUNT
58C7 3E08      MVI      A,BACKUP    #CHARACTER
58C9 C3A258    JMP      INPLE      #SEND
;
; GET A CHARACTER FROM CONSOLE BUFFER
; SET CARRY IF EMPTY

```

```

;
58CC E5      GETCH:  PUSH    H          ;SAVE REGS
58CD 2AA357   LHL    IBUFF    ;GET POINTER
58D0 3AA557   LDA     IBUFC    ;AND COUNT
58D3 D401     SUI     1        ;DECR WITH CARRY
58D5 DAE058   JC      GETC4    ;NO MORE CHAR
58D8 32A557   STA     IBUFC    ;SAVE NEW COUNT
58DB 7E       MOV     A,M      ;GET CHARACTER
58DC 23       INX     H        ;INCR POINTER
58DD 22A357   SHLD    IBUFF    ;AND SAVE
58E0 E1       GETC4:  POP     H          ;RESTORE REGS
58E1 C9       RET

;
; SEND ASCII MESSAGE UNTIL BINARY ZERO
; IS FOUND. POINTER IS D,E
;
58E2 1A       SENDM:  LDAX    D        ;GET BYTE
58E3 B7       ORA     A        ;ZERO?
58E4 C8       RZ          ;YES, DONE
58E5 CD1B58   CALL    OUTT    ;SEND IT
58E8 13       INX     D        ;POINTER
58E9 C3E258   JMP     SENDM    ;NEXT

;
58EC                      END

```

If you don't know the addresses of the console status and data registers and you are using the CP/M operating system, there is another approach you can take. You can use the I/O routines in the CP/M BIOS. The disadvantage of this approach is that CP/M must always be in place whenever the monitor is used. The BIOS entry address is given at memory address 1. The console status, input and output addresses are obtained by adding, respectively, 3, 6, and 9 to this address. The following I/O routines in Listing 6.1B can be substituted for the subroutines in Listing 6.1A starting with the label INPUTT and ending with the label OUT2. If this version is utilized, the addresses in the following sections will not agree with your assembly listings.

Listing 6.1B. Alternate I/O routines using CP/M BIOS.

```

; CONSOLE INPUT ROUTINE USING CP/M BIOS
;
INPUTT:
5806 E5      INPUT2:  PUSH    H          ;SAVE REGISTERS
5807 D5       PUSH    D
5808 C5       PUSH    B
5809 211558   LXI     H,IN5    ;RETURN ADDRESS
580C E5       PUSH    H        ;PUT ON STACK
580D 2A0100   LHL    1        ;BIOS WARM START
5810 110600   LXI     D,6      ;OFFSET TO INPUT
5813 19       DAD     D        ;ADD IN
5814 E9       PCHL          ;CALL BIOS
5815 C1       IN5:    POP     B        ;RESTORE REGISTERS
5816 D1       POP     D
5817 E1       POP     H
5818 FE18     CFI     CTRX    ;ABORT?
581A CA0058   JZ      START    ;YES
581D C9       RET

```

```

; GET CONSOLE-INPUT STATUS USING CP/M
;
581E E5      INSTAT: PUSH    H      ;SAVE REGISTERS
581F D5      PUSH    D
5820 C5      PUSH    B
5821 212D58  LXI      H,ST5      ;RETURN ADDRESS
5824 E5      PUSH    H      ;PUT ON STACK
5825 2A0100  LHLD     1      ;BIOS ENTRY
5828 110300  LXI      D,3      ;OFFSET TO STATUS
582B 19      DAD     D      ;ADD TO ADDR
582C E9      PCHL     ;CALL BIOS
582D C1      ST5:   POP     B      ;RESTORE REGISTERS
582E D1      POP     D
582F E1      POP     H
5830 B7      ORA     A
5831 C9      RET

;
; CONSOLE OUTPUT ROUTINE USING CP/M BIOS
;
5832 F5      OUTT:   PUSH    PSW    ;SAVE BYTE
5833 CD1E58  OUT2:   CALL    INSTAT ;INPUT?
5836 CA4C58  JZ      OUT4      ;NO
5839 CD0658  CALL    INPUT2    ;GET INPUT
583C FE13    CPI     CTR5      ;FREEZE?
583E C23358  JNZ     OUT2      ;NO
5841 CD0658  OUT3:   CALL    INPUTT ;INPUT?
5844 FE11    CPI     CTRQ      ;RESUME?
5846 C24158  JNZ     OUT3      ;NO
5849 C33358  JMP     OUT2

;
584C F1      OUT4:   POP     PSW    ;GET BYTE
584D E5      PUSH    H      ;SAVE REGISTERS
584E D5      PUSH    D
584F C5      PUSH    B
5850 4F      MOV     C,A      ;MOVE BYTE
5851 F5      PUSH    PSW
5852 215E58  LXI      H,OUT5    ;RETURN ADDRESS
5855 E5      PUSH    H      ;PUT ON STACK
5856 2A0100  LHLD     1      ;BIOS ENTRY
5859 110900  LXI      D,9      ;OFFSET TO OUTPUT
585C 19      DAD     D      ;ADD TOGETHER
585D E9      PCHL     ;CALL BIOS
585E F1      OUT5:   POP     PSW    ;RESTORE REGISTERS
585F C1      POP     B
5860 D1      POP     D
5861 E1      POP     H
5862 C9      RET

```

Some of the constants such as PORTN will not be used at this time. However, their inclusion now will simplify things later. There are four occurrences of the dummy instruction

JZ WARM

following the label WARM. Each is followed by an instruction that will be needed later. These latter instructions are preceded by a semicolon so that they will be treated as comments by the assembler.

There are some other matters that may need to be considered. One has to do with the sense of the input and output ready flags. There are three conditional jump instructions based on console-ready flags that display a logical 1 (active high) when ready. If your flags are inverted, that is, they present a logic zero when ready, then the three JZ commands must be changed to JNZ commands. These lines, indicated by three stars in the listing below, should be changed to

```

INPUTT: CALL    INSTAT  ;CHECK STATUS
          JNZ     INPUTT  ;NOT READY ***

OUT2:    CALL    INSTAT  ;INPUT?
          JNZ     OUT4    ;NO ***

OUT4:    IN      CSTAT   ;CHECK STATUS
          ANI     OMSK
          JNZ     OUT2    ;NOT READY ***

```

The routine that corrects keyboard errors is programmed for a video console. If you have a console printer instead, change the backspace character to a slash.

```
BACKUP EQU      '/'      ;CORRECTION
```

This will print a slash when an error is corrected. Otherwise the printer will back up during error correction, overstriking the old character with the new. You may also need to add some nulls after each carriage return. The problem here will be evidenced by missing characters at the beginning of each line. The solution is to place additional instructions in the subroutine called CRLF. Replace the last statement in this routine with the following.

```

CALL     OUTT      ;SEND LINE FEED
XRA      A         ;GET A ZERO
CALL     OUTT      ;SEND NULL
CALL     OUTT      ;AND ANOTHER
. . .
. . .      (one line for each null)
JMP      OUTT      ;LAST NULL

```

The rest of the program can be copied directly as it is. The abort command is a control-X. Initially, the abort address of HOME will be needed to leave the new monitor and return to your regular system. We will change this in version 3 when we will add a routine for branching to any memory address.

If you have a TRS-80 Model I, you won't have a control key. Therefore, you will have to change several of the commands shown in the listing. The original commands follow.

```
CTRH      (Control-H)
TAB        (Control-I)
CTRQ       (Control-Q)
CTRS       (Control-S)
CTR        (Control-X)
DEL        (DEL/RUB)
ESC        (Escape)
```

After you have finished typing the program, exit from the editor and assemble the source program with the assembler. The command line might be

```
B>A:ASM MON1
```

or

```
B>A:MAC MON1
```

for the Digital Research assemblers. These two assemblers will produce two files.

```
MON1.ASM      (assembly listing)
MON1.HEX      (hex code)
```

In addition, MAC will produce a symbol table

```
MON1.SYM      (symbol table)
```

Inspect the hex code given in the assembly listing to see that it matches the corresponding instructions given in this chapter. These 8080 listings have all been generated with the Digital Research assembler MAC. This assembler displays the hex code for 16-bit operands in the usual reverse order. The low-order byte appears first followed by the high-order byte. Thus:

```
CD1B58 means CALL 581B and
C3B458 means JMP 58B4
```

By contrast, the assembly listing produced by the Microsoft assembler reverses the usual order of the two bytes. The high-order byte is given first; this is followed by the low-order byte. In this case, the listing

```
CD 581B means CALL 581B and
C3 58B4 means JMP 58B4
```

The next step is to load the hex program into memory using the debugger. The CP/M command would be

```
B>A:DDT MON1.HEX or
B>A:SID MON1.HEX
```

Now branch to the beginning of the monitor using the debugger G command.

G5800

The first thing that the monitor will do is display the version number on the first line and a prompt symbol of > underneath it.

Try out this first version by typing a series of letters and numbers. Each character that is typed should appear (echo) on the console. Try the correction keys. Typing either a control-H (backspace) or the RUB/DEL key should back up the cursor on a video terminal. Type a carriage return. The prompt symbol should appear at the beginning of the next line. If all of the features are working properly, type a control-X to return to your regular system. If something appears to be wrong, carefully compare your assembly listing with the one given in Listing 6.1A. *Don't proceed to the next version until the current one is working.*

VERSION 2: A MEMORY DISPLAY

A provision for examining the contents of memory will now be added. This routine is called a *memory dump*, or dump for short; it displays the contents of memory in both hex and ASCII notation. The dump feature is initiated with a command of D followed by the address limits in hexadecimal. For example, the statement

```
>D100 18F
```

will dump memory from address 100 to 18F hex. The first address (100 in this case) must immediately follow the letter D. A space is typed and then the second address (18F in this case) is entered. Leading zeros are unnecessary.

Each line will display 16 memory locations. The hexadecimal address of the first location will appear at the beginning of the line. Then the hexadecimal representation of the contents will follow, two characters per byte. These are arranged in four groups of four bytes. The ASCII representations of the data will be given at the end of the line if printable. Otherwise, a period is given. A dump of the first line of the monitor might look like this.

```
>D5800 580F      (your command)

5800 C35C58C3 6558CD16 58CA0658 DB11E67F .\X.eX..X.X....
```

Use your system editor to make the necessary alterations and additions to version 1. First, change the version number at the beginning of the program.

```
VERS      EQU      '2'      ;VERSION NUMBER
```

Next, locate the instruction

JZ DUMP

that follows the label WARM. Remove the semicolon at the beginning of this line. Also delete the line just before it that jumps to WARM. The region should now look like this.

```
CALL        GETCH
CPI        'D'        ;DUMP?
JZ        DUMP
. . .        . . .
```

The remaining instructions, shown in Listing 6.2, will be placed at the end of version 1, just preceding the END statement. It might be easier to delete the END statement, type in the new code, and then add a new END statement. The END statement is usually optional, anyway. One of the subroutines (READHL) will translate the dump limits from ASCII-encoded hexadecimal into binary. One routine gets both the start and the stop address (using READHL) then checks to see that the second address is larger than the first. If the second address is smaller than the first, then the task will be aborted. Subroutine OUTHEX will convert the binary data already in memory into ASCII-coded hex for output to the console. Subroutine TSTOP is used to determine when to terminate the dump process. Finally, an error routine (ERROR) will be needed in case an invalid character is entered by the user.

Listing 6.2. Memory display

```
                  ; DUMP MEMORY IN HEXADECIMAL AND ASCII
                  ;
58EC CD2D59        DUMP:    CALL    RDHLDE    ;RANGE
58EF CD8359        DUMP2:   CALL    CRHL     ;NEW LINE
58F2 4E            DUMP3:   MOV     C,M     ;GET BYTE
58F3 CD9359               CALL    OUTHX    ;PRINT
58F6 23                   INX     H        ;POINTER
58F7 7D                   MOV     A,L    
58F8 E60F                   ANI     0FH     ;LINE END?
58FA CA0559               JZ       DUMP4    ;YES, ASCII
58FD E603                   ANI     3       ;SPACE
58FF CC8E59               CZ       OUTSP    ; 4 BYTES
5902 C3F258               JMP     DUMP3    ;NEXT HEX
5905 CD8E59        DUMP4:   CALL    OUTSP   
5908 D5                   PUSH    D      
5909 11F0FF               LXI     D,-10H   ;RESET LINE
590C 19                   DAD     D      
590D D1                   POP     D      
590E CD1D59        DUMP5:   CALL    PASCII   ;ASCII DUMP
5911 CDA759               CALL    TSTOP   ;DONE?
5914 7D                   MOV     A,L     ;NO
5915 E60F                   ANI     0FH     ;LINE END?
5917 C20E59               JNZ     DUMP5   ;NO
591A C3EF58               JMP     DUMP2
```

```

;
; DISPLAY MEMORY BYTE IN ASCII IF
; POSSIBLE, OTHERWISE GIVE DECIMAL PNT
;
591D 7E      PASCII: MOV     A,M      ;GET BYTE
591E FE7F    CPI     DEL      ;HIGH BIT ON?
5920 D22859  JNC     PASC2     ;YES
5923 FE20    CPI     ' '      ;CONTROL CHAR?
5925 D22A59  JNC     PASC3     ;NO
5928 3E2E    PASC2: MVI     A,'.'   ;CHANGE TO DOT
592A C31B58  PASC3: JMP     OUTT    ;SEND
;
; GET H,L AND D,E FROM CONSOLE
; CHECK THAT D,E IS LARGER
;
592D CD3859  RDHLDE: CALL    HHLDE
5930 7B      RDHLD2: MOV     A,E
5931 95      SUB     L          ;E - L
5932 7A      MOV     A,D
5933 9C      SBB     H          ;D - H
5934 DA7B59  JC      ERROR     ;H,L BIGGER
5937 C9      RET
;
; INPUT H,L AND D,E. SEE THAT
; 2 ADDRESSES ARE ENTERED
;
5938 CD4459  HHLDE: CALL    READHL  ;H,L
593B DA7B59  JC      ERROR     ;ONLY 1 ADDR
593E EB      XCHG          ;SAVE IN D,E
593F CD4459  CALL    READHL  ;D,E
5942 EB      XCHG          ;PUT BACK
5943 C9      RET
;
; INPUT H,L FROM CONSOLE
;
5944 D5      READHL: PUSH    D
5945 C5      PUSH    B        ;SAVE REGS
5946 210000  LXI     H,0      ;CLEAR
5949 CDCC58  RDHL2: CALL    GETCH  ;GET CHAR
594C DA6859  JC      RDHL5     ;LINE END
594F CD6B59  CALL    NIB      ;TO BINARY
5952 DA5E59  JC      RDHL4     ;NOT HEX
5955 29      DAD     H        ;TIMES 2
5956 29      DAD     H        ;TIMES 4
5957 29      DAD     H        ;TIMES 8
5958 29      DAD     H        ;TIMES 16
5959 B5      ORA     L        ;ADD NEW CHAR
595A 6F      MOV     L,A
595B C34959  JMP     RDHL2     ;NEXT
;
; CHECK FOR BLANK AT END
;
595E FEF7    RDHL4: CPI     APOS   ;APOSTROPHE
5960 CA6859  JZ      RDHL5     ;ASCII INPUT
5963 FEF0    CPI     (' ' - '0') AND OFFH
5965 C27B59  JNZ     ERROR     ;NO
5968 C1      RDHL5: POP     B
5969 D1      POP     D        ;RESTORE
596A C9      RET

```



```

;
; CONVERT ASCII CHARACTERS TO BINARY
;
596B D630 NIB: SUI '0' ;ASCII BIAS
596D D8 RC ; < 0
596E FE17 CPI 'F'-'0'+1
5970 3F CMC ;INVERT
5971 D8 RC ;ERROR, > F
5972 FE0A CPI 10
5974 3F CMC ;INVERT
5975 D0 RNC ;NUMBER 0-9
5976 D607 SUI 'A'-'9'-1
5978 FE0A CPI 10 ;SKIP : TO
597A C9 RET ;LETTER A-F
;
; PRINT ? ON IMPROPER INPUT
;
597B 3E3F ERROR: MVI A,'?'
597D CD1B58 CALL OUTT
5980 C30058 JMP START ;TRY AGAIN
;
; START NEW LINE, GIVE ADDRESS
;
5983 CDB658 CRHL: CALL CRLF ;NEW LINE
;
; PRINT H,L IN HEX
;
5986 4C OUTHL: MOV C,H
5987 CD9359 CALL OUTHX ;H
598A 4D OUTLL: MOV C,L
;
; OUTPUT HEX BYTE FROM C AND A SPACE
;
598B CD9359 OUTHEX: CALL OUTHX
;
; OUTPUT A SPACE
;
598E 3E20 OUTSP: MVI A,' '
5990 C31B58 JMP OUTT
;
; OUTPUT A HEX BYTE FROM C
; BINARY TO ASCII HEX CONVERSION
;
5993 79 OUTHX: MOV A,C
5994 1F RAR ;ROTATE
5995 1F RAR ; FOUR
5996 1F RAR ; BITS TO
5997 1F RAR ; RIGHT
5998 CD9C59 CALL HEX1 ;UPPER CHAR
599B 79 MOV A,C ;LOWER CHAR
599C E60F HEX1: ANI 0FH ;TAKE 4 BITS
599E C690 ADI 90H
59A0 27 DAA ;DAA TRICK
59A1 CE40 ACI 40H
59A3 27 DAA
59A4 C31B58 JMP OUTT
;
; CHECK FOR END, H,L MINUS D,E
; INCREMENT H,L

```

```

;
59A7 23      TSTOP: INX      H
59A8 7B      MOV      A,E
59A9 95      SUB      L      ; E - L
59AA 7A      MOV      A,D
59AB 9C      SBB      H      ; D - H
59AC D0      RNC      ;NOT DONE
59AD E1      POP      H      ;RAISE STACK
59AE C9      RET
;
59B1                      END

```

Type up the new instructions, then, after you leave the editor, rename the new file. The CP/M command will be

```
REN MON2.ASM=MON1.ASM
```

Rename the backup file to its original name.

```
REN MON1.ASM=MON1.BAK
```

Assemble version 2 and load it into memory. Start it up by branching to the address of START. Again, the version number should be printed, and the prompt symbol should appear. Test the new feature by dumping a portion of the monitor.

```
>D5800 585F
```

Be sure to type a carriage return at the end of the line. Input errors can be corrected by typing a backspace or DEL. Check to see that the hex code displayed on the screen matches the assembly listing code. Most of the ASCII representation will be meaningless. But the section from 5842 to 585A hex will read

```
Ver 2
```

Now test the scroll-freeze commands. Dump a large section of memory.

```
>D0 1000
```

Type a control-S as the data are being displayed on the console. The console screen should freeze. Now type a control-Q. The screen should again resume displaying the data. The commands of Control-S and control-Q will alternately freeze and resume the scrolling.

Try the routine that checks for proper dump limits by typing a larger address first, then a smaller address.

```
D300 200
```

As a result of this improper input, a question mark should be printed. Then the prompt will appear on a new line. If everything is all right, return to your regular system by entering a control-X.

If version 2 does not perform satisfactorily, compare the hex code in your assembly listing with the values given in Listing 6.2 for the new code. Correct any errors, reassemble the program, and try it again.

VERSION 3: A CALL AND GO ROUTINE

Now that both hex-to-binary and binary-to-hex routines are available, we can easily include new features. A CALL routine and a GO routine will be added in version 3. These routines will allow you to branch to any address in memory. The GO command will be useful for testing subroutines. For this latter command, the monitor warm-start address (WARM) is on the stack when the call is made. A subroutine can be called with the C command. The execution of an RET instruction at the end of the subroutine will cause a return to the monitor.

First, change the version number to 3. Then find the instructions corresponding to the C and G commands after the label WARM. Remove the semicolons from the beginning of the lines that branch to CALLS and GO. Delete the prior lines that jump to WARM. The program should now look like

```
CPI      'C'      ;CALL?
JZ       CALLS
CPI      'G'      ;GO?
JZ       GO
```

The remaining lines of code (and some comments) are placed at the end of the source program just prior to the END statement. They are given in Listing 6.3.

Listing 6.3. A CALL and a GO routine.

```
                ; ROUTINE TO GO ANYWHERE IN MEMORY
                ; ADDRESS OF WARM IS ON STACK, SO A
                ; SIMPLE RET WILL RETURN TO THIS MONITOR
                ;
59AF E1         GO:      POP      H          ;RAISE STACK
59B0 CD4459     CALLS:   CALL     READHL    ;GET ADDRESS
59B3 E9                PCHL     ;GO THERE
                ;
59B4                        END
```

Another important change should be made at this time. Since we can now branch to any place in memory with the GO command, we can change the abort command, control-X. Redefine HOME near the beginning of the source program so that an abort command of control-X will restart the monitor.

HOME EQU ORGIN ;ABORT ADDRESS

This line was originally entered as a comment. Remove the semicolon at the beginning of the line and delete the previous line.

Assemble the new version and load it into memory. Branch to the monitor and try the dump routine as before. Try the CALL feature by calling the monitor itself.

>C5800

The cold-start message should appear. Now use the GO routine to return to your main system. If the GO address is zero, then no argument need follow the G command.

>G

VERSION 4: A MEMORY-LOAD ROUTINE

In version 2 we added a routine that could be used to inspect any memory location. A routine which can be used to change memory will now be added. Change the version number to 4. Locate the instruction

; JZ LOAD

following WARM. Remove the semicolon at the beginning of the line. Delete the original JZ WARM on the prior line. The program should now look like

CPI 'L'
JZ LOAD

Add the load routines shown in Listing 6.4 to the end of the source program.

Listing 6.4. A memory-load routine.

```

; LOAD HEX OR ASCII CHAR INTO MEMORY
; FROM CONSOLE. CHECK TO SEE IF
; THE DATA ACTUALLY GOT THERE
; APOSTROPHE PRECEEDS ASCII CHAR
; CARRIAGE RETURN PASSES OVER LOCATION
;
59B4 CD4459  LOAD:  CALL  READHL  ;ADDRESS
59B7 CD8659  LOAD2: CALL  OUTHL  ;PRINT IT
59BA CD1D59          CALL  FASCI  ;ASCII
59BD CD8E59          CALL  OUTSP
59C0 4E      MOV   C,M    ;ORIG BYTE
59C1 CD8B59          CALL  OUTHEX ;HEX
59C4 E5      PUSH  H      ;SAVE FNTR
59C5 CD7C58          CALL  INFL2  ;INPUT
59C8 CD4459          CALL  READHL  ; BYTE
59CB 45      MOV   B,L    ; TO B

```

```
59CC E1          POP      H
59CD FEF7        CPI      APOS
59CF CADE59      JZ       LOAD6    ;ASCII INPUT
59D2 79          MOV      A,C      ;HOW MANY?
59D3 B7          ORA      A        ;NONE?
59D4 CADA59      JZ       LOAD3    ;YES
59D7 CDE559      LOAD4: CALL    CHEKM ;INTO MEMORY
59DA 23          LOAD3: INX      H  ;POINTER
59DB C3B759      JMP      LOAD2
;
; LOAD ASCII CHARACTER
;
59DE CDCC58      LOAD6: CALL    GETCH
59E1 47          MOV      B,A
59E2 C3D759      JMP      LOAD4
;
; COPY BYTE FROM B TO MEMORY
; AND SEE THAT IT GOT THERE
;
59E5 70          CHEKM: MOV      M,B    ;PUT IN MEM
59E6 7E          MOV      A,M    ;GET BACK
59E7 B8          CMP      B        ;SAME?
59E8 C8          RZ
59E9 C37B59      JMP      ERROR    ;BAD
;
59EC              END
```

Assemble version 4 and compare the assembly listing of the new part to Listing 6.4. Load the new program and branch to the beginning. Recheck the dump command by examining the new code for the load routine

>D59B4 59EB

Now try the load command. Great care must be taken when typing the load address. This command will actually change the contents of memory, including the monitor itself.

Type the letter L, the hexadecimal address, and a carriage return. The response will be the address that was typed and the current contents of that memory location. The data are represented two ways: in ASCII and in hex. If the ASCII value is not a printable character, it is rendered as a period.

The displayed location can now be changed by typing the new value and a carriage return. The data can be entered in several ways. It can be in the form of one or two hex characters. If more than two characters are entered, only the last two are actually used. This allows you to correct an error by continuing to type. Errors can also be corrected with the backspace or the DEL/RUB key. A single ASCII character can be entered into memory by preceding it with an apostrophe.

As each new value and a carriage return is typed, the next address and the present data value will appear. In this way, a machine-language routine can be entered from the console. Of course, using an assembler is a more efficient way to generate a long program. But our load routine will be useful for making simple changes or for writing short routines.

The load command is terminated by typing a control-X (if you redefined HOME as ORGIN back in version 3). It is also terminated if you enter a nonhex character. Control then returns to the monitor. If the load command is used to revise existing code, another feature is useful. A carriage return is given without entering any data. The memory pointer then skips over the current location and the corresponding value is not changed.

After each revised byte is entered into memory, the monitor checks to see that the new value is correct. If an attempt is made to write into protected, nonexistent, or defective memory, the load process is terminated and a question mark is printed.

Try the load routine by entering the following five bytes into a convenient location such as 4000 hex.

```
3E 7 D3 XX C9
```

This sequence corresponds to the assembly language program

```
3E07    MVI    A,7
D3XX    OUT    XX
C9      RET
```

The value of XX is the console-data address (CDATA in the source program). Check the code with the dump command.

```
D4000 4004
```

Now use the CALL command to execute the routine

```
C4000
```

The console bell should sound and control will return to the command level of our monitor.

VERSION 5: USEFUL ENTRY POINTS

Changes to the first four versions were made for the most part by adding new instructions to the end of the existing program. For versions 5, 6, and 7, we are going to start the process over to some extent by inserting some new instructions in the middle of the existing program.

At the beginning of the monitor there are two jump instructions.

```
JMP     COLD
JMP     WARM
```

Entry points such as these are sometimes called *vectors*. The first jump to COLD is the initial, cold-start entry point into the monitor. Stack initialization and printing of the sign-on message occur at this time. But other

housekeeping chores, such as interface initialization, could be performed in this section. The second vector causes a jump to WARM, a restart entry point that does not alter the stack pointer.

We will now insert some additional vectors after these first two. The additional jumps will provide fixed entry points to useful subroutines in the monitor. These routines can then be easily called by other programs outside the monitor. Since these jump instructions are all at the beginning of the monitor, their addresses won't change when the monitor is altered. Furthermore, new vectors can be added to the end of the group without affecting those already present.

Place the five jump instructions shown in Listing 6.5 at the beginning of the monitor just after the first two (START and RESTRT).

Listing 6.5. Some useful entry points.

```
                ; VECTORS TO USEFUL ROUTINES
                ;
5806 C32A58      COUT:   JMP      OUTT    ;OUTPUT CHAR
5809 C31558      CIN:    JMP      INPUTT  ;INPUT CHAR
580C C3D058      INLN:   JMP      INPLN   ;INPUT LINE
580F C32559      GCHAR:  JMP      GETCH   ;GET CHAR
5812 C3EC59      OUTH:   JMP      OUTHX   ;BIN TO HEX
                ;
```

Reassemble the monitor, load it into memory, and try the DUMP, LOAD, and GO routines again to be sure that they still work. Now, when separate, external routines are written, they need not contain subroutines for console input, output, conversion of binary to hex, and so on.

A character can be displayed on the console by calling COUT with the character in the accumulator. A single console character is obtained by calling CIN. The byte is returned in the accumulator.

An entire line of characters can be easily obtained by calling the line-input entry INLN. As each character is typed, it is automatically printed on the console. The error-correction commands are available at this time. The backspace and DEL/RUB keys can be used to delete the previously typed character. A line is normally terminated with a carriage return. After the console-input buffer has been filled by a call to INLN, the GCHAR address can be called.

A character is returned in the accumulator for each call to GCHAR. When the input buffer has been exhausted, the carry flag is set. Typing a control-X will abort a routine and return control to the monitor. Therefore, it is not necessary to include an abort routine in separate, external programs.

The fifth new entry point will perform a conversion from binary to ASCII-coded hexadecimal. This will allow display of individual memory locations or any of the CPU registers. The byte to be converted is placed in the C register and the address of OUTH is called. The accumulator is also used by the conversion routine in this case, so it may be necessary to save the accumulator's original contents on the stack by using a PUSH instruction.

Use the monitor to write the following short routine. This program will demonstrate the new vectors.

```
3E07      MVI      A,7
C30658    JMP      COUT
```

This program, which is similar to the one written in the last section, can be placed almost anywhere in memory. This time, however, there is no need to worry about the output device address since the monitor takes care of this. Branch to the routine by giving the monitor command of C and the address

>C4000

The monitor output routine will ring the console bell, then cause a return to the address WARM.

The monitor now contains a bare minimum of features. The DUMP, LOAD, GO, and CALL routines can be used to write and inspect simple routines. The several vectors located at the beginning of the monitor, allow easy access to useful subroutines within. These vectors will greatly simplify the task of writing and debugging simple routines.

At this point, you may wish to go on to Chapter 8 and try some of the routines discussed there. Otherwise, continue in this chapter as we add more features to the monitor. The new features will include memory fill and zero, memory search, ASCII load and dump, input from and output through any port, a memory test, byte replacement, and memory comparison.

VERSION 6: AUTOMATIC MEMORY SIZE

A routine that will automatically find the top of usable memory will be added for version 6. The routine is executed each time a cold or warm start is performed. The first byte of memory in each page of 256 bytes of memory is checked, starting with page zero. The byte in memory is moved to the accumulator, complemented, then written back to the same memory location. The result is compared to the accumulator to see if it is the same. If so, then the byte in the accumulator is complemented back to the original byte and it is written back into memory. This effectively restores the original byte.

Each page of memory is checked in this way until the monitor stack area is encountered or until defective, missing, or protected memory is found. The hexadecimal value of this top page is printed just preceding the monitor greater-than prompt (>). For example, if the monitor starts at 5800 hex and the stack is located at 57A0, then the prompt will appear as

57>

This routine provides a regular, continuous check on the memory size. It does not check all of the memory, but only the first byte of each 256 bytes of the page. Nevertheless, this check may point up potential problems. A more complete memory test program will be added in version 15.

Listing 6.6. Automatic memory check.

```

;
; FIND TOP OF USABLE MEMORY.
; CHECK FIRST BYTE OF EACH PAGE OF MEMORY
; STARTING AT ADDRESS ZERO. STOP AT STACK
; OR MISSING/DEFECTIVE/PROTECTED MEMORY.
; DISPLAY HIGH BYTE OF MEMORY TOP.

5865 210000          LXI      H,0      ;PAGE ZERO
5868 0457            MVI      B,STACK  SHR B
586A 7E              NPAGE: MOV     A,M      ;GET BYTE
586B 2F              CMA                ;COMPLEMENT
586C 77              MOV     M,A      ;PUT IT BACK
586D BE              CMP     M      ;SAME?
586E C27858          JNZ      MSIZE      ;NO, MEM TOP
5871 2F              CMA                ;ORIG BYTE
5872 77              MOV     M,A      ;RESTORE IT
5873 24              INR      H      ;NEXT PAGE
5874 05              DCR      B
5875 C26A58          JNZ      NPAGE      ;KEEP GOING
5878 4C              MSIZE: MOV     C,H      ;MEM TOP
5879 CD0F59          CALL     CRLF      ;NEW LINE
587C CDEC59          CALL     OUTHX     ;PRINT MEM SIZE
587F CDD058          CALL     INPLN     ;CONSOLE LINE
5882 CD2559          CALL     GETCH     ;FIRST CHAR
;

```

Insert the new instructions shown in Listing 6.6 right after the PUSH H instruction that follows the label WARM.

```

WARM:  LXI      H,WARM  ;RET TO
        PUSH    H      ; HERE

```

(add new code here)

If your assembler does not have the shift-right operation SHR, then just code the high half of the stack address. The second line in Listing 6.6 might look like this instead.

```
MVI      B,57H
```

Assemble the new version. Check the assembly listing to see that the new additions are correct. Then try out version 6.

The symbol table at this point follows.

symbols:

00F7 AFOS	0008 BACKUP	59B0 CALLS	0011 CDATA
0011 CDATA0	59E5 CHEKM	584A COLD	000D CR
5983 CRHL	58B6 CRLF	0010 CSTAT	0010 CSTAT0
0008 CTRH	0011 CTRQ	0013 CTRS	0018 CTRX
007F DEL	58EC DUMP	58EF DUMP2	58F2 DUMP3
5905 DUMP4	590E DUMP5	597B ERROR	001B ESC
58E0 GETC4	58CC GETCH	59AF GO	599C HEX1
5938 HHLDE	0000 HOME	57A5 IBUFC	57A6 IBUFF
57A3 IBUFF	00DB INC	0001 INMSK	587C INFL2
5898 INFL3	58C0 INFLB	58A8 INFLC	58A2 INPLE
5884 INPLI	5877 INFLN	580C INPUT2	5806 INPUTT
5816 INSTAT	000A LF	59B4 LOAD	59B7 LOAD2
59DA LOAD3	59D7 LOAD4	59DE LOAD6	596B NIB
0002 OMSK	5800 ORGIN	581C OUT2	582A OUT3
5835 OUT4	00D3 OUTC	598B OUTHEX	5986 OUTHL
5993 OUTHX	598A OUTLL	598E OUTSP	581B OUTT
5928 PASC2	592A PASC3	591D PASCII	57A0 PORTN
5949 RDHL2	595E RDHL4	5968 RDHL5	5930 RDHLD2
592D RDHLDE	5944 READHL	5803 RESTRT	00C9 RETC
58E2 SENDM	5840 SIGNON	57A0 STACK	5800 START
0009 TAB	0018 TOP	59A7 TSTOP	0031 VERS
5853 WARM			

VERSION 7: COMMAND-BRANCH TABLE

Before incorporating additional features into the monitor, we should make a fundamental change in the *command processor routine*. This routine interprets the initial character of the command line. The routine looks for commands beginning with the letter D, C, G, or L. Five bytes of instruction are needed for each one of these commands. For example, the LOAD routine uses the instructions

```
CPI    'L'
JZ     LOAD
```

Since there are 26 letters of the alphabet, there will eventually be 26 times 5, or 130 bytes needed if 26 different commands are incorporated. This approach is satisfactory for a short table, but there is a better approach when there are many entries.

An alternate method is to use a command branch table. This method only requires two bytes per table entry plus 23 bytes of decoding instructions. The disadvantage of this method is that all 26 table entries will have to be allocated, even if only a few are needed. Thus, there may be a lot of unallocated table entries.

Delete the 13 lines of program immediately following the command of CALL GETCH, just after the label MSIZE.

```

CPI      'D'      ;DUMP <delete 13 lines> <====!
. . .
. . .
JMP      WARM      ;TRY AGAIN          <====!

```

The new code that will be added is given in Listing 6.7. Notice that there are 26 table entries. Each line corresponds to one letter of the alphabet. At this time, most of the entries refer to the error routine called ERROR. This is because we have not yet incorporated many features. As new features are added to the monitor, these error references will be replaced by the desired subroutine names.

Listing 6.7. Command-branch table.

```

; MAIN COMMAND PROCESSOR
;
5885 D641      SUI      'A'      ;CONVERT OFFSET
5887 DAD459      JC      ERROR    ; < A
588A FE1A      CPI      'Z'-'A'+1
588C D2D459      JNC      ERROR    ; > Z
588F 87        ADD      A        ;DOUBLE
5890 219C58      LXI      H, TABLE ;START
5893 1600      MVI      D,0
5895 5F        MOV      E,A      ;OFFSET
5896 19        DAD      D        ;ADD TO TABLE
5897 5E        MOV      E,M      ;LOW BYTE
5898 23        INX      H
5899 56        MOV      D,M      ;HIGH BYTE
589A EB        XCHG
589B E9        PCHL      ;GO THERE

;
; COMMAND TABLE
;
589C D459      TABLE: DW      ERROR    ;A, ASCII
589E D459      DW      ERROR    ;B
58A0 095A      DW      CALLS     ;C, CALL SUBR
58A2 4559      DW      DUMP      ;D, DUMP
58A4 D459      DW      ERROR     ;E
58A6 D459      DW      ERROR     ;F, FILL
58A8 085A      DW      GO        ;G, GO
58AA D459      DW      ERROR     ;H, HEX MATH
58AC D459      DW      ERROR     ;I, PORT INPUT
58AE D459      DW      ERROR     ;J, MEMORY TEST
58B0 D459      DW      ERROR     ;K
58B2 0D5A      DW      LOAD      ;L, LOAD
58B4 D459      DW      ERROR     ;M, MOVE
58B6 D459      DW      ERROR     ;N
58B8 D459      DW      ERROR     ;O, PORT OUTPUT
58BA D459      DW      ERROR     ;P
58BC D459      DW      ERROR     ;Q
58BE D459      DW      ERROR     ;R, REPLACE
58C0 D459      DW      ERROR     ;S, SEARCH
58C2 D459      DW      ERROR     ;T
58C4 D459      DW      ERROR     ;U
58C6 D459      DW      ERROR     ;V, VERIFY MEM
58C8 D459      DW      ERROR     ;W
58CA D459      DW      ERROR     ;X, STACK POINTER
58CC D459      DW      ERROR     ;Y
58CE D459      DW      ERROR     ;Z, ZERO

```

Generate the new version, assemble it, and compare the resulting assembly listing to the one given in Listing 6.7. Try out version 7. It should behave exactly like version 6. It will be a bit longer than version 6 at this stage, but it will not grow as rapidly as we add new features. In the remainder of this chapter, we will add the new subroutines to the end of source program. The label for the subroutine will be placed in the appropriate place of the command branch table.

VERSION 8: DISPLAY THE STACK POINTER

By adding seven bytes of new code, we will be able to examine our monitor's stack pointer. This will alert us to a possible problem with the monitor itself. We may find, for example, that as we use the monitor, the stack tends to grow up or down in memory, rather than remain in the same place. This is undesirable and indicates that we are not properly lowering or raising the stack somewhere in the program. For example, subroutine TSTOP increments the pointer then checks to see if the current task should be terminated. If so, the stack is raised with a POP instruction. Then a return instruction skips one level of subroutines, so that control returns to the address of WARM.

Change the version number to 8. Also change the entry in the command table that corresponds to the command of X. This is the third from the last entry. Delete the word ERROR and replace it with the word REGS.

```
DW      REGS      ;X, STK POINTER
```

Then go to the end of the source program. We will make a minor change in subroutine CHECKM, the last subroutine in the monitor. Then the new instructions will be added. Delete the END statement and the instruction just prior to the END statement.

```
JMP      ERROR      ;BAD
```

Then add the new instructions as shown in Listing 6.8.

Listing 6.8. Display the stack pointer.

```
5A42 F1      ERRP:  POP      PSW      ;RAISE STACK
5A43 3E42     ERRB:  MVI      A,'B'    ;BAD
5A45 CD2A58   ERR2:  CALL     OUTT
5A48 CDE759   CALL     OUTSP
5A4B C3DF59   JMP      OUTHL    ;POINTER
;
; DISPLAY STACK POINTER REGISTER
;
5A4E 210000   REGS:  LXI      H,0
5A51 39      DAD     SP
5A52 C3DF59   JMP      OUTHL
```

Reassemble the monitor and try it out. First give the X command (with no argument). Make a note of the value given for the stack pointer. Now, try other monitor features such as the dump and load commands. After each of these commands, give the X command to see that the stack pointer remains in the same place.

Try the separate routine that rings the console bell. This routine, which was written for version 4, may have to be rewritten if it was destroyed by the assembler or the editor. Again, check that the stack pointer is still in the same place. When you are convinced that everything is all right, continue to the next version.

VERSION 9: ZERO AND FILL ROUTINES

In version 4, we added a routine that could be used to change individual memory locations, one at a time. We will now add a routine which will allow us to fill a portion of memory with a constant value. A separate command for zeroing memory is also added for convenience, even though this operation could be performed with the FILL command.

Change the version number to 9, then alter the two command table entries that correspond to the F (fill) and Z (zero) commands.

```
DW      FILL      ;F, MEMORY
. . .
DW      ZERO      ;Z, MEMORY
```

Add the new code shown in Listing 6.9 to the end of the program.

Listing 6.9. Zero and fill routines.

```
                ; ZERO A PORTION OF MEMORY
                ; THE MONITOR AND STACK ARE
                ; PROTECTED
                ;
5A55 CD8659      ZERO:  CALL    RDHLDE  ;RANGE
5A58 0600                MVI     B,0
5A5A C3665A                JMP     FILL2
                ;
                ; FILL A PORTION OF MEMORY
                ;
5A5D CD7C5A      FILL:  CALL    HLDEBC  ;RANGE, BYTE
5A60 FEF7                CPI     APOS   ;APOSTROPHE?
5A62 CA755A                JZ      FILL4  ;YES ASCII
5A65 41                MOV     B,C
5A66 7C                FILL2: MOV     A,H      ;FILL BYTE
5A67 FE57                CPI     STACK SHR 8 ;TOO FAR?
5A69 D2D459                JNC     ERROR   ;YES
5A6C CD3E5A      FILL3:  CALL    CHEKM   ;PUT, CHECK
5A6F CD005A                CALL    TSTOP  ;DONE?
5A72 C3665A                JMP     FILL2  ;NEXT
                ;
```

```

5A75 CD2559      FILL4:  CALL      GETCH      ;ASCII CHAR
5A78 47          MOV       B,A
5A79 C36C5A      JMP       FILL3
;
; GET H,L D,E AND B,C
;
5A7C CD8A5A      HLDEBC: CALL      HLDECK     ;RANGE
5A7F DAD459      JC         ERROR      ;NO BYTE
5A82 E5          PUSH      H
5A83 CD9D59      CALL      READHL      ;3RD INPUT
5A86 44          MOV       B,H         ;MOVE TO
5A87 4D          MOV       C,L         ; B,C
5A88 E1          POP       H
5A89 C9          RET
;
; GET 2 ADDRESSES, CHECK THAT
; ADDITIONAL DATA IS INCLUDED
;
5A8A CD9159      HLDECK: CALL      HHLDE      ;2 ADDR
5A8D DAD459      JC         ERROR      ;THAT'S ALL
5A90 C38959      JMP       RDHL D2     ;CHECK

```

Assemble the program, load it into memory, and try it out. First, display a portion of memory.

```
>D4000 404F
```

Then, zero out a part of this region.

```
>Z4000 403F
```

Display the region again to be sure that the zero routine is working. Now fill a portion of the previously zeroed memory with A5 hex bytes.

```
>F4001 401E A5
```

Again, dump this region of memory to ensure that the fill routine is working.

```
>D4000 404F
```

Finally, check the ASCII fill command by filling with a \$ symbol.

```
>F4020 402F '$
```

As with the load command, ASCII input is preceded by an apostrophe.

VERSION 10: A BLOCK-MOVE ROUTINE

The next routine to be added will allow us to move a block data from one memory location to another. This is actually a duplication routine, since the original memory block will remain unchanged. As each byte is moved to the new location, a check is made to ensure that it actually got there.

First, change the version number to 10. Then add the new lines to the end of the source program. Change the branch table entry corresponding to the command of M.

DW MOVE ;M, MEMORY

Insert the instructions given in Listing 6.10 to the end of the source program. Assemble the monitor and try it out.

Listing 6.10. A block-move routine.

```

; MOVE A BLOCK OF MEMORY H,L-D,E TO B,C
;
5A93 CD7C5A  MOVE:  CALL  HLDEBC  ;3 ADDR
5A96 CDA05A  MOVDN:  CALL  MOVIN   ;MOVE/CHECK
5A99 CD005A          CALL  TSTOP   ;DONE?
5A9C 03              INX    B       ;NO
5A9D C3965A          JMP     MOVDN

;
5AA0 7E          MOVIN:  MOV     A,M   ;BYTE
5AA1 02          STAX   B       ;NEW LOCATION
5AA2 0A          LDAX   B       ;CHECK
5AA3 BE          CMP    M       ;IS IT THERE?
5AA4 C8          RZ        ;YES
5AA5 60          MOV    H,B     ;ERROR
5AA6 69          MOV    L,C     ;INTO H,L
5AA7 C3425A          JMP    ERRP   ;SHOW BAD

```

The move command requires three addresses. These are the start and stop address of the source block and the start address of the destination block. For example,

>M5800 58FF 4000

will move the first page of the monitor (5800 to 58FF hex) down to the address range 4000 to 40FF hex.

The move routine is designed to move data downward. Thus the first byte of a block can be deleted by moving the remainder of the program downward by one byte. The command

>M103 1000 100

moves the memory block in the address range 103 through 1000 down three bytes to the memory range 100 through FFD hex. On the other hand, a block move in the upward direction must be done carefully.

If the new block does not overlap the old, then there is no problem. But if there is an overlap, then the upward move will destroy some of the data. One possible solution to this problem is to first move the block downward until it is clear of the new upper block. Then move the block up to the desired location. Another possibility is to move the upper half of the block first, then move the lower half.

The best solution is to have a more sophisticated move routine. This routine should first determine whether the move is to be upward or downward. If the movement is downward, then the move commences with the lower part of the block (as with the present program). But if the move is upward, then it should begin with the upper end of the block. The memory pointers should now move downward in memory. With this approach, the original data will be unaltered. This additional feature is more easily coded with the Z-80 block-move routines than with the 8080 instructions.

We have not incorporated the upward-move feature at this time. In developing a system monitor, there must be a tradeoff between features and space. A minimum of idiot-proofing is necessary. But, if we want to have a monitor that will fit into 1K bytes of ROM, we will have to make some compromises.

Notice that this move routine moves a byte from the source location into the destination location. It then reads the byte back from the new location to see that it actually got there. If an attempt is made to move data into read-only memory, protected memory, or defective memory, the process will be terminated. The address of the location will be printed following the letter B (for "bad").

If we want to retain this memory-checking feature, we will not be able to use the Z-80 block-move routines. The problem is that the Z-80 routines perform an automatic pointer increment after each byte is moved. If a memory check is desired, then the destination pointer will have to be backed up after each byte is moved. This will allow the newly moved byte to be checked. Finally, the pointer will have to be incremented again.

VERSION 11: A SEARCH ROUTINE

Sometimes it is necessary to find a particular data byte or address in memory. Or perhaps all occurrences of a data byte or an address within a memory block are needed. For version 11, we will add a hex search routine. Change the version number and the branch table entry for the letter S.

DW SEARCH ;S, MEMORY

Add the new instructions as given in Listing 6.11.

Listing 6.11. Search for 1 or 2 bytes.

```

; SEARCH FOR 1 OR 2 BYTES OVER THE
; RANGE H,L D,E. BYTES ARE IN B,C
; B HAS CARRIAGE RETURN IF ONLY ONE BYTE
; PUT SPACE BTWEEN BYTES IF TWO
; FORMAT: START STOP BYTE1 BYTE2
;
5AAA CD7C5A SEARCH: CALL HLDEBC ;RANGE, 1ST BYTE
5AAD 060D SEAR2: MVI B,CR ;SET FOR 1 BYTE
```



```
5AAF DAB85A      JC      SEAR3      ;ONLY ONE
5AB2 E5          PUSH     H
5AB3 CD9D59      CALL     READHL     ;2ND BYTE
5AB6 45          MOV      B,L        ;INTO C
5AB7 E1          POP      H
5AB8 7E          SEAR3: MOV      A,M    ;GET BYTE
5AB9 B9          CMP      C          ;MATCH?
5ABA C2CF5A      JNZ      SEAR4      ;NO
5ABD 23          INX      H          ;YES
5ABE 78          MOV      A,B        ;ONLY 1?
5ABF FE0D        CPI      CR
5AC1 CAC95A      JZ       SEAR5      ;YES
;
; FOUND FIRST MATCH, CHECK FOR SECOND
;
5AC4 7E          MOV      A,M        ;NEXT BYTE
5AC5 B8          CMP      B          ;MATCH?
5AC6 C2CF5A      JNZ      SEAR4      ;NO
;
5AC9 2B          SEAR5: DCX      H        ;A MATCH
5ACA C5          PUSH     B
5ACB CDDC59      CALL     CRHL     ;SHOW ADDR
5ACE C1          POP      B
5ACF CD005A      SEAR4: CALL     TSTOP   ;DONE?
5AD2 C3B85A      JMP      SEAR3      ;NO
```

Our new feature will display the address of every occurrence of one or two chosen bytes. For example, the command

```
>S100 4FF 0D
```

will print the address of each occurrence of a carriage return (0D hex) over the memory block 100 to 4FF hex. The alternate command

```
>S0 FFFF 3E 10
```

includes two search bytes. This command will look for the byte 3E followed by the byte 10 over the entire 64K-byte memory range. These two bytes might represent the 8080 instruction MVI A,10 or perhaps the address 103E hex.

Notice that if two search bytes are given in the command, they must be separated by a space. If the command is incorrectly given without the space between the bytes, the search will only include the second byte. For example, the command

```
>S0 FFFF 3E10
```

will be interpreted as a search for the byte 10 hex. This occurs because only the last two characters of the field are used.

VERSION 12: ASCII LOAD, SEARCH, AND DISPLAY

At this time, the monitor is hex oriented, but it is capable of limited ASCII operations. For example, the DUMP routine gives both the hex and the ASCII representation of the data. The load and fill commands will accept ASCII characters when preceded by an apostrophe. In version 12, we will add three new ASCII commands: ASCII load, ASCII dump, and ASCII search. A continuous series of ASCII characters (a string), including a carriage return, line feed, tab, and so on, can be entered directly into memory. A straight ASCII dump will render an ASCII portion of memory in its natural form. And we will be able to search the memory for one or two ASCII characters. If the command line begins with the letter A, a branch will occur to a second command processor. The letter following the A will cause a jump to the desired task of dump, load, or search.

Change the version number to 12 and the command table entry for the letter A.

DW ASCII #A, DUMP, LOAD

Type the code from Listing 6.12; assemble the new version and start it up.

Listing 6.12. ASCII load, search, and display.

```

; ASCII SUB-COMMAND PROCESSOR
;
5AD5 CD2559  ASCII:  CALL    GETCH    #NEXT CHAR
5AD8 FE44          CPI      'D'      #DISPLAY
5ADA CA045B          JZ      ADUMP
5ADD FE53          CPI      'S'      #SEARCH
5ADF CA2C5B          JZ      ASCS
5AE2 FE4C          CPI      'L'      #LOAD
5AE4 C2D459          JNZ      ERROR
;
; LOAD ASCII CHARACTERS INTO MEMORY
; QUIT ON CONTROL-X
;
5AE7 CD9D59          CALL     READHL   #ADDRESS
5AEA CDDF59          CALL     OUTHL    #PRINT IT
5AED CD1558  ALOD2:  CALL     INPUTT   #NEXT CHAR
5AF0 CD2A58          CALL     OUTT     #PRINT IT
5AF3 47             MOV      B,A      #SAVE
5AF4 CD3E5A          CALL     CHEKM    #INTO MEMORY
5AF7 23             INX      H        #POINTER
5AF8 7D             MOV      A,L
5AF9 E67F          ANI      7FH      #LINE END?
5AFB C2ED5A          JNZ      ALOD2    #NO
5AFE CDDC59          CALL     CRHL     #NEW LINE
5B01 C3ED5A          JMP      ALOD2
;
; DISPLAY MEMORY IN STRAIGHT ASCII.
; KEEP CARRIAGE RETURN, LINE FEED, CHANGE
; TAB TO SPACE, REMOVE OTHER CONTROL CHAR.
;
```

```

5B04 CD8659      ADUMP: CALL    RDHLDE  ;RANGE
5B07 7E          ADMP2: MOV     A,M     ;GET BYTE
5B08 FE7F        CPI         DEL      ;HIGH BIT ON?
5B0A D2265B      JNC         ADMP4    ;YES
5B0D FE20        CPI         ' '      ;CONTROL?
5B0F D2235B      JNC         ADMP3    ;NO
5B12 FE0D        CPI         CR       ;CARR RET?
5B14 CA235B      JZ          ADMP3    ;YES, OK
5B17 FE0A        CPI         LF       ;LINE FEED?
5B19 CA235B      JZ          ADMP3    ;YES, OK
5B1C FE09        CPI         TAB
5B1E C2265B      JNZ         ADMP4    ;SKIP OTHER
5B21 3E20        MVI         A,' '    ;SPACE FOR TAB
5B23 CD2A58      ADMP3: CALL    OUTT    ;SEND
5B26 CD005A      ADMP4: CALL    TSTOP  ;DONE?
5B29 C3075B      JMP         ADMP2    ;NO

;
; SEARCH FOR 1 OR 2 ASCII CHARACTERS
; NO SPACE BETWEEN ASCII CHARS
; FORMAT: START STOP 1 OR 2 ASCII CHAR
;
5B2C CD8659      ASCS:  CALL    RDHLDE  ;RANGE
5B2F CD2559      CALL    GETCH    ;FIRST CHAR
5B32 4F          MOV     C,A
5B33 CD2559      CALL    GETCH    ;2ND OR CARR RET
5B36 DAAD5A      JC      SEAR2    ;ONLY ONE CHAR
5B39 47          MOV     B,A      ;2ND
5B3A C3B85A      JMP     SEAR3

```

Dump a section of memory with the regular hex dump command. Then enter a line of ASCII characters using the new ASCII load command.

```

>AL4000 <carriage return>
4000 This is a test of the new <cr><lf>
ASCII load routine. <cr><lf>

```

All of these characters will be deposited directly into memory, including the carriage returns and line feeds. Type a control-X to abort the task. Inspect the new addition first with the hex dump

```
>D4000 404F
```

then inspect it with the new ASCII dump:

```
>AD4000 404F
```

Notice the difference. The ASCII dump renders the data as it was originally typed.

A carriage-return line-feed pair will cause a real carriage-return line-feed pair to be sent to the console. Tab characters are not expanded but are rendered as blanks (in line with our goal of reducing the monitor size). All other control characters are ignored.

VERSION 13: INPUT AND OUTPUT TO ANY PORT

The load routines added in versions 4 and 12 allow us to change individual memory locations. And the dump routines added in versions 2 and 12 allow us to inspect individual memory locations. For version 13, we will add a routine to read any I/O port and another to send a byte to any I/O port. This feature will allow us to initialize and test I/O ports.

The 8080 and Z-80 microprocessors can address 256 separate, 8-bit input/output ports. These ports are used for communicating with the console, list, and tape devices. In addition, if there is a front panel, the switches are usually assigned to a separate data port. Also, some disk-controller boards use several I/O ports for communication with the CPU.

It is more difficult to implement these I/O features on an 8080 CPU than on a Z-80. The reason is that the 8080 I/O instructions require the port address to be placed in memory immediately following the IN or OUT command

```
DB 10    IN    10H
D3 11    OUT   11H
```

By comparison, the Z-80 can execute I/O instructions with the device address located in the C register. Nevertheless, we will implement the input and output instructions, at this time, using only 8080 code.

The plan is to write the IN or OUT instruction in memory, write the port number in the next byte, then write a RET instruction in the third position. A call to the address of PORTN will then produce the desired effect. The routine that writes these bytes in the stack area is called PUTIO. Since we are developing a monitor that can be placed in ROM, we will have to perform the actual I/O instructions outside of the regular monitor code area. Three bytes of memory just above the stack were previously set aside for this purpose. They start with the address PORTN.

A fourth routine is also needed. Subroutine BITS is used to convert the binary data read from the selected port into ASCII-coded binary characters. An IN command then prints on the console the port data in both hex and binary. For example, the command

```
>IFF
```

will give the front-panel switch setting in both hex and binary notation.

```
FB 11110000
```

The BITS routine can be coded more efficiently if a Z-80 CPU is available. This is because the Z-80 can shift data in the general-purpose registers, as well as in the accumulator. This is discussed in Chapter 7.

Change the version number to 13 and alter the branch table entries for the letters I and O.

```

DW      IPORT  #I, PORT INPUT
      .
      .
DW      OPORT  #O, PORT OUTPUT

```

Add the new routines to the end of the source code. Assemble version 13 and try it out.

Listing 6.13. Input and output to any port.

```

; INPUT FROM ANY PORT (8080 VERSION)
;
5B3D CD9D59  IPORT: CALL  READHL  #PORT
5B40 4D      MOV    C,L      #PORT TO C
5B41 3EDB      MVI    A,INC   #IN CODE
5B43 CD635B      CALL  PUTIO   #SETUP INPUT
5B46 6F      MOV    L,A
5B47 CDE359      CALL  OUTLL   #HEX VALUE
;
; PRINT L REGISTER IN BINARY (8080 VER)
;
5B4A 0608  BITS:  MVI    B,8    #8 BITS
5B4C 7D      BIT2:  MOV    A,L
5B4D 87      ADD    A        #SHIFT LEFT
5B4E 6F      MOV    L,A
5B4F 3E18      MVI    A,'0'/2 #HALF OF 0
5B51 8F      ADC    A        #DOUBLE+CARRY
5B52 CD2A58      CALL  OUTT    #PRINT BIT
5B55 05      DCR    B
5B56 C24C5B      JNZ    BIT2   #8 TIMES
5B59 C9      RET
;
; OUTPUT BYTE FROM PORT (8080 VERSION)
; FORMAT IS: O,PORT,BYTE
;
5B5A CD9D59  OPORT: CALL  READHL  #PORT
5B5D 4D      MOV    C,L
5B5E CD9D59      CALL  READHL  #DATA
5B61 3ED3      MVI    A,OUTC   #OUT OPCODE
;
; EMULATE Z80 INP AND OUTP FOR 8080
;
5B63 32A057  PUTIO: STA    PORTN  #IN OR OUT CODE
5B66 79      MOV    A,C      #PORT NUMBER
5B67 32A157      STA    PORTN+1
5B6A 3EC9      MVI    A,RETC  #RET OPCODE
5B6C 32A257      STA    PORTN+2
5B6F 7D      MOV    A,L      #OUTPUT BYTE
5B70 C3A057      JMP    PORTN  #EXECUTE

```

If you have a set of front panel switches, give the command

```
>IFF
```

and see if the bit pattern matches the actual switch setting. Next, try to ring your console bell by sending a binary 7.

>011 7

The value of 11 should be changed to your console data port address if it is different.

Modern serial and parallel ports need to be initialized before use. These initialization routines could be placed in the monitor cold-start routines. Initialization can also be performed with the new monitor output command. A Motorola 6850 serial port can be initialized for one stop bit with the two commands

```
>010 3      <reset>
>010 15     <set>
```

where 10 is the address of the status/control port.

VERSION 14: HEXADECIMAL ARITHMETIC

A routine for obtaining the sum and difference of two hexadecimal numbers will now be added. Change the version number to 14. Change the branch table corresponding to the entry H.

```
DW      HMATH      ;H, HEX MATH
```

Place the remaining new lines at the end as usual.

Listing 6.14. Hexadecimal addition and subtraction.

```

; HEXADECIMAL MATH, SUM AND DIFFERENCE
;
5B73 CD9159  HMATH:  CALL    HHLDE  ;TWO NUMBERS
5B76 E5      PUSH    H          ;SAVE H,L
5B77 19      DAD     D          ;SUM
5B78 CDDF59  CALL    OUTHL  ;PRINT IT
5B7B E1      POP     H
5B7C 7D      MOV     A,L
5B7D 93      SUB     E          ;LOW BYTES
5B7E 6F      MOV     L,A
5B7F 7C      MOV     A,H
5B80 9A      SBB     D
5B81 67      MOV     H,A      ;HIGH BYTES
5B82 C3DF59  JMP     OUTHL  ;DIFFERENCE
```

The new feature is executed by typing the letter H and the hex numbers. The response is the sum and the difference.

```
>H8000 4000
C000 4000
```

VERSION 15: MEMORY-TEST PROGRAM

Back in version 6, we installed an automatic memory-size routine. This addition performs a memory check of sorts by testing the first byte of each page. In version 15, we will add a more complete memory-test program. Change the version number and the branch table entry for the letter J (justification):

DW JUST J, MEMORY TEST

Then, type in the new lines as shown in Listing 6.15.

Listing 6.15. A memory-test program.

```

;
; MEMORY TEST
; THAT DOESN'T ALTER CURRENT BYTE
; INPUT RANGE OF ADDRESSES, ABORT WITH ^X
;
5B85 CD8659 JUST: CALL RDHLDE ;RANGE
5B88 E5 PUSH H ;SAVE START ADDR
5B89 7E JUST2: MOV A,M ;GET BYTE
5B8A 2F CMA ;COMPLEMENT IT
5B8B 77 MOV M,A ;PUT IT BACK
5B8C BE CMP M ;DID IT GO?
5B8D C2A55B JNZ JERR ;NO
5B90 2F CMA ;ORIGINAL BYTE
5B91 77 MOV M,A ;PUT IT BACK
5B92 7D JUST3: MOV A,L ;PASS
5B93 93 SUB E ; COMPLETED?
5B94 7C MOV A,H
5B95 9A SBB D
5B96 23 INX H
5B97 DA895B JC JUST2 ;NO
;
; AFTER EACH PASS,
; SEE IF ABORT WANTED
;
5B9A CD2558 CALL INSTAT ;INPUT?
5B9D C4155B CNZ INPUTT ;YES, GET IT
5BA0 E1 POP H ;START ADDR
5BA1 E5 PUSH H ;SAVE AGAIN
5BA2 C3895B JMP JUST2 ;NEXT PASS
;
; FOUND MEMORY ERROR, PRINT POINTER AND
; BIT MAP: 0=GOOD, 1=BAD BIT
;
5BA5 F5 JERR: PUSH PSW ;SAVE COMPLEMENT
5BA6 CDDC59 CALL CRHL ;PRINT POINTER
5BA9 F1 POP PSW
5BAA AE XRA M ;SET BAD BITS
5BAB E5 PUSH H ;SAVE POINTER
5BAC 6F MOV L,A ;BIT MAP TO L
5BAD CD4A5B CALL BITS ;PRINT BINARY
5BB0 E1 POP H
5BB1 C3925B JMP JUST3 ;CONTINUE

```

Assemble the program, load it into memory, and try it out. The memory range from zero to 58FF hex is tested with the command

```
>JO 5800
```

This is a continuing test. The given range is tested over and over until aborted with a control-X command. This memory-test program is not very sophisticated. The routine will not find unusual problems in flakey, dynamic memories. It will, however, locate those regions with no memory, protected memory, and grossly defective memory. The address of each bad location is printed in hex, then the bit pattern follows. ASCII ones are shown for the bad bits and ASCII zeros are given for the good bits.

The test program gets the original memory byte, complements it, and puts it back. It then complements it a second time and restores the original byte. Thus, the original memory is left intact. The only caution here is that the stack area should not be tested.

Much more sophisticated memory test programs are needed for difficult memory errors. Of course, such programs will require a lot of memory, and so would not fit into a compact system monitor. One feature of such a program is to provide a delay between the time the test byte is placed into memory and the time that the byte is checked. One disadvantage of a more powerful memory-test program is that it does not protect the original memory contents.

VERSION 16: REPLACE ONE BYTE WITH ANOTHER

In version 11 we added a memory-search routine. This feature gives us the ability to find every occurrence of a particular byte. A companion feature added in version 16 allows us to change every occurrence of a particular byte to a different byte. Change the version number and the branch table corresponding to the letter R.

```
DW      REPL      ;R, REPLACE
```

Add the new lines shown in listing 6.16 to the end of the program.

Listing 6.16. Replace one hex byte with another.

```

; REPLACE HEX BYTE WITH ANOTHER
; OVER GIVEN RANGE
; FORMAT IS: START, STOP, ORIG, NEW
;
5BB4 CD7C5A    REPL:  CALL    HLDEBC  ;RANGE, 1ST BYTE
5BB7 DAD459    JC      ERROR    ;NO 2ND
5BBA 41        MOV     B,C      ;1ST TO B
5BBB E5        PUSH    H
```


5BBC CD9D59		CALL	READHL	\$2ND BYTE
5BBF 4D		MOV	C,L	\$INTO C
5BC0 E1		POP	H	
5BC1 7E	REPL2:	MOV	A,M	\$FETCH BYTE
5BC2 B8		CMF	B	\$A MATCH?
5BC3 C2CC5B		JNZ	REPL3	\$NO
5BC6 71		MOV	M,C	\$SUBSTITUTE
5BC7 79		MOV	A,C	
5BC8 BE		CMF	M	\$SAME?
5BC9 C2435A		JNZ	ERRB	\$NO, BAD
5BCC CD005A	REPL3:	CALL	TSTOP	\$DONE?
5BCF C3C15B		JMP	REPL2	

Assemble version 16 and try it out. Move three lines of the monitor's code to a lower place using the M command.

```
>M5800 582F 4000
```

Dump these three lines of memory with the D command.

```
>D4000 402F
```

Change every occurrence of the byte C3 found in those lines to a 40 hex using the command

```
>R4000 402F C3 40
```

Notice that a space must separate the two bytes C3 and 40. Now, dump this portion of memory with the command

```
>D4000 402F
```

The new byte is an ASCII "at" sign (@), therefore it will show up clearly on the ASCII portion of the dump.

The replace routine can be useful for relocating a short executable program. Suppose that a routine is programmed for execution at 3000 hex. It can be moved to 4000 hex with the block-move command

```
>M3000 3FFF 4000
```

However, the program will not run at the new location if there are absolute jumps present. The high byte of each jump address will have to be changed from 30 to 40 in this case. The search routine can be used to find all occurrences of 30 hex in the program.

```
>S4000 4FFF 30
```

Then the replace command can be given to convert each 30 hex into a 40 hex.

```
>R4000 4FFF 30 40
```

Another use for the replace command is to convert an assembly language source file from one format to another. For example, the CP/M format requires a line feed to follow a carriage return. But another assembler may generate lines in which only the carriage return is placed at the end of each line. In this case, the original file can be loaded into memory. Then, all of the carriage returns (OD hex) can be replaced with an ASCII character such as a # symbol (23 hex).

```
>R100 38FF 0D 23
```

After the file is altered with the monitor, it can be saved on a disk. The final step can be performed with the system editor. The global replace command of this editor can be used to replace every occurrence of the # sign with a carriage-return/line-feed pair. With the Word-Master editor, the command would be

```
*MR#$AN$OTT
```

The first step required the monitor because the system editors cannot be directed to globally change a carriage return to something else. The carriage-return/line-feed pair must be treated as a unit.

VERSION 17: COMPARE TWO BLOCKS OF MEMORY

This last addition to our system monitor will fill out the size to just under 1K bytes. The new routine will allow us to compare two blocks of memory. If discrepancies are found, the address and the contents of the appropriate location in both blocks will be shown. Change the version number and the branch table corresponding to the letter R.

```
DW      VERM      $V
```

Add the new lines shown in Listing 6.17.

Listing 6.17. Compare two blocks of memory.

```

                                ; GIVE RANGE OF 1ST BLOCK
                                ; AND START OF SECOND
                                ;
5BD2 CD7C5A    VERM:  CALL    HLDEBC  ;3 ADDRESSES
5BD5 0A        VERM2: LDAX    B        ;FETCH BYTE
5BD6 BE        CMP     M        ;SAME AS OTHER?
5BD7 CAF35B    JZ      VERM3    ;YES
5BDA E5        PUSH   H        ;DIFFERENT
5BDB C5        PUSH   B
5BDC CDDC59    CALL    CRHL     ;PRINT 1ST POINTER
5BDF 4E        MOV     C,M      ;FIRST BYTE
5BE0 CDE459    CALL    OUTHEX   ;PRINT IT
5BE3 3E3A      MVI     A,';'

```

5BE5 CD2A58	CALL	OUTT	
5BE8 E1	POP	H	#B,C TO H,L
5BE9 CDDF59	CALL	OUTH	#SECOND POINTER
5BEC 4E	MOV	C,M	#2ND BYTE
5BED CDEC59	CALL	OUTHX	#PRINT IT
5BF0 4D	MOV	C,L	#RESTORE C
5BF1 44	MOV	B,H	#AND B
5BF2 E1	POP	H	#AND H,L
5BF3 CD005A	VERM3: CALL	TSTOP	#DONE?
5BF6 03	INX	B	#2ND POINTER
5BF7 C3D55B	JMP	VERM2	

The symbol table should now look like this.

5B07 ADMP2	5B23 ADMP3	5B26 ADMP4	5B04 ADUMP
5AED ALOD2	00F7 AFOS	5AD5 ASCII	5B2C ASCS
0008 BACKUP	5B4C BIT2	5B4A BITS	5A09 CALLS
0011 CDATE	0011 CDATE0	5A3E CHEKM	5B09 CIN
5B58 COLD	5B06 COUT	000D CR	59DC CRHL
590F CRLF	0010 CSTAT	0010 CSTAT0	0008 CTRH
0011 CTRQ	0013 CTRS	0018 CTRX	007F DEL
5945 DUMP	5948 DUMP2	594B DUMP3	595E DUMP4
5967 DUMP5	5A45 ERR2	5A43 ERRLB	59D4 ERROR
5A42 ERRP	001B ESC	5A5D FILL	5A66 FILL2
5A6C FILL3	5A75 FILL4	5B0F GCHAR	5939 GETC4
5925 GETCH	5A08 GO	59F5 HEX1	5991 HHLDE
5A7C HLDEBC	5A8A HLDECK	5B73 HMATH	57A5 IBUFC
57A6 IBUFF	57A3 IBUFF	00DB INC	5B0C INLN
0001 INMSK	5B05 INPL2	5B11 INPL3	5919 INPLB
5901 INPLC	5BFB INPLE	5BDD INPLI	5B00 INPLN
5B1B INPUT2	5B15 INPUTT	5B25 INSTAT	5B3D IPORT
5BA5 JERR	5B85 JUST	5B89 JUST2	5B92 JUST3
000A LF	5A0D LOAD	5A10 LOAD2	5A33 LOAD3
5A30 LOAD4	5A37 LOAD6	5A96 MOVDN	5A93 MOVE
5AA0 MOVIN	5B78 MSIZE	59C4 NIB	5B6A NPAGE
0002 OMSK	5B5A OPORT	5B00 ORGIN	5B2B OUT2
5B39 OUT3	5B44 OUT4	00D3 OUTC	5B12 OUTH
59E4 OUTHEX	59DF OUTHL	59EC OUTHX	59E3 OUTLL
59E7 OUTSP	5B2A OUTT	59B1 PASC2	59B3 PASC3
5976 PASCI	57A0 PORTN	5B63 PUTIO	59A2 RDHL2
59B7 RDHL4	59C1 RDHL5	59B9 RDHL2	59B6 RDHLDE
599D READHL	5A4E REGS	5B84 REPL	5B01 REPL2
5BCC REPL3	5B03 RESTRT	00C9 RETC	5AAD SEAR2
5AB8 SEAR3	5ACF SEAR4	5AC9 SEAR5	5AAA SEARCH
593B SENDM	5B4F SIGNON	57A0 STACK	5B00 START
0009 TAB	5B9C TABLE	0018 TOP	5A00 TSTOP
5B02 VERM	5B05 VERM2	5BF3 VERM3	3731 VERS
5B61 WARM	5A55 ZERO		

Try the new addition by first moving a copy of the monitor down to a lower memory location.

```
>M5B00 5BFF 4B00
```

Then verify that the two copies are the same.

```
>V5800 5BFF 4800
```

Of course this step is not necessary, since there is a verification step included in the block-move routine. Change one byte in the new location so that there will be a difference.

```
>L4820
4820 . XX 0      <zero location 4820>
. . .      AX    <quit>
```

Then, give the verification command again.

```
>V5800 5BFF 4800
```

Because you changed one byte of the copy, there should be an indication of error.

This compare routine completes the 1K 8080 system monitor. We have incorporated many useful features into a minimum of space. We have carefully distinguished program code from data code so that the monitor can be placed into ROM or PROM.

AUTOMATIC EXECUTION OF THE MONITOR

If you program the monitor into ROM, it will be ready to use each time the computer is turned on. On the other hand, you may want to copy it from disk into memory each time it is needed. We have been loading the monitor with the system debugger each time it is needed. But it is easier to include a short loader program at the beginning of the monitor. Then you can execute the monitor just by typing its name.

A suitable loader program is given in Listing 6.18. Type the program into your editor. There are two locations that need to be matched to your monitor; these are the addresses of START and FINAL. START must correspond to the first address of your monitor. The address FINAL is the last address of the monitor.

Listing 6.18. Loader program to move the monitor.

```
5800 =      START    EQU      5800H    ;MONITOR START
5BFF =      FINAL    EQU      5BFFH    ;MONITOR END
A920 =      OFFST    EQU      120-START ;LOAD OFFSET
;
0100      ORG      100H          ;START HERE
;
0100 210058      LXI      H,START ;NEW START
0103 012001      LXI      B,120H  ;OLD START
0106 11FF5B      LXI      D,FINAL
;
0109 0A          ; LOOP:  LDAX    B          ;GET A BYTE
010A 77          MOV     M,A        ;TO NEW PLACE
010B BE          CMP     M          ;DID IT GO?
```

```
010C C20000      JNZ      0          ;NO, QUIT
010F 23          INX      H          ;INCREMENT
0110 03          INX      B          ; POINTERS
0111 7B          MOV      A,E        ;DONE?
0112 95          SUB      L
0113 7A          MOV      A,D
0114 9C          SBB      H
0115 D20901      JNC      LOOP        ;KEEP GOING
0118 C30058      JMP      START      ;DONE
;
011B            END
```

Assemble the loader program, then load it into memory with the debugger SID or DDT.

```
A>DDT  MOVE.HEX
```

Next, place a copy of the monitor into memory starting at address 120 hex. If the monitor is already in memory, a copy can be generated with the monitor itself. DDT or SID can also be used for this task. The command is

```
M5800 5BFF 120
```

If the monitor resides on disk as a hex file, it can be loaded with the debugger after you calculate the offset. The offset is necessary since hex files are normally loaded at the operating address, but we want to put it somewhere else.

The required offset should be given in the assembly listing of the loader program as the value of the equate OFFST. If your assembler doesn't print such values, then use the debugger to calculate the value.

```
H120  5800  <starting value of monitor>
5920  A920
<sum>  <difference>
```

Give the commands

```
IMON17.HEX
R<offset>
```

so that the monitor will be loaded starting at address 120 hex.
Return to the CP/M system

```
GO      <so to zero>
```

and save the combination

```
A>SAVE 5  MONITOR.COM
```

From now on, all you have to do is type the command

A>MONITOR

and the monitor will automatically start up.

What actually happens is that the combination of the monitor and the loader program is first copied into memory at 100 hex. The move program relocates the monitor from address 120 hex to its proper place. Then control is transferred to the monitor. As each byte is moved to the new location, it is checked to see that it actually got there. If not, the process is terminated and control returns to CP/M.

This short loader can be placed on the front of any program that must be relocated. Only the first two instructions may have to be changed to reflect the proper starting and ending addresses.

In the next chapter, we will convert our monitor to Z-80 code. The Z-80 version will be smaller so that we can incorporate a few additional features and still be able to fit the program into 1K of ROM. The features in the next chapter can be incorporated in the 8080 version, but they will take so much space that the monitor will no longer fit into 1K bytes.

CHAPTER SEVEN

A Z-80 System Monitor

The system monitor developed in Chapter 6 contains many features. Since the size is less than 1,024 bytes, it will easily fit into a 1K PROM, such as the 2708 EPROM. It can then be ready for use as soon as the computer is turned on. But, in this case, it may be necessary to include a routine to initialize the peripheral ports, such as those that handle the console and printer. In addition, you might want to send output to a printer as well as to the video console. If these two features are added to the monitor, the size will increase beyond 1K bytes and it will not fit into a single 1K PROM.

One way to add these new features without increasing the monitor's size is to remove some of the original routines. Another way, if you have a Z-80 CPU, is to convert some of the instructions to the more compact Z-80 equivalent operations. The latter approach will be followed in this chapter. Listing 7.1 gives the final version with all changes discussed in this chapter. The symbol table at the end can be used to find the routines of interest.

Listing 7.1 The Z-80 version of the system monitor.

```

                                TITLE    Z-80 SYSTEM MONITOR
                                $
                                $ (Date goes here)
                                $
                                $ FOUR SECTIONS HAVE BEEN REMOVED:
                                $  VERS EQU      ...      (1 LINE)
                                $  SIGNON:      ...      (4 LINES)
                                $  LXI   D,SIGNON  (2 LINES)
                                $  SENDM:      ...      (6 LINES)
                                $
                                $ ONE SECTION HAS BEEN ADDED:
                                $  LIST OUPUT ROUTINES
                                $
0018                                TOP      EQU      24      ;MEMORY TOP, K BYTES
5800                                ORGIN    EQU      (TOP-2)*1024 ;PROGRAM START
                                $
```

```

0000      ASEG      #ABSOLUTE CODE
      .Z80
      ORG      ORGIN
      ;
57A0      STACK    EQU      ORGIN-60H
0010      CSTAT    EQU      10H      #CONSOLE STATUS
0011      CDATA    EQU      CSTAT+1 #CONSOLE DATA
0001      INMSK    EQU      1        #INPUT MASK
0002      OMSK     EQU      2        #OUTPUT MASK
0012      LSTAT    EQU      12H      #LIST STATUS (18)
0013      LDATA    EQU      LSTAT+1 #LIST DATA (18)
0002      LOMSK    EQU      2        #OUTPUT MASK (18)
0004      NNULS    EQU      4        #LIST NULLS (18)
      ;
57A0      PORTN    EQU      STACK    #CONS=0,LIST=1
57A3      IBUFF    EQU      STACK+3 #BUFFER POINTER
57A5      IBUFC    EQU      IBUFF+2 #BUFFER COUNT
57A6      IBUFF    EQU      IBUFF+3 #INPUT BUFFER
      ;
0008      CTRH     EQU      8        #^H BACKSPACE
0009      TAB      EQU      9        #^I
0010      CTRP     EQU      16       #^P (18)
0011      CTRQ     EQU      17       #^Q
0013      CTRS     EQU      19       #^S
0018      CTRX     EQU      24       #^X, ABORT
0008      BACKUP   EQU      CTRH     #BACKUP CHAR
007F      DEL      EQU      127      #RUBOUT
00F7      APOS     EQU      (39-'0') AND OFFH
000D      CR       EQU      13       #CARRIAGE RET
000A      LF       EQU      10       #LINE FEED
      ;
      START:
5800 C3 587E      JP      COLD      #COLD START
5803 C3 5891      RESTR: JP      WARM  #WARM START
      ;
      ; VECTORS TO USEFUL ROUTINES
      ;
5804 C3 5835      COUT:  JP      OUTT   #OUTPUT CHAR
5809 C3 5815      CIN:   JP      INPUTT #INPUT CHAR
580C C3 58FD      INLN:  JP      INPLN  #INPUT LINE
580F C3 5949      GCHAR: JP      GETCH  #GET CHAR
5812 C3 59F8      OUTH:  JP      OUTHX  #BIN TO HEX
      ;
      ; CONSOLE INPUT ROUTINE
      ; CHECK FOR CONTROL-P, LIST TOGGLE
      ;
5815 CD 5827      INPUTT: CALL INSTAT  #CHECK STATUS
5818 28 FB        JR      Z,INPUTT  #NOT READY
581A DB 11        INPUT2: IN      A,(CDATA) #GET BYTE
581C E6 7F        AND      DEL
581E FE 18        CP      CTRX     #ABORT?
5820 28 DE        JR      Z,START  #YES
5822 FE 10        CP      CTRP     #^P?
5824 28 06        JR      Z,SETLST #LIST
5826 C9          RET
      ;
      ; GET CONSOLE-INPUT STATUS
      ;

```



```

5827 DB 10      INSTAT: IN      A,(CSTAT)
5829 E6 01      AND      INMSK
582B C9      RET

;
; TOGGLE LIST OUTPUT WITH CONTROL-P
;
582C 3A 57A0    SETLST: LD      A,(PORTN) ;CHECK FLAG
582F 2F      CPL      ;INVERT
5830 32 57A0    LD      (PORTN),A ;SAVE
5833 18 E0      JR      INPUTT ;NEXT BYTE

;
; CONSOLE OUTPUT ROUTINE
;
5835 F5      OUTT:  PUSH     AF
5836 3A 57A0    LD      A,(PORTN) ;WHERE?
5839 B7      OR      A ;ZERO?
583A 20 1F      JR      NZ,LOUT ;LIST OUTPUT
583C CD 5827    OUT2:  CALL    INSTAT ;INPUT?
583F 28 10      JR      Z,OUT4 ;NO
5841 CD 581A    CALL    INPUT2 ;GET INPUT
5844 FE 13      CP      CTRS ;FREEZE?
5846 20 F4      JR      NZ,OUT2 ;NO
5848 CD 5815    OUT3:  CALL    INPUTT ;INPUT?
584B FE 11      CP      CTRQ ;RESUME?
584D 20 F9      JR      NZ,OUT3 ;NO
584F 18 EB      JR      OUT2

;
5851 DB 10      OUT4:  IN      A,(CSTAT) ;GET STATUS
5853 E6 02      AND      OMSK
5855 28 E5      JR      Z,OUT2 ;NOT READY
5857 F1      POP     AF
5858 D3 11      OUT     (CDATA),A ;SEND DATA
585A C9      RET

;
; LIST OUTPUT ROUTINE
; SEND TO CONSOLE TOO
;
585B CD 5827    LOUT:  CALL    INSTAT ;INPUT?
585E C4 581A    CALL    NZ,INPUT2 ;YES, GET IT

;
5861 DB 12      IN      A,(LSTAT) ;CHECK STATUS
5863 E6 02      AND      OMSK
5865 28 F4      JR      Z,LOUT ;NOT READY
5867 F1      POP     AF
5868 D3 13      OUT     (LDATA),A ;SEND DATA
586A D3 11      OUT     (CDATA),A ;CONSOLE TOO
586C E6 7F      AND      7FH ;MASK PARITY

;
; ADD TIME DELAY AFTER CARRIAGE RETURN
;
586E FE 0D      CP      CR ;CARRIAGE RET?
5870 C0      RET     NZ ;NO
5871 D5      PUSH    DE ;USE D,E
5872 16 78      LD      D,30 * NNULS
5874 1E FA      OUTCR: LD      E,250
5876 1D      OUTCR2: DEC     E
5877 20 FD      JR      NZ,OUTCR2 ;INNER LOOP
5879 15      DEC     D

```

```

587A 20 F8      JR      NZ,OUTCR  ;OUTER LOOP
587C D1         POP      DE        ;RESTORE
587D C9         RET

;
; CONTINUATION OF COLD START
;
587E 31 57A0    COLD:  LD      SP,STACK
;
; INITIALIZE I/O PORTS
;
5881 3E 03      LD      A,3
5883 D3 10      OUT      (CSTAT),A ;RESET
5885 D3 12      OUT      (LSTAT),A
5887 3E 15      LD      A,15H
5889 D3 10      OUT      (CSTAT),A ;SET
588B D3 12      OUT      (LSTAT),A
588D AF         XOR      A        ;GET A ZERO
588E 32 57A0    LD      (PORTN),A ;RESET
;
; WARM-START ENTRY
;
5891 21 5891    WARM:  LD      HL,WARM ;RET TO
5894 E5         PUSH     HL        ; HERE
;
; FIND TOP OF USABLE MEMORY.
; CHECK FIRST BYTE OF EACH PAGE OF MEMORY
; STARTING AT ADDRESS ZERO. STOP AT STACK
; OR MISSING/DEFECTIVE/PROTECTED MEMORY.
; DISPLAY HIGH BYTE OF MEMORY TOP.
;
5895 21 0000    LD      HL,0      ;PAGE ZERO
5898 06 57      LD      B,HIGH STACK ;STOP HERE
589A 7E         LD      A,(HL)    ;GET BYTE
589B 2F         CPL             ;COMPLEMENT
589C 77         LD      (HL),A    ;PUT IT BACK
589D BE         CP      (HL)     ;SAME?
589E 20 05      JR      NZ,MSIZE ;NO, MEM TOP
58A0 2F         CPL             ;ORIG BYTE
58A1 77         LD      (HL),A    ;RESTORE IT
58A2 24         INC      H        ;NEXT PAGE
58A3 10 F5      DJNZ    NPAGE    ;KEEP GOING
58A5 4C         MSIZE: LD      C,H ;MEM TOP
58A6 CD 5935    CALL     CRLF     ;NEW LINE
58A9 CD 59F8    CALL     OUTHX    ;PRINT MEM SIZE
58AC CD 58FD    CALL     INPLN    ;CONSOLE LINE
58AF CD 5949    CALL     GETCH    ;FIRST CHAR
;
; MAIN COMMAND PROCESSOR
;
58B2 D6 41      SUB      'A'      ;CONVERT OFFSET
58B4 DA 59E0    JF      C,ERROR ; < A
58B7 FE 1A      CP      'Z'-'A'+1
58B9 D2 59E0    JF      NC,ERROR ; > Z
58BC 87         ADD      A,A      ;DOUBLE
58BD 21 58C9    LD      HL,TABLE ;START
58C0 16 00      LD      D,0
58C2 5F         LD      E,A      ;OFFSET
58C3 19         ADD      HL,DE    ;ADD TO TABLE

```

58C4 5E	LD	E,(HL)	LOW BYTE
58C5 23	INC	HL	
58C6 56	LD	D,(HL)	HIGH BYTE
58C7 EB	EX	DE,HL	INTO H,L
58C8 E9	JP	(HL)	GO THERE

;
 ; COMMAND TABLE
 ;

58C9 5AD3	TABLE:	DW	ASCII	A, DUMP,LOAD
58CB 59E0		DW	ERROR	B
58CD 5A15		DW	CALLS	C, SUBROUTINE
58CF 595E		DW	DUMP	D, DUMP
58D1 59E0		DW	ERROR	E
58D3 5A64		DW	FILL	F, MEMORY
58D5 5A14		DW	GO	G, GO
58D7 5B51		DW	HMATH	H, HEX MATH
58D9 5B31		DW	IPORT	I, PORT INPUT
58DB 5B60		DW	JUST	J, MEMORY TEST
58DD 59E0		DW	ERROR	K
58DF 5A19		DW	LOAD	L, LOAD
58E1 5A97		DW	MOVE	M, MEMORY
58E3 59E0		DW	ERROR	N
58E5 5B47		DW	OPORT	O, PORT OUTPUT
58E7 59E0		DW	ERROR	P
58E9 59E0		DW	ERROR	Q
58EB 5B8C		DW	REPL	R, REPLACE
58ED 5AAD		DW	SEARCH	S, MEMORY
58EF 59E0		DW	ERROR	T
58F1 59E0		DW	ERROR	U
58F3 5BA8		DW	VERM	V, VERIFY MEM
58F5 59E0		DW	ERROR	W
58F7 5A56		DW	REGS	X, STK PNTR
58F9 59E0		DW	ERROR	Y
58FB 5A5D		DW	ZERO	Z, MEMORY

;
 ; INPUT A LINE FROM CONSOLE AND PUT IT
 ; INTO THE BUFFER. CARRIAGE RETURN ENDS
 ; THE LINE. RUBOUT OR ^H CORRECTS LAST
 ; LAST ENTRY. CONTROL-X RESTARTS LINE.
 ; OTHER CONTROL CHARACTERS ARE IGNORED
 ;

58FD 3E 3E	INPLN:	LD	A,'>'	PROMPT
58FF CD 5835		CALL	OUTT	
5902 21 57A6	INPL2:	LD	HL,IBUFF	BUFFER ADDR
5905 22 57A3		LD	(IBUFF),HL	SAVE POINTER
5908 0E 00		LD	C,0	COUNT
590A CD 5815	INPLI:	CALL	INPUTT	CONSOLE CHAR
590D FE 20		CP	' '	CONTROL?
590F 38 18		JR	C,INPLC	YES
5911 FE 7F		CP	DEL	DELETE
5913 28 2A		JR	Z,INPLB	YES
5915 FE 5B		CP	'Z'+1	UPPER CASE?
5917 38 02		JR	C,INPL3	YES
5919 E6 5F		AND	5FH	MAKE UPPER
591B 77	INPL3:	LD	(HL),A	INTO BUFFER
591C 3E 20		LD	A,32	BUFFER SIZE
591E B9		CP	C	FULL?
591F 28 E9		JR	Z,INPLI	YES, LOOP

```

5921 7E          LD      A,(HL)  ;GET CHAR
5922 23          INC      HL      ;INCR POINTER
5923 0C          INC      C       ;AND COUNT
5924 CD 5835     INPLE: CALL OUTT  ;SHOW CHAR
5927 18 E1       JR       INPLI   ;NEXT CHAR

;
; PROCESS CONTROL CHARACTER
;
5929 FE 08     INPLC: CP      CTRH  ;^H?
592B 28 12     JR       Z,INPLB  ;YES
592D FE 0D     CP      CR       ;RETURN?
592F 20 D9     JR       NZ,INPLI ;NO, IGNORE

;
; END OF INPUT LINE
;
5931 79          LD      A,C      ;COUNT
5932 32 57A5     LD      (IBUFC),A ;SAVE

;
; CARRIAGE-RETURN, LINE-FEED ROUTINE
;
5935 3E 0D     CRLF: LD      A,CR
5937 CD 5835     CALL OUTT  ;SEND CR
593A 3E 0A     LD      A,LF
593C C3 5835     JP       OUTT  ;SEND LF

;
; DELETE PRIOR CHARACTER IF ANY
;
593F 79     INPLB: LD      A,C      ;CHAR COUNT
5940 B7     OR      A       ;ZERO?
5941 28 C7     JR       Z,INPLI  ;YES
5943 2B     DEC     HL      ;BACK POINTER
5944 0D     DEC     C       ;AND COUNT
5945 3E 08     LD      A,BACKUP  ;CHARACTER
5947 18 DB     JR       INPLE     ;SEND

;
; GET A CHARACTER FROM CONSOLE BUFFER
; SET CARRY IF EMPTY
;
5949 E5     GETCH: PUSH     HL      ;SAVE REGS
594A 2A 57A3 LD      HL,(IBUFF) ;GET POINTER
594D 3A 57A5 LD      A,(IBUFC) ;AND COUNT
5950 D6 01     SUB     1       ;DECR WITH CARRY
5952 38 08     JR       C,GETC4  ;NO MORE CHAR
5954 32 57A5     LD      (IBUFC),A ;SAVE NEW COUNT
5957 7E     LD      A,(HL)  ;GET CHARACTER
5958 23     INC     HL      ;INCR POINTER
5959 22 57A3     LD      (IBUFF),HL ;AND SAVE
595C E1     GETC4: POP     HL      ;RESTORE REGS
595D C9     RET

;
; DUMP MEMORY IN HEXADECIMAL AND ASCII
;
595E CD 5999     DUMP: CALL     RDHLDE ;RANGE
5961 CD 59E8     DUMP2: CALL    CRHL  ;NEW LINE
5964 4E     DUMP3: LD      C,(HL)  ;GET BYTE
5965 CD 59F8     CALL    OUTHX  ;PRINT
5968 23     INC     HL      ;POINTER
5969 7D     LD      A,L

```

```

596A E6 0F      AND      0FH      $LINE END?
596C 28 07      JR       Z,DUMP4  $YES, ASCII
596E E6 03      AND      3        $SPACE
5970 CC 59F3     CALL     Z,OUTSP  $ 4 BYTES
5973 18 EF      JR       DUMP3   $NEXT HEX
5975 CD 59F3     DUMP4: CALL    OUTSP
5978 D5         PUSH     DE
5979 11 FFF0     LD       DE,-10H $RESET LINE
597C 19         ADD      HL,DE
597D D1         POP      DE
597E CD 598B     DUMP5: CALL    PASCII $ASCII DUMP
5981 CD 5A0C     CALL     TSTOP  $DONE?
5984 7D         LD       A,L      $NO
5985 E6 0F      AND      0FH      $LINE END?
5987 20 F5      JR       NZ,DUMP5 $NO
5989 18 D6      JR       DUMP2

$
$ DISPLAY MEMORY BYTE IN ASCII IF
$ POSSIBLE, OTHERWISE GIVE DECIMAL PNT
$

598B 7E         LD       A,(HL)  $GET BYTE
598C FE 7F      CP       DEL     $HIGH BIT ON?
598E 30 04      JR       NC,PASC2 $YES
5990 FE 20      CP       ' '     $CONTROL CHAR?
5992 30 02      JR       NC,PASC3 $NO
5994 3E 2E      PASC2: LD      A,'.' $CHANGE TO DOT
5996 C3 5835     PASC3: JP      OUTT  $SEND

$
$ GET H,L AND D,E FROM CONSOLE
$ CHECK THAT D,E IS LARGER

5999 CD 59A3     RDHLDE: CALL   HHLDE
599C 7B         RDHLD2: LD      A,E
599D 95         SUB      L        $E - L
599E 7A         LD       A,D
599F 9C         SBC      A,H      $D - H
59A0 38 3E      JR       C,ERROR  $H,L BIGGER
59A2 C9         RET

$
$ INPUT H,L AND D,E
$

59A3 CD 59AE     HHLDE: CALL    READHL $H,L
59A6 38 38      JR       C,ERROR  $ONLY 1 ADDR
59A8 EB         EX       DE,HL    $SAVE IN D,E
59A9 CD 59AE     CALL     READHL  $D,E
59AC EB         EX       DE,HL    $PUT BACK
59AD C9         RET

$
$ INPUT H,L FROM CONSOLE
$

59AE D5         READHL: PUSH    DE
59AF C5         PUSH     BC      $SAVE REGS
59B0 21 0000     LD       HL,0    $CLEAR
59B3 CD 5949     RDHL2: CALL    GETCH $GET CHAR
59B6 38 15      JR       C,RDHL5  $LINE END
59B8 CD 59D0     CALL     NIB     $TO BINARY
59BB 38 08      JR       C,RDHL4  $NOT HEX
59BD 29         ADD      HL,HL    $SHIFT LEFT
59BE 29         ADD      HL,HL    $FOUR

```

```

59BF 29          ADD     HL,HL    ; BYTES
59C0 29          ADD     HL,HL
59C1 B5          OR      L        ;ADD NEW CHAR
59C2 6F          LD      L,A
59C3 18 EE       JR      RDHL2    ;NEXT
;
; CHECK FOR COMMA OR BLANK AT END
;
59C5 FE F7       RDHL4: CP      APOS    ;APOSTROPHE
59C7 28 04       JR      Z,RDHL5 ;ASCII INPUT
59C9 FE F0       CP      (' '-0') AND OFFH
59CB 20 13       JR      NZ,ERROR ;NOT BLANK
59CD C1          RDHL5: POP      BC
59CE D1          POP      DE      ;RESTORE
59CF C9          RET
;
; CONVERT ASCII CHARACTERS TO BINARY
;
59D0 D6 30       NIB:  SUB      '0'    ;ASCII BIAS
59D2 D8          RET      C          ; < 0
59D3 FE 17       CP      'F'-'0'+1
59D5 3F          CCF          ;INVERT
59D6 D8          RET      C          ;ERROR, > F
59D7 FE 0A       CP      10
59D9 3F          CCF          ;INVERT
59DA D0          RET      NC        ;NUMBER 0-9
59DB D6 07       SUB      'A'-'9'-1
59DD FE 0A       CP      10        ;REMOVE :-
59DF C9          RET              ;LETTER A-F
;
; PRINT ? ON IMPROPER INPUT
;
59E0 3E 3F       ERROR: LD      A,'?'
59E2 CD 5835     CALL     OUTT
59E5 C3 5800     JP      START    ;TRY AGAIN
;
; START NEW LINE, GIVE ADDRESS
;
59E8 CD 5935     CRHL:  CALL     CRLF    ;NEW LINE
;
; PRINT H,L IN HEX
;
59EB 4C          OUTHL: LD      C,H
59EC CD 59F8     CALL     OUTHX    ;H
59EF 4D          OUTLL: LD      C,L
;
; OUTPUT HEX BYTE FROM C AND A SPACE
;
59F0 CD 59F8     OUTHEX: CALL     OUTHX
;
; OUTPUT A SPACE
;
59F3 3E 20       OUTSP: LD      A,' '
59F5 C3 5835     JP      OUTT
;
; OUTPUT A HEX BYTE FROM C
; BINARY TO ASCII HEX CONVERSION
;

```

```

59F8 79          OUTHX: LD      A,C
59F9 1F          RRA          #ROTATE
59FA 1F          RRA          # FOUR
59FB 1F          RRA          # BITS TO
59FC 1F          RRA          # RIGHT
59FD CD 5A01     CALL      HEX1 #UPPER CHAR
5A00 79          LD      A,C   #LOWER CHAR
5A01 E6 0F       HEX1: AND     0FH #TAKE 4 BITS
5A03 C6 90       ADD     A,90H
5A05 27          DAA          #DAA TRICK
5A06 CE 40       ADC     A,40H
5A08 27          DAA
5A09 C3 5835     JP      OUTT

```

```

;
; CHECK FOR END, H,L MINUS D,E
; INCREMENT H,L
;

```

```

5A0C 23          TSTOP: INC     HL
5A0D 7B          LD      A,E
5A0E 95          SUB     L      # E - L
5A0F 7A          LD      A,D
5A10 9C          SBC     A,H    # D - H
5A11 D0          RET     NC     #NOT DONE
5A12 E1          POP     HL     #RAISE STACK
5A13 C9          RET

```

```

;
; ROUTINE TO GO ANYWHERE IN MEMORY
; FOR CALL ENTRY, ADDRESS OF WARM
; IS ON STACK, SO A SIMPLE RET
; WILL RETURN TO THIS MONITOR
;

```

```

5A14 E1          GO:   POP     HL      #RAISE STACK
5A15 CD 59AE     CALLS: CALL    READHL #GET ADDRESS
5A18 E9          JP      (HL)    #GO THERE

```

```

;
; LOAD HEX OR ASCII CHAR INTO MEMORY
; FROM CONSOLE. CHECK TO SEE IF
; THE DATA ACTUALLY GOT THERE
; APOSTROPHE PRECEEDS ASCII CHAR
; CARRIAGE RET PASSES OVER LOCATION
;

```

```

5A19 CD 59AE     LOAD:  CALL    READHL #ADDRESS
5A1C CD 59EB     LOAD2: CALL    OUTHL #PRINT IT
5A1F CD 598B     CALL    PASCII #ASCII
5A22 CD 59F3     CALL    OUTSP
5A25 4E          LD      C,(HL) #ORIG BYTE
5A26 CD 59F0     CALL    OUTHEX #HEX
5A29 E5          PUSH    HL      #SAVE PNTR
5A2A CD 5902     CALL    INPL2 #INPUT
5A2D CD 59AE     CALL    READHL #BYTE
5A30 45          LD      B,L     # TO B
5A31 E1          POP     HL
5A32 FE F7       CP      APOS
5A34 28 0A       JR      Z,LOAD6 #ASCII INPUT
5A36 79          LD      A,C     #HOW MANY?
5A37 B7          OR      A       #NONE?
5A38 28 03       JR      Z,LOAD3 #YES

```

```

5A3A CD 5A46      LOAD4:  CALL      CHEKM   ;INTO MEMORY
5A3D 23          LOAD3:  INC       HL      ;POINTER
5A3E 18 DC
;
; LOAD ASCII CHARACTER
;
5A40 CD 5949      LOAD6:  CALL      GETCH
5A43 47          LD       B,A
5A44 18 F4        JR       LOAD4
;
; COPY BYTE FROM B TO MEMORY
; AND SEE THAT IT GOT THERE
;
5A46 70          CHEKM:  LD        (HL),B ;PUT IN MEM
5A47 7E          LD      A,(HL) ;GET BACK
5A48 B8          CP       B      ;SAME?
5A49 C8          RET      Z      ;OK
5A4A F1          ERRP:  POP      AF    ;RAISE STACK
5A4B 3E 42        ERRB:  LD      A,'B' ;BAD
5A4D CD 5835      CALL      OUTT
5A50 CD 59F3      CALL      OUTSP
5A53 C3 59EB      JP       OUTHL    ;POINTER
;
; DISPLAY STACK POINTER REGISTER
;
5A56 21 0000      REGS:  LD      HL,0
5A59 39          ADD      HL,SP
5A5A C3 59EB      JP       OUTHL
;
; ZERO A PORTION OF MEMORY
;
5A5D CD 5999      ZERO:   CALL      RDHLDE ;RANGE
5A60 06 00        LD      B,0
5A62 18 08        JR       FILL2
;
; FILL A PORTION OF MEMORY
;
5A64 CD 5A80      FILL:   CALL      HLDEBC ;RANGE, BYTE
5A67 FE F7        CP      APOS    ;APOSTROPHE?
5A69 28 0F        JR      Z,FILL4 ;YES, ASCII
5A6B 41          LD      B,C
5A6C 7C          FILL2:  LD      A,H ;FILL BYTE
5A6D FE 57        CP      HIGH STACK ;TOO FAR?
5A6F D2 59E0      JP      NC,ERROR ;YES
5A72 CD 5A46      FILL3:  CALL      CHEKM ;PUT, CHECK
5A75 CD 5A0C      CALL      TSTOP  ;DONE?
5A78 18 F2        JR      FILL2   ;NEXT
;
5A7A CD 5949      FILL4:  CALL      GETCH ;ASCII CHAR
5A7D 47          LD      B,A
5A7E 18 F2        JR      FILL3
;
; GET H,L D,E AND B,C
;
5A80 CD 5A8E      HLDEBC: CALL      HLDECK ;RANGE
5A83 DA 59E0      JP      C,ERROR ;NO BYTE
5A86 E5          PUSH     HL

```



```

5A87 CD 59AE      CALL    READHL  #3RD INPUT
5A8A 44          LD      B,H      #MOVE TO
5A8B 4D          LD      C,L      # B,C
5A8C E1          POP     HL
5A8D C9          RET

;
; GET 2 ADDRESSES, CHECK THAT
; ADDITIONAL DATA IS INCLUDED
;
5A8E CD 59A3      HLDECK: CALL   HHLDE   #2 ADDR
5A91 DA 59E0      JP      C,ERROR #THAT'S ALL
5A94 C3 599C      JP      RDHLD2 #CHECK

;
; MOVE A BLOCK OF MEMORY H,L-D,E TO B,C
;
5A97 CD 5A80      MOVE:  CALL   HLDEBC  #3 ADDR
5A9A CD 5AA3      MOVDN: CALL   MOVIN   #MOVE/CHECK
5A9D CD 5A0C      CALL   TSTOP   #DONE?
5AA0 03          INC     BC        #NO
5AA1 18 F7        JR      MOVDN

;
MOVIN: LD         A,(HL) #BYTE
5AA4 02          LD      (BC),A #NEW LOCATION
5AA5 0A          LD      A,(BC) #CHECK
5AA6 BE          CP      (HL)    #IS IT THERE?
5AA7 C8          RET     Z        #YES
5AA8 60          LD      H,B      #ERROR
5AA9 69          LD      L,C      #INTO H,L
5AAA C3 5A4A      JP      ERRP    #SHOW BAD

;
; SEARCH FOR 1 OR 2 BYTES OVER THE
; RANGE H,L D,E. BYTES ARE IN B,C
; B HAS CARRIAGE RETURN IF ONLY ONE BYTE
; PUT SPACE BTWEEN BYTES IF TWO
; FORMAT: START STOP BYTE1 BYTE2
;
5AAD CD 5A80      SEARCH: CALL   HLDEBC #RANGE, 1ST BYTE
5AB0 06 0D        SEAR2: LD      B,CR  #SET FOR 1 BYTE
5AB2 38 06        JR      C,SEAR3 #ONLY ONE
5AB4 E5          PUSH    HL
5AB5 CD 59AE      CALL    READHL  #2ND BYTE
5AB8 45          LD      B,L      #INTO C
5AB9 E1          POP     HL
5ABA 7E          SEAR3: LD      A,(HL) #GET BYTE
5ABB B9          CP      C        #MATCH?
5ABC 20 10        JR      NZ,SEAR4 #NO
5ABE 23          INC     HL        #YES
5ABF 78          LD      A,B      #ONLY 1?
5AC0 FE 0D        CP      CR
5AC2 28 04        JR      Z,SEAR5 #YES

;
; FOUND FIRST MATCH, CHECK FOR SECOND
;
5AC4 7E          LD      A,(HL) #NEXT BYTE
5AC5 B8          CP      B        #MATCH?
5AC6 20 06        JR      NZ,SEAR4 #NO

```

```

5AC8 2B          SEAR5: DEC      HL      ;A MATCH
5AC9 C5          PUSH     BC
5ACA CD 59E8     CALL     CRHL    ;SHOW ADDR
5ACD C1          POP      BC
5ACE CD 5A0C     SEAR4: CALL     TSTOP  ;DONE?
5AD1 18 E7       JR       SEAR3   ;NO
;
; ASCII SUB-COMMAND PROCESSOR
;
5AD3 CD 5949     ASCII: CALL     GETCH  ;NEXT CHAR
5AD6 FE 44       CP       'D'      ;DISPLAY
5AD8 28 24       JR       Z,ADUMP
5ADA FE 53       CP       'S'      ;SEARCH
5ADC 28 42       JR       Z,ASCS
5ADE FE 4C       CP       'L'      ;LOAD
5AE0 C2 59E0     JP       NZ,ERROR
;
; LOAD ASCII CHARACTERS INTO MEMORY
; QUIT ON CONTROL-X
;
5AE3 CD 59AE     CALL     READHL    ;ADDRESS
5AE6 CD 59EB     CALL     OUTHL     ;PRINT IT
5AE9 CD 5815     ALOD2: CALL     INPUTT ;NEXT CHAR
5AEC CD 5835     CALL     OUTT      ;PRINT IT
5AEF 47          LD       B,A       ;SAVE
5AF0 CD 5A46     CALL     CHEKM     ;INTO MEMORY
5AF3 23          INC      HL        ;POINTER
5AF4 7D          LD       A,L
5AF5 E6 7F       AND      7FH      ;LINE END?
5AF7 20 F0       JR       NZ,ALOD2 ;NO
5AF9 CD 59E8     CALL     CRHL     ;NEW LINE
5AFC 18 EB       JR       ALOD2
;
; DISPLAY MEMORY IN STRAIGHT ASCII.
; KEEP CARRIAGE RETURN, LINE FEED, CHANGE
; TAB TO SPACE, REMOVE OTHER CONTROL CHAR.
;
5AFE CD 5999     ADUMP: CALL     RDHLDE ;RANGE
5B01 7E          ADMP2: LD       A,(HL) ;GET BYTE
5B02 FE 7F       CP       DEL      ;HIGH BIT ON?
5B04 30 15       JR       NC,ADMP4 ;YES
5B06 FE 20       CP       ' '      ;CONTROL?
5B08 30 0E       JR       NC,ADMP3 ;NO
5B0A FE 0D       CP       CR       ;CARR RET?
5B0C 28 0A       JR       Z,ADMP3 ;YES, OK
5B0E FE 0A       CP       LF       ;LINE FEED?
5B10 28 06       JR       Z,ADMP3 ;YES, OK
5B12 FE 09       CP       TAB
5B14 20 05       JR       NZ,ADMP4 ;SKIP OTHER
5B16 3E 20       LD       A,' '    ;SPACE FOR TAB
5B18 CD 5835     ADMP3: CALL     OUTT  ;SEND
5B1B CD 5A0C     ADMP4: CALL     TSTOP ;DONE?
5B1E 18 E1       JR       ADMP2   ;NO
;
; SEARCH FOR 1 OR 2 ASCII CHARACTERS
; NO SPACE BETWEEN ASCII CHARS
; FORMAT: START STOP 1 OR 2 ASCII CHAR
;

```

```

5B20 CD 5999   ASCS:  CALL    RDHLDE  #RANGE
5B23 CD 5949   CALL    GETCH    #FIRST CHAR
5B26 4F        LD      C,A
5B27 CD 5949   CALL    GETCH    #2ND OR CARR RET
5B2A DA 5AB0   JP      C,SEAR2  #ONLY ONE CHAR
5B2D 47        LD      B,A      #2ND
5B2E C3 5ABA   JP      SEAR3

;
; INPUT FROM ANY PORT (Z-80 VERSION)
;
5B31 CD 59AE   IPORT:  CALL    READHL  #PORT
5B34 4D        LD      C,L      #PORT TO C
5B35 ED 68     IN      L,(C)    #INPUT
5B37 CD 59EF   CALL    OUTLL   #HEX VALUE

;
; PRINT L REGISTER IN BINARY (Z-80 VER)
;
5B3A 06 08     BITS:   LD      B,8    #8 BITS
5B3C CB 25     BIT2:   SLA      L      #SHIFT L LEFT
5B3E 3E 18     LD      A,'0'/2    #HALF OF 0
5B40 8F        ADC      A,A      #DOUBLE+CARRY
5B41 CD 5835   CALL    OUTT     #PRINT BIT
5B44 10 F6     DJNZ    BIT2     #8 TIMES
5B46 C9        RET

;
; OUTPUT BYTE FROM PORT (Z-80 VERSION)
; FORMAT IS: O,PORT,BYTE
;
5B47 CD 59AE   OPORT:  CALL    READHL  #PORT
5B4A 4D        LD      C,L
5B4B CD 59AE   CALL    READHL  #DATA
5B4E ED 69     OUT     (C),L    #OUTPUT
5B50 C9        RET

;
; HEXADECIMAL MATH, SUM AND DIFFERENCE
;
5B51 CD 59A3   HMATH:  CALL    HHLDE   #TWO NUMBERS
5B54 E5        PUSH    HL        #SAVE H,L
5B55 19        ADD     HL,DE     #SUM
5B56 CD 59EB   CALL    OUTHL    #PRINT IT
5B59 E1        POP     HL
5B5A B7        OR      A        #CLEAR CARRY
5B5B ED 52     SBC     HL,DE
5B5D C3 59EB   JF      OUTHL    #DIFFERENCE

;
; MEMORY TEST THAT DOESN'T ALTER CURRENT BYTE
; INPUT RANGE OF ADDRESSES, ABORT WITH ^X
;
5B60 CD 5999   JUST:   CALL    RDHLDE  #RANGE
5B63 E5        PUSH    HL        #SAVE START ADDR
5B64 7E        LD      A,(HL)    #GET BYTE
5B65 2F        CPL      #COMPLEMENT IT
5B66 77        LD      (HL),A    #PUT IT BACK
5B67 BE        CP      (HL)     #DID IT GO?
5B68 C2 5B7E   JP      NZ,JERR   #NO
5B6B 2F        CPL      #ORIGINAL BYTE
5B6C 77        LD      (HL),A    #PUT IT BACK

```

```

5B6D 7D      JUST3: LD      A,L      ;PASS
5B6E 93      SUB      E          ; COMPLETED?
5B6F 7C      LD      A,H
5B70 9A      SBC      A,D
5B71 23      INC      HL
5B72 38 F0   JR      C,JUST2 ;NO
;
; AFTER EACH PASS,
; SEE IF ABORT WANTED
;
5B74 CD 5827 CALL      INSTAT ;INPUT?
5B77 C4 5815 CALL      NZ,INPUTT ;YES, GET IT
5B7A E1      POP      HL      ;START ADDR
5B7B E5      PUSH     HL      ;SAVE AGAIN
5B7C 18 E6   JR      JUST2 ;NEXT PASS
;
; FOUND MEMORY ERROR, PRINT POINTER AND
; BIT MAP: 0=GOOD, 1=BAD BIT
;
5B7E F5      JERR:  PUSH    AF      ;SAVE COMPLEMENT
5B7F CD 59E8 CALL      CRHL   ;PRINT POINTER
5B82 F1      POP      AF
5B83 AE      XOR      (HL)   ;SET BAD BITS
5B84 E5      PUSH     HL      ;SAVE POINTER
5B85 6F      LD      L,A      ;BIT MAP TO L
5B86 CD 5B3A CALL      BITS   ;PRINT BINARY
5B89 E1      POP      HL
5B8A 18 E1   JR      JUST3 ;CONTINUE
;
; REPLACE HEX BYTE WITH ANOTHER
; FORMAT IS: START, STOP, ORIG, NEW
;
5B8C CD 5A80 REPL:  CALL    HLDEBC ;RANGE, 1ST BYTE
5B8F DA 59E0 JP      C,ERROR ;NO 2ND
5B92 41      LD      B,C      ;1ST TO B
5B93 E5      PUSH     HL
5B94 CD 59AE CALL      READHL ;2ND BYTE
5B97 4D      LD      C,L      ;INTO C
5B98 E1      POP      HL
5B99 7E      REPL2: LD      A,(HL) ;FETCH BYTE
5B9A B8      CP      B          ;A MATCH?
5B9B 20 06   JR      NZ,REPL3 ;NO
5B9D 71      LD      (HL),C ;SUBSTITUTE
5B9E 79      LD      A,C
5B9F BE      CP      (HL)   ;SAME?
5BA0 C2 5A4B JP      NZ,ERRB ;NO, BAD
5BA3 CD 5A0C REPL3: CALL    TSTOP  ;DONE?
5BA6 18 F1   JR      REPL2
;
; GIVE RANGE OF 1ST BLOCK AND START OF SECOND
;
5BA8 CD 5A80 VERM:  CALL    HLDEBC ;3 ADDRESSES
5BAB 0A      VERM2: LD      A,(BC) ;FETCH BYTE
5BAC BE      CP      (HL)   ;SAME AS OTHER?
5BAD 28 19   JR      Z,VERM3 ;YES
5BAF E5      PUSH     HL      ;DIFFERENT
5BB0 C5      PUSH     BC

```

```

5BB1 CD 59E8      CALL    CRHL    #PRINT 1ST POINTER
5BB4 4E          LD      C,(HL) #FIRST BYTE
5BB5 CD 59F0      CALL    OUTHEX #PRINT IT
5BB8 3E 3A       LD      A,':'
5BBA CD 5835      CALL    OUTT
5BBD E1          POP     HL      #B,C TO H,L
5BBE CD 59EB      CALL    OUTHL  #SECOND POINTER
5BC1 4E          LD      C,(HL) #2ND BYTE
5BC2 CD 59F8      CALL    OUTHX  #PRINT IT
5BC5 4D          LD      C,L     #RESTORE C
5BC6 44          LD      B,H     #AND B
5BC7 E1          POP     HL      #AND H,L
5BC8 CD 5A0C      CALL    TSTOP  #DONE?
5BCB 03          INC     BC      #2ND POINTER
5BCC 18 DD       JR      VERM2
;
END              START

```

Symbols:

ADMP2	5B01	ADMP3	5B18	ADMP4	5B1B	ADUMP	5AFE
ALOD2	5AE9	AP05	FFF7	ASCII	5AD3	ASCS	5B20
BACKUP	0008	BIT2	5B3C	BITS	5B3A	CALLS	5A15
CDATA	0011	CHEKM	5A46	CIN	5B09	COLD	5B7E
COUT	5B06	CR	000D	CRHL	59E8	CRLF	5935
CSTAT	0010	CTRH	0008	CTRP	0010	CTRQ	0011
CTRS	0013	CTRX	0018	DEL	007F	DUMP	595E
DUMP2	5961	DUMP3	5964	DUMP4	5975	DUMP5	597E
ERRB	5A4B	ERROR	59E0	ERRP	5A4A	FILL	5A64
FILL2	5A6C	FILL3	5A72	FILL4	5A7A	GCHAR	5B0F
GETC4	595C	GETCH	5949	GO	5A14	HEX1	5A01
HHLDE	59A3	HLDEBC	5A80	HLDECK	5A8E	HMATH	5B51
IBUFC	57A5	IBUFF	57A6	IBUFF	57A3	INLN	5B0C
INMSK	0001	INPL2	5902	INPL3	591B	INFLB	593F
INPLC	5929	INPLE	5924	INPLI	590A	INPLN	5BFD
INPUT2	5B1A	INPUTT	5B15	INSTAT	5B27	IPORT	5B31
JERR	5B7E	JUST	5B60	JUST2	5B64	JUST3	5B6D
LDATA	0013	LF	000A	LOAD	5A19	LOAD2	5A1C
LOAD3	5A3D	LOAD4	5A3A	LOAD6	5A40	LOMSK	0002
LOUT	5B5B	LSTAT	0012	MOVDN	5A9A	MOVE	5A97
MOVIN	5AA3	MSIZE	5BAA	NIB	59D0	NNULS	0004
NPAGE	5B9A	OMSK	0002	OPORT	5B47	ORGIN	5B00
OUT2	5B3C	OUT3	5B48	OUT4	5B51	OUTCR	5B74
OUTCR2	5B76	OUTH	5B12	OUTHEX	59F0	OUTHL	59EB
OUTHX	59F8	OUTLL	59EF	OUTSP	59F3	OUTT	5B35
PASC2	5994	PASC3	5996	PASCI	598B	PORTN	57A0
RDHL2	59B3	RDHL4	59C5	RDHL5	59CD	RDHLD2	599C
RDHLDE	5999	READHL	59AE	REGS	5A56	REPL	5B8C
REPL2	5B99	REPL3	5BA3	RESTR	5B03	SEAR2	5AB0
SEAR3	5ABA	SEAR4	5ACE	SEAR5	5AC8	SEARCH	5AAD
SETLST	5B2C	STACK	57A0	START	5B00	TAB	0009
TABLE	5B09	TOP	0018	TSTOP	5A0C	VERM	5BAA
VERM2	5BAB	VERM3	5B08	WARM	5B91	ZERO	5A5D

CONVERSION OF THE MONITOR TO Z-80 MNEMONICS

If you used 8080 mnemonics to program the monitor in Chapter 6, you can now convert it to Z-80 mnemonics. The form of the mnemonics depends on the type of assembler you have. The Microsoft assembler accepts both the Intel 8080 and the Zilog Z-80 mnemonics. Since most other assemblers use only one or the other, you may need a second assembler.

The Digital Research assembler MAC requires the 8080 mnemonics, but it can generate Z-80 code with an accompanying macro library. The Xitan assembler utilizes 8080 mnemonics for the common set of 8080-type instructions and Zilog-like instructions for the others.

First, make a working copy of the monitor using PIP, a CP/M utility routine.

```
PIP MONZ.ASM=MON17.ASMCVJ
```

If you are using MAC or the Xitan assembler, skip to the next section. Otherwise, use the system editor to make the necessary changes to the new file. The conversion can be easily performed with the global substitute command of the Word-Master or the CP/M editor. For example, the 8080 mnemonic

```
MOV A,M
```

can be changed to the equivalent Z-80 mnemonic

```
LD A,(HL)
```

with the command

```
*SMOV<tab>A,M$LD<tab>A,(HL)$OTT
```

The \$ symbols indicate that the escape key is pressed. The "tab" refers to the ASCII tab key, a control-I. You may find the cross-reference list for 8080 and Z-80 mnemonics, given in Appendix G, helpful in the conversion process.

After changing the monitor to Z-80 mnemonics, assemble it and carefully check the assembly listing to see that the hex code is correct. The Z-80 version at this time should generate the same hex code as the 8080 version. A further check can be made with the monitor's V command. Load the binary code into memory with an offset. A command of

```
DDT
IMONZ.HEX
RF000
```

will load the new version 4K bytes below the regular monitor position. Branch to the monitor prepared in the last chapter. Then compare its code to the new version using the verify command. If there is a discrepancy, find the error and correct it. When you are convinced that the Z-80 version produces the same code as the 8080 version, you can begin the alterations to reduce the monitor's size.

REDUCING THE MONITOR SIZE

In this section you will reduce the monitor size by converting many of the 3-byte absolute jump instructions into 2-byte relative jump instructions. This change will make room for additional features. There are five types of jumps to be changed.

absolute		relative	condition
JMP		JMP	
JP	X	JR	X
JP	Z,X	JR	Z,X
JP	NZ,X	JR	NZ,X
JP	C,X	JR	C,X
JP	NC,X	JR	NC,X
			unconditional
			zero
			not zero
			carry
			not carry

Not all of the absolute jumps can be converted in this way since the relative jumps are limited to a distance of about 126 bytes.

Another way to obtain more space is to move some of the subroutines to more advantageous locations. This will allow a few more absolute jumps to be converted into relative jumps. For example, several routines contain a jump to the routine ERROR. These can be placed together in a group. Then the ERROR routine can be moved into the middle of the group.

Another change will free up three more bytes. Notice that subroutine OUTSP ends with the instruction

```
JP    OUTT
```

If this subroutine were located directly ahead of subroutine OUTT, then the jump instruction would not be necessary. Actually, this type of change has already been used extensively in our monitor. Subroutines CRHL, OUTHL, OUTHEX, and OUTSP are all directly related. They initially could have been programmed (using Z-80 mnemonics) as

```
CRHL:  CALL    CRLF
        CALL    OUTHL
        RET
;
OUTHL:  LD      C,H
        CALL    OUTHX
OUTLL:  LD      C,L
        CALL    OUTHEX
        RET
;
OUTHEX: CALL    OUTHX
        CALL    OUTSP
        RET
;
OUTSP:  LD      A,' '
        CALL    OUTT
        RET
```

The CALL/RET combination at the end of each routine can be replaced by a JP instruction. Then, since the calling program is located directly above the called program, the jump instruction becomes unnecessary. Thus, four bytes are saved in each of the first three routines. Furthermore, if this entire block of four subroutines were located just prior to subroutine OUTT, we could eliminate the final JP OUTT instruction and save three more bytes.

While this kind of subroutine rearrangement can be used to make the overall program smaller, there is a penalty. The readability is reduced. We have traded comprehension for space. This may not, in general, be a worthwhile tradeoff for assembly-language programming. Such programs are more difficult to understand than those written in a high-level language such as Pascal or BASIC. Furthermore, assembly-language programs are typically much shorter than they would be if written in a higher-level language. But if packing a maximum number of features into a 1K PROM is your goal, then this technique may be worth it.

GETTING MORE FREE SPACE

The two instructions

```
DEC      B
JP       NZ,X
```

which generate four bytes of code appear in two places. Replace them with the 2-byte instruction

```
DJNZ     X
```

One location is just prior to the label MSIZE (address 58A5 in Listing 7.1) and the other is in subroutine BITS (5B3A). This change will free four more bytes.

The 16-bit subtraction routine in HMATH (5B51) has been improved. The sequence of instructions

```
LD       A,L
SUB      A,E
LD       L,A
LD       A,H
SBC      A,D
LD       H,A
```

is replaced by the shorter, double-precision subtraction:

```
OR       A           ;reset carry
SBC      HL,DE       ;subtract
```

Three more bytes are freed by this change.

Since the Z-80 contains a set of instructions for direct rotation of data in the general CPU registers, we can simplify subroutine BITS. In the 8080 version, the three instructions

```
MOV    A,L
ADD    A
MOV    L,A
```

are used to move the data from a general register to the accumulator, perform the shift, then move it back. The 2-byte, Z-80 arithmetic shift left instruction

```
SLA    L
```

performs the shift directly in the L register.

The 8080 can output a byte only from the accumulator, and can input a byte only to the accumulator. Furthermore, the address of the peripheral must be located in memory immediately following the first byte of the input or output instruction.

The port-input routine IPORT and the port-output routine OPORT in the system monitor utilized subroutine PUTIO. This routine writes the desired IN or OUT instruction in memory, the requested port address and then a return instruction. There is a Z-80 instruction that can perform I/O from any register. The address of the peripheral is located in register C in this case. Since the port address does not have to be located in memory, subroutine PUTIO can be eliminated. The resulting Z-80 code is 19 bytes shorter than the 8080 version. See Listing 7.1 for the new versions of IPORT (5B31) and OPORT (5B47).

Since you are nearly finished with the development of the monitor program, you can gain some more space by removing the routines that print the version number. There are four areas involved. First, delete the line near the beginning that identifies the version number.

```
VERS    EQU    '17'
```

Second, remove four lines starting with the label SIGNON. Third, delete the two lines starting on the line after the label COLD.

```
LD      DE,SIGNON
CALL    SENDM
```

Fourth, remove the entire subroutine SENDM, but keep a copy of it in case you want to incorporate it in another program.

PERIPHERAL PORT INITIALIZATION

There are two schools of thought on peripheral port initialization. One approach is to initialize ports only on a cold start or a warm start. The other

way is to initialize a port each time it is used. The method you use depends on the integrity of your system.

The approach taken in this chapter initializes ports only on a cold start. The instructions are placed just after the label COLD. In anticipation of adding a printer-output routine, we include the initialization for two separate peripherals.

Ports which need initialization utilize a control register for this purpose. The address of the control register is the same as the status register. A CPU IN instruction reads the status register, while a CPU OUT instruction to the same address writes into the control register. A typical initialization procedure requires two OUT instructions. The first is used to reset the port; the second is used to set the desired options. The values shown in the listing correspond to a Motorola 6850 ACIA serial port set for eight data bits, one stop bit, and no interrupts.

```
LD      A,3
OUT     (CSTAT),A      ; RESET
LD      A,15H
OUT     (CSTAT),A      ; SET FEATURES
```

PRINTER OUTPUT ROUTINES

Up to this point, we have been writing programs for output to a console video screen. We output an ASCII backspace character for error correction so that the cursor will actually back up on the screen. We also included a pair of scroll commands: control-S to freeze the display and control-Q to resume the scrolling.

Sometimes, however, we want computer output we can look at after the computer has been shut off. A printer or list device is what we need for this purpose. We will not want to use the printer as a main console, though, because it is too slow.

For sophisticated operating systems like CP/M, the software for the list device is wholly separate. For example, we can divert a disk file to the printer and none of the system commands will appear on the listing.

Our approach will be a little different. The video console will always display all output whether the printer is on or not. Of course, when the printer is engaged, the console speed will be reduced to that of the printer. We will both enable and disable the printer with a control-P command, just as in CP/M. We refer to the control-P command as a list toggle: the same command turns it on or off. The output includes the echoing of the commands typed in from the console keyboard.

Both the input and output routines will have to be changed if you want to incorporate the printer routines. In addition, two new subroutines will be added. First, add two new lines to the input routine; they will look for a control-P from the console keyboard. If a control-P is found, the program

will branch to a new subroutine called SETLST. The two new lines appear in subroutine INPUTT (5815).

```
CP      CTRP      #AP
JR      Z,SETLST  #LIST
```

Subroutine SETLST (582C), containing 4 lines of code, is added just after subroutine INSTAT.

```
SETLST: LD      A,(PORTN) #CHECK FLAG
        CPL      #INVERT
        LD      (PORTN),A #SAVE
        JR      INPUTT  #NEXT BYTE
```

This routine complements the printer flag (PORTN) when a control-P is typed. The output routine uses this flag to determine whether to send output to the printer. Notice that in Chapter 6, the identifier PORTN was used to set up the port number for the I and O commands. This feature is not needed for the Z-80 version, so we can use the location for the printer flag instead.

The third new section is placed in the output routine OUTT (5835).

```
LD      A,(PORTN) #WHERE?
OR      A      #ZERO?
JR      NZ,LOUT  #LIST OUTPUT
```

This part checks the flag PORTN to see if output is to be sent to the printer.

The fourth routine is LOUT (585B); it follows OUT4. This routine sends output to both the console and the printer. It first checks the status port for the printer. When the output bit indicates ready, a byte is sent to the printer. Since the console video screen operates so much faster than the printer, there is no need to check the console-ready flag. The byte is therefore also sent directly to the console by the next instruction. The output appears simultaneously at both devices.

DELAY AFTER A CARRIAGE RETURN

Video screens operate with electron beams that move very fast. Mechanical printers, on the other hand, are much slower. For some printers, the time it takes to execute a carriage return is so great that the first few characters of the next line may be lost. The solution is to have the computer do something else for a little while after it sends a carriage return.

One method of slowing down the computer is to arrange for it to send binary zeros, called nulls, after each carriage return or carriage-return/line-feed pair. One routine for accomplishing this is as follows.

```

CRLF:  LD      A,CR      ;CARRIAGE RET
        CALL    OUTT     ;SEND
        LD      A,LF      ;LINE FEED
        CALL    OUTT     ;SEND
        XOR     A         ;GET A NULL
        CALL    OUTT     ;SEND IT
        CALL    OUTT     ;A SECOND ONE
        CALL    OUTT     ;A THIRD
        JP      OUTT     ;THE FOURTH

```

But this approach may cause trouble if the printer circuits attempt to interpret the null characters.

A different approach is taken with the list-output routine, LOUT, shown in Listing 7.1. After each carriage return is sent, the computer starts executing a double loop. The inner loop is executed 250 times. The outer loop is set according to the equivalent number of nulls that are needed. No nulls are actually sent, though, in this case.

The disadvantage of this method is that the resultant delay time is a function of the computer speed. A Z-80 running at 4 MHz would require approximately twice the number of loops as would a 2-MHz Z-80. Thus, the loop-initialization values may have to be adjusted to the particular computer.

Be careful to tailor the port-initialization routines to your system or remove them if they are not needed. The time delay in the list-output routine should also be removed if it is not needed. If you are not sure whether a delay is necessary, then leave it in, at least for the first version. Then use the memory load command of the monitor itself to reduce the delay values on the two loops. When you reduce the delay time to too small a value, then you will notice that some of the characters are missing from the beginning of some of the lines.

A sample loop-change session could look like this.

```

>D5870 587F
5870 COD51678 1EFA1D20 1520. . .
>L5873
5873 x 78 3C
5873 . 1E 4X (to quit)

```

The first command line is used to display the memory region containing the loop constants. Then the outer loop value of 78 hex is changed to 3C hex which is half the value. As long as you change the timing-loop values with the printer disengaged, no problem should occur. After each change in the timing loops, re-engage the printer with a control-P. Display several lines on the printer by giving the D command. Check to see if any of the first few characters of each line are missing. If everything is all right, then again reduce the loop constant until characters are lost. (Be sure to disengage the printer between each change.)

CHAPTER EIGHT

Number-Base Conversion

This chapter deals with assembly language routines that can be used to convert data from one form to another. The first part deals with the conversion of a sequence of ASCII characters called a *string* into a binary number. The second part reverses the procedure; binary numbers are converted into ASCII strings. The characters in each string represent digits in one of the common bases 2, 8, 10, or 16. The corresponding binary number may be 4 bits, 8 bits, or 16 bits in size.

All of the programs in this chapter are designed to run with the system monitor developed in Chapters 6 and 7. Some of the monitor's input and output facilities are needed. These include the console input buffer which supplies the characters, the binary-to-hexadecimal conversion routine which will print the answer in hexadecimal, and the console output routine needed for the error message.

The monitor error-correction features are available during input. Pressing the DEL (or RUB) key or the backspace (control-H) key will delete the previously typed character and remove it from the console video screen. If the list routines have been incorporated into the monitor, the printer can be turned on by typing a control-P. When you have finished with each routine, you can return to the monitor simply by typing a control-X.

THE ASCII CODE

When a key is pressed on a computer terminal, a unique signal is sent to the computer. There are several, very different ways of electronically encoding this signal. ASCII, which stands for American Standard Code for Information Interchange, is the most commonly used code. Appendix A gives the 128 ASCII characters with the corresponding values expressed in decimal, hexadecimal, octal, and binary. EBCDIC, which is used by IBM, is another coding technique.

The ASCII table can be divided into four parts. Part 1 of the table contains the nonprinting control characters. Part 2 contains most of the special characters such as \$, %, and #, and the digits 0–9. The uppercase letters are found in part 3, and the lowercase letters are found in part 4.

Computer terminals typically have a keyboard that looks like a typewriter. There is a shift key to change from lowercase letters to uppercase letters. In addition to the shift key, there will usually be a control key. This key will give the letter keys a third meaning. Thus the user can enter a lowercase letter A, an uppercase letter A (a shift A), or a control-A. The bit patterns are:

110 0001	lowercase A
100 0001	uppercase A
000 0001	control-A

It can be seen from the pattern that the shift key resets bit 5 while the control key resets both bits 5 and 6.

Some of the commonly used control functions such as the carriage return (control-M), line feed (control-J), the horizontal tab (control-I), and the backspace (control-H) may have their own separate keys.

All console input to the computer will be in the form of ASCII characters. The console will send eight data bits for each character. But the ASCII code contains only seven bits per character. Consequently, the eighth, high-order bit is not needed. The user will need to have routines for converting strings of ASCII characters into the ultimate numbers that will reside in memory. For example, if the operator enters the string

3014

from the console, the computer would actually receive the bit patterns

011 0111	(ASCII 3)
011 0000	(ASCII 0)
011 0001	(ASCII 1)
011 0100	(ASCII 4)

The next step is to convert the string into a 16-bit number. The conversion scheme that is chosen depends on whether the string represents a decimal number, an octal number, or a hexadecimal number.

Additionally, a check is made to ensure that each character in the string is within the proper range. For example, octal numbers must contain only the digits zero through 7. The digits 8 and 9, the letters A through Z, and the other characters are not used. Finally, we may need a special character, called a *delimiter*, to indicate the end of a string. We will use a space or a carriage return for this purpose. Thus the string of characters

1034 2347

will be interpreted as two separate numbers since a space appears in the middle.

The ASCII string may need to be converted into a 4-bit nibble, an 8-bit byte destined for a CPU register, or a 16-bit word meant for a double register. Furthermore, the format may be either *free entry* or *fixed entry*. The choice is a matter of personal taste. With free entry, leading zeros are not needed. The entries

```
0004
004
04
4
```

are all interpreted as the same number. An additional feature is that you can recover from an error by retyping the entry on the same line. Suppose that the 4-digit number 1035 is desired but 1045 was typed by mistake. The correct value can be immediately typed without a space.

```
10351045
```

If two 4-digit numbers are needed, they must be separated by a delimiter.

```
1045 1055
```

With the fixed-entry format, the required number of digits, including leading zeros, must be entered. But since an end-of-string indicator is not needed, two numbers can be run together. The fixed-entry expression

```
10451055
```

will be interpreted as two separate numbers.

CONVERSION OF ASCII-ENCODED BINARY CHARACTERS TO AN 8-BIT BINARY NUMBER IN REGISTER C

One of the simplest base-conversion routines is the ASCII-to-binary program. This program takes a string of ASCII-encoded ones and zeros from the console input buffer and produces an 8-bit binary number in register C. The hexadecimal equivalent of the number is printed on the console. If the operator types the string

```
10101100
```

the keyboard actually transmits the following sequence.

```

011 0001
011 0000
011 0001
011 0000
011 0001
011 0001
011 0000
011 0000

```

The conversion routine will take this combination, convert it to the binary number

10101100

and place it into the C register.

Type the routine shown in Listing 8.1 Set the assembly location somewhere below the monitor's stack and include the address of the monitor using the EQU directive. The monitor I/O routines are defined relative to the monitor's address.

Listing 8.1. ASCII-encoded binary to binary in C.

```

; THIS PROGRAM IS DESIGNED TO OPERATE
; WITH THE SYSTEM MONITOR AT 5800 HEX.
;
; JAN 29, 80
;
5000      ORG      5000H
;
5800 =    MONIT    EQU      5800H
5804 =    OUTT     EQU      MONIT+6
580C =    INPLN    EQU      MONIT+0CH
580F =    GETCH    EQU      MONIT+0FH
5812 =    OUTHX    EQU      MONIT+12H
;
5000 3E0D  START:  MVI      A,0DH    ;CARR RET
5002 CD0658      CALL     OUTT
5005 3E0A      MVI      A,0AH    ;LINE FEED
5007 CD0658      CALL     OUTT
500A CD0C58      CALL     INPLN    ;GET A LINE
500D CD1B50      CALL     BBIN     ;CONVERT
5010 CD1258      CALL     OUTHX    ;HEX VALUE
5013 3E20      MVI      A,' '
5015 CD0658      CALL     OUTT
;
; THE NEXT INSTRUCTION IS NEEDED WHEN
; THE ROUTINE IN LISTING 8.9 IS APPENDED
;
5018 C30050      CALL     BITS     ;BIN TO ASCII
;
;
; JMP      START    ;NEXT VALUE
;
; SUBROUTINE TO CONVERT UP TO 8 ASCII-
; ENCODED BINARY CHARACTERS INTO AN
; 8-BIT BINARY NUMBER IN C
;

```



```

501B E5      BBIN:  PUSH    H          ;SAVE REGS
501C 210000   LXI      H,0          ;CLEAR
501F CD0F58   BBIN2:  CALL    GETCH   ;GET CHAR
5022 DA3A50   JC       BBIN3   ;LINE END
5025 D630     SUI      '0'         ;CONV TO BINARY
5027 DA3550   JC       BBIN4   ; < 0
502A FE02     CFI      2           ;
502C D23D50   JNC      ERROR   ; > 1
502F 29       DAD      H          ;SHIFT LEFT
5030 B5       ORA      L          ;ADD NEW CHAR
5031 6F       MOV      L,A
5032 C31F50   JMP      BBIN2   ;NEXT
;
; CHECK FOR BLANK AT END
;
5035 FEF0     BBIN4:  CFI      (' '- '0') AND OFFH
5037 C23D50   JNZ      ERROR   ;NOT BLANK
503A 4D       BBIN3:  MOV      C,L   ;8 BITS TO C
503B E1       POP      H          ;RESTORE
503C C9       RET
;
; PRINT ? ON IMPROPER INPUT
;
503D C1       ERROR:  POP      B          ;RAISE STACK
503E C1       POP      B
503F 3E3F     MVI      A,'?'
5041 CD0658   CALL    OUTT
5044 C30050   JMP      START   ;TRY AGAIN

```

Assemble the program and load it into memory; start it up by branching to the beginning of the program, the address of START. The monitor prompt symbol of > will appear on the console. Test the routine by entering the following binary numbers. Be sure to add a carriage return to the end of each line.

```

>0      (you type this)
00      (program responds with this)
>1
01
>10
02      (binary 10 is hexadecimal 2)
>11
03
>101
05      (binary 101 is hexadecimal 5)
>1111
0F
>11110000
F0
>10101010
AA

```

Of course, only ASCII zeros and ones are acceptable binary characters. Leading zeros are not necessary. If more than eight characters are entered, only the last eight are used. A question mark will be printed if a nonbinary

character is typed. Typing errors can be corrected with a backspace or DEL keys.

The program consists of three parts. The first and third parts will be common to other conversion programs in this chapter. The first part calls the monitor to obtain data from the console. The last part converts the data to the hexadecimal equivalent and prints it on the console if valid. If the entry is invalid, a question mark is printed.

The conversion routine occupies the middle portion of the program. It works as follows: Since HL is used as a working register, the original contents are first saved on the stack. While this step is not necessary in this case, it may be needed in a real application. The HL register is then zeroed.

As each new character is obtained from the input buffer, it is converted from ASCII to binary by subtracting 30 hex, the value of the ASCII zero. An ASCII zero, which has a value 30 hex, becomes a binary zero. Similarly, an ASCII 1, which has a value of 31 hex, becomes a binary 1.

```

011 0000  ASCII zero
011 0000  subtract ASCII zero
-----
000 0000  binary zero

011 0001  ASCII 1
011 0000  subtract ASCII zero
-----
000 0001  binary 1

```

A check is made at this point to ensure that an invalid character has not been typed. Only three characters are acceptable: An ASCII zero, an ASCII 1, and a space. If the carry flag is set after the subtraction of an ASCII zero, then the input value was neither a zero nor a 1. But it might be a space character. A jump is made to subroutine BBIN4 in this case. This routine determines whether the current character is a space or some other character. A space is the normal end-of-string character (delimiter); other characters are not.

Each character is also checked to see that it is not greater than an ASCII 1. In either case, if any character in the string is found to be other than an ASCII zero or 1, then the subroutine is terminated with a jump to the error routine. At this point, the stack is raised with a POP instruction, and control returns to START at the top of the program.

If the input value is a zero or 1, the procedure continues. The current value in the HL register is multiplied by two, the binary number base. This arithmetic shift left is accomplished by adding the HL register to itself with the double-precision add DAD H. An alternate method would be to place the sum in the accumulator. In this case the multiplication is performed with an ADD A instruction. But then the intermediate sum would have to be saved in another register while the new character was checked.

The new character, which is now a binary zero or 1 in the accumulator, is added to the value in HL. The addition of the 8-bit accumulator to the 16-bit HL register generally requires several steps.

1. Add L to A.
2. Move sum in A to L.
3. Increment H if carry is set.

But in this particular case, the carry flag will never be set. Consequently, a simpler method of addition can be used. The one chosen for this application is to perform a logical OR operation with the L register and the accumulator.

CONVERSION OF ASCII DECIMAL CHARACTERS TO A BINARY NUMBER

We frequently find it useful to input computer data in the form of decimal numbers. We may then need a program to convert ASCII-encoded decimal numbers into binary form. The program given in Listing 8.2 will perform this task for us.

Listing 8.2. ASCII decimal to binary in HL.

```

; THIS PROGRAM IS DESIGNED TO OPERATE
; WITH THE SYSTEM MONITOR AT 5800 HEX
;
; JAN 22, 80
;
5000      ORG      5000H
;
5800 =    MONIT   EQU      5800H
5806 =    OUTT    EQU      MONIT+6
580C =    INPLN   EQU      MONIT+0CH
580F =    GETCH   EQU      MONIT+0FH
5812 =    OUTHX   EQU      MONIT+12H
;
5000 3E0D  START:  MVI      A,0DH    ;CARR RET
5002 CD0658      CALL     OUTT
5005 3E0A      MVI      A,0AH    ;LINE FEED
5007 CD0658      CALL     OUTT
500A CD0C58      CALL     INPLN   ;GET A LINE
500D CD2050      CALL     DBIN    ;ASCII TO DEC
5010 4C        MOV      C,H      ;HIGH HALF
5011 CD1258      CALL     OUTHX
5014 4D        MOV      C,L
5015 CD1258      CALL     OUTHX   ;LOW HALF
5018 3E20      MVI      A,' '    ;SPACE
501A CD0658      CALL     OUTT
;
; THE NEXT INSTRUCTION IS NEEDED WHEN
; THE ROUTINE IN LISTING 8.11 IS USED
;
501D C30050      CALL     BIND    ;BIN/DECIMAL
;
;
; ASCII DECIMAL TO 16-BIT IN H,L
;
5020 D5        DBIN:  PUSH     D      ;SAVE REGS
5021 210000      LXI      H,0      ;CLEAR
```

```

5024 CD0F58      DBIN2:  CALL    GETCH    ;GET CHAR
5027 DA4650              JC      DBIN3    ;LINE END
502A D630          SUI      '0'          ;CONV TO BINARY
502C DA4150              JC      DBIN4    ; < 0
502F FE0A          CFI      10
5031 D24850              JNC      ERROR    ; > 10
5034 54            MOV      D,H          ;COPY H,L
5035 5D            MOV      E,L          ; INTO D,E
5036 29            DAD      H            ;TIMES 2
5037 29            DAD      H            ;TIMES 4
5038 19            DAD      D            ;TIMES 5
5039 29            DAD      H            ;TIMES 10
503A 5F            MOV      E,A          ;NEW BYTE
503B 1600           MVI      D,0
503D 19            DAD      D            ;ADD NEW BYTE
503E C32450         JMP      DBIN2      ;NEXT
;
; CHECK FOR BLANK AT END
;
5041 FEF0          DBIN4:  CFI      (' '-'0') AND OFFH
5043 C24850         JNZ      ERROR    ;NOT BLANK
5046 D1            DBIN3:  POP      D      ;RESTORE
5047 C9            RET
;
; PRINT ? ON IMPROPER INPUT
;
5048 E1            ERROR:  POP      H      ;RESTORE
5049 E1            POP      H      ;STACK
504A 3E3F           MVI      A,'?'
504C CD0658         CALL     OUTT
504F C30050         JMP      START    ;TRY AGAIN

```

This new program uses our monitor for some of the necessary sub-routines, just like the ASCII binary-to-binary program given in the previous section. Assemble the program, load it into memory, and branch to START. Again, the monitor prompt symbol > will appear. Try this routine by entering the following decimal numbers. Remember to type a carriage return at the end of each line.

```

>0      (you type this)
0000    (computer response)
>1
0001
>10     (decimal 10)
0A      (sives 0A hex)
>16
000F
>64
0100
>1024
0400
>65545
FFFF
>65547
0002

```

If the input consists of valid decimal characters, then the response will be the corresponding hexadecimal value. If an invalid character is typed, a question mark is printed as an error message and the program is restarted.

Since this routine generates a 16-bit binary number, the largest possible value is one less than 2 to the power 16. This is equivalent to a decimal number of 65,545. If a larger number than this is entered, the excess over 65,545 is lost. Thus, an input of 65547 will give a value of 0002. Remember that the monitor error-correction features and the control-P list toggle are available.

The algorithm is similar to the one in the previous section. The HL register pair is initially zeroed. The incoming character is converted from ASCII to binary, then checked to see that it is in the range 0-9. The current value is multiplied by 10 (the number base) prior to adding in the new character. The multiplication is accomplished with the double-register add instructions as follows.

```
MOV    D,H (duplicate H in D)
MOV    E,L (duplicate E in L)
DAD    H   (double initial value)
DAD    H   (quadruple it)
DAD    D   (5 times initial value)
DAD    H   (double, making 10 times
           the initial value)
```

The total is first duplicated in the DE register. Two double-precision DAD H operations multiply the original value by 4. Adding in the original value with the DAD D makes it 5. A final DAD H produces the desired multiplication by 10.

If only an 8-bit binary number is needed, then the multiplication can be performed in the accumulator rather than in the HL register. This will free the HL register for some other use, such as a memory pointer. The 8-bit version is given in Listing 8.3

Listing 8.3. ASCII decimal to binary in C

```

; THIS PROGRAM IS DESIGNED TO OPERATE
; WITH THE SYSTEM MONITOR AT 5800 HEX
;
; JAN 12, 80
;
5000      ORG      5000H
;
5800 =     MONIT   EQU      5800H
5804 =     OUTT    EQU      MONIT+4
580C =     INPLN   EQU      MONIT+0CH
580F =     GETCH   EQU      MONIT+0FH
5812 =     OUTTHX  EQU      MONIT+12H
;
5000 3E0D  START:  MVI      A,0DH   ;CARR RET
5002 CD0658      CALL     OUTT
5005 3E0A      MVI      A,0AH   ;LINE FEED
5007 CD0658      CALL     OUTT
```

```

500A CD0C58      CALL    INPLN    ;GET A LINE
500D CD1650      CALL    DBIN     ;DEC TO BIN
5010 CD1258      CALL    OUTHX    ;HEX
5013 C30050      JMP      START

;
; CONVERT ASCII-DECIMAL TO 8-BIT BINARY
;
5016 0E00      DBIN:  MVI      C,0    ;CLEAR C
5018 CD0F58      DBIN2: CALL    GETCH  ;GET CHAR
501B D8        RC          ;LINE END
501C D630      SUI      '0'    ;CONV TO BINARY
501E DA3250      JC      DBIN4    ; < 0
5021 FE0A      CPI      10
5023 D23850      JNC     ERROR    ; > 10
5026 57        MOV      D,A      ;SAVE NEW
5027 79        MOV      A,C      ;SUM
5028 87        ADD      A        ;TIMES 2
5029 4F        MOV      C,A      ;SAVE
502A 87        ADD      A        ;TIMES 4
502B 87        ADD      A        ;TIMES 8
502C 81        ADD      C        ;TIMES 10
502D 82        ADD      D        ;COMBINE
502E 4F        MOV      C,A      ;SAVE IN C
502F C31850      JMP      DBIN2    ;NEXT

;
; CHECK FOR BLANK AT END
;
5032 FEF0      DBIN4:  CPI      (' '- '0') AND OFFH
5034 C23850      JNZ     ERROR    ;NOT BLANK
5037 C9        RET

; PRINT ? ON IMPROPER INPUT
;
5038 F1        ERROR:  POP      PSW    ;RESTORE
5039 3E3F      MVI      A,'?'
503B CD0658      CALL    OUTT
503E C30050      JMP      START    ;TRY AGAIN

;
5041          END

```

CONVERSION OF ASCII HEXADECIMAL CHARACTERS TO A 16-BIT BINARY NUMBER IN HL

The development of a routine to convert a string of ASCII-encoded hexadecimal characters into a 16-bit binary number will now be considered. This is the routine most frequently used in a system monitor. In fact, this was one of the first routines to be incorporated into our system monitor. Somewhere along the way there will have to be a multiplication by 16, since this is the base of the hexadecimal number. The multiplication can be easily performed by shifting the results left by four bits. Shifting left one bit is equivalent to multiplying by 2. Consequently, shifting by two bits performs a multiplication by 4.

For the binary routine we considered first, only the characters 1 and zero were valid. In the decimal routine that followed, the range of valid

input was zero to 9. The hexadecimal routine we will now consider is complicated by the fact that both the digits 0-9 and the letters A-F are valid.

Two separate algorithms will be considered; one produces an 8-bit result, the other gives a 16-bit result. The program given in Listing 8.4 is similar to the previous ones. It will convert a string of ASCII-encoded hex characters into a 16-bit binary number in the H,L register pair. The double-precision add, DAD H, is used four times to perform the multiplication by 16.

Listing 8.4. ASCII hex to binary in HL.

```

; THIS PROGRAM IS DESIGNED TO OPERATE
; WITH THE SYSTEM MONITOR AT 5800 HEX
;
; JAN 18, 80
;
5000      ORG      5000H
;
5800 =    MONIT    EQU      5800H
5806 =    OUTT     EQU      MONIT+6
580C =    INFLN    EQU      MONIT+0CH
580F =    GETCH    EQU      MONIT+0FH
5812 =    OUTHX    EQU      MONIT+12H
;
5000 3E0D  START: MVI      A,0DH  ;CARR RET
5002 CD0658 CALL      OUTT
5005 3E0A    MVI      A,0AH  ;LINE FEED
5007 CD0658 CALL      OUTT
500A CD0C58 CALL      INFLN  ;GET A LINE
500D CD2150 CALL      READHL  ;CONVERT
5010 4C      MOV      C,H
5011 CD1258 CALL      OUTHX  ;HIGH HALF
5014 4D      MOV      C,L
5015 CD1258 CALL      OUTHX  ;LOW HALF
5018 3E20    MVI      A,' '  ;SPACE
501A CD0658 CALL      OUTT
501D 7C      MOV      A,H  ;HIGH BYTE
;
; THE NEXT INSTRUCTION IS NEEDED
; WHEN LISTING 8.10 IS APPENDED
;
501E C30050 CALL      DEC8  ;H IN DECIMAL
;
; READ UP TO 4 ASCII HEX DIGITS FROM
; CONSOLE AND CONVERT TO 16-BIT
; BINARY NUMBER IN H,L
;
5021 210000 READHL: LXI      H,0  ;CLEAR
5024 CD0F58 RDHL2: CALL      GETCH  ;GET CHAR
5027 D8      RC          ;LINE END
5028 CD3E50 CALL      NIB    ;TO BINARY
502B DA3750 JC      RDHL4  ;NOT HEX
502E 29      DAD      H  ;TIMES 2
502F 29      DAD      H  ;TIMES 4
5030 29      DAD      H  ;TIMES 8
5031 29      DAD      H  ;TIMES 16

```

```

5032 B5          ORA     L        ;NEW CHAR
5033 6F          MOV     L,A
5034 C32450      JMP     RDHL2    ;NEXT
                ; CHECK FOR BLANK AT END
                ;
5037 FEFO      RDHL4: CPI     (' '- '0') AND OFFH
5039 C0          RNZ
503A E1          POP     H        ;RAISE STACK
503B C34C50      JMP     ERROR
                ;
                ; CONVERT ASCII CHARACTERS TO BINARY
                ;
503E D630      NIB:  SUI     '0'    ;ASCII BIAS
5040 D8          RC          ; < 0
5041 FE17      CPI     'F'-'0'+1
5043 3F          CMC          ;INVERT
5044 D8          RC          ;ERROR, > F
5045 FE0A      CPI     10
5047 3F          CMC          ;INVERT
5048 D0          RNC          ;NUMBER 0-9
5049 D607      SUI     'A'-'9'-1
504B C9          RET          ;LETTER A-F
                ;
                ; PRINT ? ON IMPROPER INPUT
                ;
504C 3E3F      ERROR: MVI     A,'?'
504E CD0658      CALL     OUT
5051 C30050      JMP     START    ;TRY AGAIN

```

Each ASCII character is converted to binary in subroutine NIB. This routine subtracts an ASCII zero, then checks to see that the character is valid. If it was originally in the range of an ASCII zero to ASCII 9, it will now be converted to the binary number 0-9. If a hex character A-F was entered, it will be converted to binary form by the additional subtraction of 7. Of course, nonhex characters will produce the error message of a question mark.

Assemble the program, load it into memory, and start it up. Type the following series of hex numbers.

```

>1
0001
>10
0010
>A
000A
>FFFF
FFFF
>12345
2345      (only last 4 characters used)

```

As with the other programs, leading zeros are not needed. If more than four characters are input, only the last four are used. Return to the monitor with a control-X.

CONVERSION OF TWO ASCII HEXADECIMAL CHARACTERS TO AN 8-BIT BINARY NUMBER IN REGISTER C

In the previous section, HL was used to convert hex characters into a binary number. But, if the HL register pair is needed as a memory pointer, then the accumulator can be used for this conversion. In this case, however, only an 8-bit binary number is produced. Listing 8.5 gives this version. Since the routine uses a fixed format, exactly two characters must be typed. This means that leading zeros must be entered.

Listing 8.5. ASCII hex to 8-bit binary C.

```

; THIS PROGRAM IS DESIGNED TO OPERATE
; WITH THE SYSTEM MONITOR AT 5800 HEX
;
; JAN 22, 80
;
5000      ORG      5000H
;
5800 =    MONIT    EQU      5800H
5806 =    OUTT     EQU      MONIT+6
580C =    INPLN    EQU      MONIT+0CH
580F =    GETCH    EQU      MONIT+0FH
;
; REMOVE NEXT LINE WHEN LISTING 8.12 ADDED
; OUTHX EQU      MONIT+12H
;
5000 3E0D      START: MVI      A,0DH      ;CARR RET
5002 CD0658      CALL      OUTT
5005 3E0A      MVI      A,0AH      ;LINE FEED
5007 CD0658      CALL      OUTT
500A CD0C58      CALL      INPLN      ;GET A LINE
500D CD1650      CALL      RDHEX      ;ASCII TO HEX
5010 CD4350      CALL      OUTHX      ;BIN TO HEX
5013 C30050      JMP      START
;
; CONVERT 2 ASCII-HEX CHARACTERS TO
; AN 8-BIT BINARY NUMBER IN C
;
5016 CD2450      RDHEX: CALL      HEX2      ;LEFT CHAR
5019 87          ADD      A          ;TIMES 2
501A 87          ADD      A          ;TIMES 4
501B 87          ADD      A          ;TIMES 8
501C 87          ADD      A          ;TIMES 16
501D 4F          MOV      C,A        ;SAVE
501E CD2450      CALL      HEX2      ;RIGHT CHAR
5021 B1          ORA      C          ;COMBINE
5022 4F          MOV      C,A
5023 C9          RET
;
5024 CD0F58      HEX2:  CALL      GETCH      ;HEX CHAR
;
; CONVERT ASCII CHARACTERS TO BINARY
;

```

```

5027 D630          SUI    '0'      ;ASCII BIAS
5029 DA3950        JC     ERROR    ; < 0
502C FE17          CPI     'F'-'0'+1
502E D23950        JNC     ERROR    ;ERROR, > F
5031 FE0A          CPI     10
5033 D8            RC      ;NUMBER 0-9
5034 D607          SUI     'A'-'9'-1
5036 FE0A          CPI     10
5038 D0            RNC      ;LETTER A-F
                ;
                ; PRINT ? ON IMPROPER INPUT
                ;
5039 F1            ERROR: POP     PSW      ;RAISE STACK
503A F1            POP     PSW
503B 3E3F          MVI     A,'?'
503D CD0658        CALL    OUTT
5040 C30050        JMP     START    ;TRY AGAIN

```

The multiplication by 16 is performed in the accumulator by using four ADD A instructions. The ADD A instruction is equivalent to an arithmetic shift left. Data is moved from the lower four bits to the upper four, and fills the lower bits with zero.

Assemble the program shown in the listing, load it into memory, and try it out. Remember, for this version, exactly two hex characters must be entered.

```

>01
01
>10
10
>0A
0A
>12
12

```

If everything is all right, return to the monitor with a control-X.

CONVERSION OF ASCII OCTAL CHARACTERS TO A 16-BIT BINARY NUMBER IN REGISTER HL

We did not use octal operations in the system monitor developed in Chapter 6, yet they can be very useful in trying to understand 8080 assembly language instructions. From the 8080 instruction set in Appendix D, it can be seen that the registers are assigned values as shown in the following table.

register	value
0	B
1	C
2	D
3	E
4	H
5	L
6	memory
7	A

Thus the register-move operations are obvious from the octal representation, but not from the hex or decimal form.

octal	hex	decimal	operation
101	41	65	MOV B,C
123	53	83	MOV D,E
167	77	119	MOV M,A

While octal numbers appear to be better than hexadecimal for expressing the 8080 operation codes, they leave something to be desired as memory pointers. The problem is that 16-bit addresses must be considered as two 8-bit bytes. But octal numbers represent groupings of three bits, and 8 is not evenly divisible by 3. An address of FFFF hex is equivalent to 177777 octal. But if this address is stored in two consecutive bytes, each byte will contain FF hex or 377 octal. This peculiarity of octal has given rise to the expression "crazy octal." A value of FFFF hex is 377:377 crazy octal.

hex	octal	crazy octal
FF	377	000:377
FFF	7777	017:377
7FFF	77777	177:377
FFFF	177777	377:377

Assemble the program, load it into memory, and try it out. The octal numbers input to this routine can be in the range of 0 to 177777. Try various octal numbers.

```
>0
0000
>10
0008
>20
0010
>177
007F
>377
00FF
>400
0100
>123456
A72E
>200000 (too big)
0000
```

Listing 8.6 ASCII octal to binary in HL.

```

; THIS PROGRAM IS DESIGNED TO OPERATE
; WITH THE SYSTEM MONITOR AT 5800 HEX
;
; JAN 22,79
;
5000      ORG      5000H
;
5800 =    MONIT    EQU      5800H
5806 =    OUTT     EQU      MONIT+6
580C =    INPLN    EQU      MONIT+0CH
580F =    GETCH    EQU      MONIT+0FH
5812 =    OUTHX    EQU      MONIT+12H
;
5000 3E0D  START:  MVI      A,0DH    ;CARR RET
5002 CD0658 CALL     OUTT
5005 3E0A          MVI      A,0AH    ;LINE FEED
5007 CD0658 CALL     OUTT
500A CD0C58 CALL     INPLN    ;GET A LINE
500D CD2050 CALL     RDOCT    ;OCT TO BIN
5010 4C          MOV      C,H      ;HIGH HALF
5011 CD1258 CALL     OUTHX    ;BIN-HEX
5014 4D          MOV      C,L      ;LOW HALF
5015 CD1258 CALL     OUTHX    ;BIN-HEX
5018 3E20          MVI      A,' '    ;SPACE
501A CD0658 CALL     OUTT
;
; THE NEXT INSTRUCTION IS NEEDED WHEN
; THE ROUTINE IN LISTING 8.13 IS USED
;
;      CALL     OUTOCT  ;BIN-OCT
501D C30050 JMP      START    ;NEXT VALUE
;
; INPUT H,L FROM CONSOLE
;
5020 D5      RDOCT:  PUSH     D      ;SAVE REGS
5021 210000   LXI      H,0      ;CLEAR
5024 CD0F58   OBIN2:  CALL     GETCH  ;GET CHAR
5027 DA4350   JC       OBIN3    ;LINE END
502A D630     SUI      '0'      ;TO BINARY
502C DA3E50   JC       OBIN4    ; < 0
502F FE08     CPI      8
5031 D24550   JNC      ERROR    ; > 8
5034 29       DAD      H        ;TIMES 2
5035 29       DAD      H        ;TIMES 4
5036 29       DAD      H        ;TIMES 8
5037 5F       MOV      E,A      ;NEW BYTE
5038 1600     MVI      D,0
503A 19       DAD      D        ;ADD NEW BYTE
503B C32450   JMP      OBIN2    ;NEXT
;
; CHECK FOR BLANK AT END
;
503E FEF0     OBIN4:  CPI      (' '- '0') AND 0FH
5040 C24550   JNZ      ERROR    ;NOT BLANK
5043 D1       OBIN3:  POP      D      ;RESTORE
5044 C9       RET
;

```

```
          ; PRINT ? ON IMPROPER INPUT
          ;
5045 E1      ERROR:  POP     H           ;RAISE STACK
5046 E1      POP     H
5047 3E3F    MVI     A,'?'
5049 CD0658  CALL    OUTT
504C C30050  JMP     START ;TRY AGAIN
```

This routine will convert a string of ASCII-encoded octal characters into a 16-bit binary number in the HL register pair. The current value in the HL register pair is multiplied by 8 (the number base) by performing three DAD H instructions. The new byte is converted from ASCII to binary by subtracting an ASCII zero. It is checked at this time to ensure that it is in the proper octal range of 0 to 7. The addition of the new digit to the present value is more complicated than it was for the binary or hex routines. The problem is that there can be a carry out from the low-order byte. For this reason, the new byte is placed into the DE register pair, then combined with the value in HL by using the double-precision DAD D instruction.

CONVERSION OF THREE ASCII OCTAL CHARACTERS TO AN 8-BIT BINARY NUMBER IN REGISTER C

The routine given in Listing 8.7 will convert exactly three ASCII-encoded octal characters into an 8-bit octal number in register C. The routine is programmed for fixed-format input; therefore, exactly three characters must be given. Assemble the program, load it into memory, and start it up. Type in the following octal numbers, including the leading zeros.

```
>000
00
>010
08
>020
10
>177
7F
>377
FF
```

Since the largest 8-bit number is 255 decimal or 377 octal, the first digit must be in the range 0-3. The remaining two digits must be in the range 0-7. A check is made to ensure that the characters are in the proper range. The first ASCII character in the input string is converted to binary by subtracting an ASCII zero. The result is multiplied by 8 with three ADD A instructions and the result is saved in the C register. The next character is converted to binary and added to the first with the ORA C instruction. The new sum is multiplied by 8 again with three ADD A instructions, then saved in the C register. Finally, the third character is converted to binary and added in. The final result is moved to the C register.

Listing 8.7. ASCII octal 8-bit binary in C.

```

; IF THREE DIGITS, LEFT ONE MUST BE <4
;
; THIS PROGRAM IS DESIGNED TO OPERATE
; WITH THE SYSTEM MONITOR AT 5800 HEX
;
; JAN 22, 80
;
5000      ORG      5000H
;
5800 =    MONIT   EQU      5800H
5806 =    OUTT    EQU      MONIT+6
580C =    INPLN   EQU      MONIT+0CH
580F =    GETCH   EQU      MONIT+0FH
5812 =    OUTHX   EQU      MONIT+12H
;
5000 3E0D  START:  MVI     A,0DH    ;CARR RET
5002 CD0658      CALL    OUTT
5005 3E0A      MVI     A,0AH    ;LINE FEED
5007 CD0658      CALL    OUTT
500A CD0C58      CALL    INPLN   ;GET A LINE
500D CD1B50      CALL    OCT8    ;OCT/BIN
5010 CD1258      CALL    OUTHX   ;PRINT HEX
5013 3E20      MVI     A,' '    ;BLANK
5015 CD0658      CALL    OUTT
;
; THE NEXT INSTRUCTION IS NEEDED WHEN
; THE ROUTINE IN LISTING 8.14 IS USED
;
5018 C30050      CALL    OCT      ;BIN TO ASCII
;                      JMP      START  ;NEXT VALUE
;
; CONVERT ASCII-ENCODED OCTAL
; TO 8-BIT BINARY NUMBER IN C
;
501B CD3550  OCT8:  CALL    OCTIN   ;1ST CHAR
501E FE04      CPI     4          ;FIRST
5020 D24750      JNC     ERROR    ;TOO LARGE
5023 87         ADD     A          ;TIMES 2
5024 87         ADD     A          ;TIMES 4
5025 87         ADD     A          ;TIMES 8
5026 4F         MOV     C,A        ;SAVE BYTE
5027 CD3550      CALL    OCTIN   ;2ND CHAR
502A B1         ORA     C          ;COMBINE
502B 87         ADD     A          ;TIMES 2
502C 87         ADD     A          ;TIMES 4
502D 87         ADD     A          ;TIMES 8
502E 4F         MOV     C,A        ;SAVE IN C
502F CD3550      CALL    OCTIN   ;3RD CHAR
5032 B1         ORA     C          ;COMBINE
5033 4F         MOV     C,A        ;SAVE IN C
5034 C9         RET
;
; CONVERT INPUT CHARACTER 0-7 TO BINARY
;
5035 CD0F58  OCTIN:  CALL    GETCH
5038 DA4650      JC      ERR2     ;NO CHAR
503B D630      SUI     '0'       ;ASCII BIAS
503D DA4650      JC      ERR2     ;TOO SMALL

```

```

5040 FE08          CPI      B
5042 D24658        JNC      ERR2    ;TOO LARGE
5045 C9            RET

;
; PRINT ? ON IMPROPER INPUT
;
5046 C1            ERR2:    POP      B    ;RAISE STACK
5047 C1            ERROR:   POP      B
5048 3E3F          MVI      A,'?'
504A CD0658        CALL     OUTT
504D C30050        JMP      START    ;TRY AGAIN

```

CONVERSION OF TWO ASCII BCD DIGITS TO AN 8-BIT BINARY NUMBER IN REGISTER C

The binary coded decimal (BCD) notation was introduced in Chapter 2. This method of encoding is less efficient than the binary notation. It takes more memory space to encode numbers, and mathematical operations can be considerably slower. The BCD notation, however, has two advantages. One is that conversion from decimal to BCD is simpler than conversion from decimal to binary. The second advantage is freedom from round-off error.

The conversion routine given in Listing 8.8 accepts exactly two ASCII-encoded decimal digits and converts them into an 8-bit BCD number in the C register. The routine can be repeatedly called to convert numbers with more than two characters.

Listing 8.8. ASCII hex to BCD in C.

```

; THIS PROGRAM IS DESIGNED TO OPERATE
; WITH THE SYSTEM MONITOR AT 5800 HEX
;
; JAN 13, 80
;
5000          ORG      5000H
;
5800 =        MONIT    EQU      5800H
5806 =        OUTT     EQU      MONIT+6
580C =        INPLN    EQU      MONIT+0CH
580F =        GETCH    EQU      MONIT+0FH
5812 =        OUTHX    EQU      MONIT+12H
;
5000 3E0D      START:   MVI      A,0DH    ;CARR RET
5002 CD0658    CALL     OUTT
5005 3E0A      MVI      A,0AH    ;LINE FEED
5007 CD0658    CALL     OUTT
500A CD0C58    CALL     INPLN    ;GET A LINE
500D CD2050    RDHL2:    CALL     HEX2    ;LEFT CHAR
5010 87        ADD      A        ;TIMES 2
5011 87        ADD      A        ;TIMES 4
5012 87        ADD      A        ;TIMES 8
5013 87        ADD      A        ;TIMES 16
5014 4F        MOV      C,A      ;SAVE

```

```

5015 CD2050      CALL    HEX2      %RIGHT CHAR
5018 B1          ORA      C          %COMBINE
5019 4F          MOV      C,A
501A CD1258      CALL    OUTHX     %PRINT
501D C30050      JMP      START     %NEXT

;
5020 CD0F58      HEX2:  CALL    GETCH  %HEX CHAR
;
; CONVERT ASCII CHARACTERS TO BINARY
;
5023 D630      NIB:    SUI      '0'    %ASCII BIAS
5025 DA2B50      JC      ERROR    % < 0
5028 FE0A      CPI      10
502A DB          RC              %NUMBER 0-9
;
; PRINT ? ON IMPROPER INPUT
;
502B 3E3F      ERROR:  MVI      A,'?'
502D CD0658      CALL    OUTT
5030 C30050      JMP      START     %TRY AGAIN
;
5033          END

```

With the BCD notation, there is a 2:1 correspondence between the number of BCD digits and the necessary number of bytes. Or, put another way, two decimal digits are stored in each byte. This arrangement is sometimes called *packed decimal*. The right decimal digit is encoded in the low-order four bits and the left digit is encoded into the high-order four bits.

```

38    0011 1000
27    0010 0111
59    0101 1001

```

BCD encoding involves essentially the same steps as does the hex-to-binary routine, except that only the characters 0 through 9 are allowed. The bit patterns corresponding to the hexadecimal numbers A through F are not allowed.

CONVERSION OF AN 8-BIT BINARY NUMBER IN C TO A STRING OF EIGHT ASCII BINARY CHARACTERS

In the first part of this chapter we developed programs to convert strings of ASCII-encoded characters into binary numbers. The programs in the following sections will perform the reverse operation. Binary numbers will be converted into strings of ASCII-encoded characters. Furthermore, we will combine the new routines with those already developed so that they may be more easily tested.

The program shown in Listing 8.9 can be used to convert an 8-bit binary number in register C into eight ASCII-encoded binary characters. The resulting characters are sent to the console in this case, but they could be

placed into sequential memory locations instead. This routine is incorporated into the system monitor developed in Chapters 6 and 7.

Listing 8.9 Binary in C to ASCII binary.

```

; THIS PROGRAM IS DESIGNED TO RUN WITH
; THE SYSTEM MONITOR AND WITH THE
; PROGRAM SHOWN IN LISTING 8.1
;
; PRINT AN 8-BIT BINARY NUMBER IN C AS
; 8 ASCII-ENCODED BITS
;
504A 0608      BITS:  MVI     B,8      ;8 BITS
504C 79        BIT2:  MOV     A,C      ;GET BYTE
504D 87        ADD     A            ;SET CARRY
504E 4F        MOV     C,A          ;PUT BACK
504F 3E18      MVI     A,'0'/2      ;HALF OF 0
5051 8F        ADC     A            ;DOUBLE+CARRY
5052 CD0658    CALL    OUTT         ;ONE BIT
5055 05        DCR     B            ;COUNT
5056 C24C50    JNZ     BIT2         ;8 TIMES
5059 C9        RET
;
505A                      END

```

Make a duplicate copy of the source program shown in Listing 8.1. This routine was used to convert ASCII-encoded binary characters into an 8-bit binary number in C. Remove the semicolon from the instruction that reads

```

;          CALL    BITS    ;BIN TO ASCII

```

Also delete the END directive if you used one. Add the lines given in Listing 8.9 to the end of the program.

The new routine works in the following way. Register B is initialized with the value of 8, the number of bits to be generated. Register C begins with the original binary byte. The bits of this byte are shifted to the left one at a time into the carry flag. The carry flag is then added to an ASCII zero to produce a 0 or a 1 at the console. For the 8080 version, the byte is moved to the accumulator, shifted left with an add instruction, then returned to register C.

If the current high-order bit is a zero, then the carry flag is reset and a zero is printed. If the current high-order bit is a 1, then the carry flag is set and a 1 is printed. The count in the B register is decremented after each character is printed. When the count reaches zero, the process is terminated.

Notice that the addition of the carry flag to the ASCII zero could have been accomplished with the instructions

```

MVI     A,'0'
ACI     0

```

However, this will require four bytes. The code we will use, which is not so obvious, requires only three bytes.

```
MVI    A,'0'/2
ADC     A
```

If you have a Z-80 CPU, this routine can be simplified and shortened by three bytes. Performing the rotation directly in the C register reduces the program by one byte. Two additional bytes are gained by using the decrement B, jump-not-zero operation. Now the accumulator can be zeroed with an exclusive-or operation and the carry can be added directly to an ASCII zero.

```
BITS:   LD      B,B      ;8 BITS
BIT2:   XOR     A        ;ZERO A
        SLA     L        ;SHIFT L LEFT
        ADC     A,'0'    ;ADD CARRY TO 0
        CALL    OUTT     ;SEND
        DJNZ    BIT2     ;8 TIMES
        RET
```

Assemble the combined program, load it into memory, and start it up. Be sure that the monitor is in place at the address of MONIT. The new binary-to-ASCII binary routine has been added in addition to the original binary to ASCII hex in the system monitor (OUTHX). Consequently, each number will now be rendered in both hex and binary. Type in the following binary numbers.

```
>0          (you type this)
00 00000000 (both hex and binary are given)
>1
01 00000001
>101
05 00000101
>10101010
AA 10101010
>11110000
F0 11110000
```

Remember that the error-correction features of the monitor are available. If you inadvertently type a control-X, you will end up in the monitor itself. You can return from the monitor to the new program, however, by typing

```
>G5000
```

if this is where you assembled the new routine.

CONVERSION OF AN 8-BIT BINARY NUMBER INTO THREE ASCII DECIMAL CHARACTERS

An 8-bit binary number can be converted into a string of ASCII-encoded decimal characters by repeated subtraction of powers of 10, the number base. The corresponding decimal number will lie in the range of zero to 255. The value of 100 (decimal) is repeatedly subtracted from the original binary number until the result becomes negative. One less than the number of subtractions is the number of hundreds in the decimal form. The result, which in this case can only be 0, 1, or 2, is added to the value of an ASCII zero, then sent to the console.

As an example of the 100s subtraction, consider the number 137.

$$\begin{array}{r} 137 \\ -100 \text{ (one subtraction)} \\ \hline 37 \\ -100 \text{ (too many)} \\ \hline \text{(negative number)} \end{array}$$

Since there was one subtraction of 100 before the number became negative, the number is in the range 100 to 199.

The value of the last 100 is added back to make the number positive again. Then the value of 10 is repeatedly subtracted from the new value until a negative result is again obtained. The number of tens in the decimal form is one smaller than the number of subtractions. This count is added to an ASCII zero and sent to the console for the middle digit. The value of ten is added back to the remainder. This adjusted remainder is then added to an ASCII zero to produce the units digit. It too is sent to the console.

Continuing with the example:

$$\begin{array}{r} \text{(negative number)} \\ +100 \text{ (add back last 100)} \\ \hline 37 \\ -10 \text{ (first subtraction)} \\ \hline 27 \\ -10 \text{ (2nd subtraction)} \\ \hline 17 \\ -10 \text{ (3rd subtraction)} \\ \hline 7 \\ -10 \text{ (too many)} \\ \hline \text{(negative number)} \\ +10 \text{ (add back last 10)} \\ \hline 7 \text{ (units)} \end{array}$$

Since there were three subtractions of 10 before the remainder became negative, the middle digit is a 3. Finally, the right digit is 7, the remainder after the last subtraction of 10.

Listing 8.10 gives the instructions for the conversion of an 8-bit binary number in register H. Register D initially contains the value of 100 (decimal) that is to be repeatedly subtracted from the number in H. As soon as the result of the subtraction becomes negative, the last 100 is added back, and the value in D is changed to a 10 by subtraction of 90. Register C is used to count the number of subtractions. It is initialized with the value of one less than an ASCII zero to simplify the conversion.

Listing 8.10. Binary in A to ASCII decimal.

```

; THIS PROGRAM IS DESIGNED TO RUN WITH
; THE SYSTEM MONITOR AND WITH THE
; PROGRAM SHOWN IN LISTING 8.4
;
; FEB 27, 80
;
; PRINT BINARY NUMBER IN A AS ASCII
; DECIMAL DIGITS. LEADING ZEROS SUPPRESSED
;
5057 D5      DEC8:  PUSH    D
5058 C5      PUSH    B
5059 1E00    MVI      E,0      ;LEADING 0 FLAG
505B 1664    MVI      D,100
505D 0E2F    DEC81: MVI      C,'0'-1
505F 0C      DEC82: INR      C
5060 92      SUB      D        ;100 OR 10
5061 D25F50  JNC      DEC82    ;STILL +
5064 82      ADD      D        ;ADD BACK
5065 47      MOV      B,A      ;REMAINDER
5066 79      MOV      A,C      ;GET 100/10
5067 FE31    CFI      '1'     ;ZERO?
5069 D27250  JNC      DEC84    ;YES
506C 7B      MOV      A,E      ;CHECK FLAG
506D B7      ORA      A        ;RESET?
506E 79      MOV      A,C      ;RESTORE BYTE
506F CA7750  JZ       DEC85    ;LEADING ZERO
5072 CD0658  DEC84: CALL    OUTT ;PRINT IT
5075 1EFF    MVI      E,0FFH   ;SET 0 FLAG
5077 7A      DEC85: MOV      A,D
5078 D65A    SUI      90       ;100 TO 10
507A 57      MOV      D,A
507B 78      MOV      A,B      ;REMAINDER
507C D25D50  JNC      DEC81    ;AGAIN
507F C630    ADI      '0'     ;ASCII BIAS
5081 CD0658  CALL    OUTT
5084 C1      POP      B
5085 D1      POP      D
5086 C9      RET
;
5087                      END

```

There is an additional feature added to this routine: leading-zero suppression. Leading zeros are typically suppressed when a number is expressed

in decimal form. On the other hand, leading zeros are commonly left in place for binary, octal, and hexadecimal numbers. Thus, we write

1
2
18
197
207

for decimal numbers, but

00001111 (binary)
040 (octal)
0FE3 (hexadecimal)

for the others.

One reason for keeping leading zeros is to make it easier to distinguish octal or hex numbers from decimal numbers. With this convention, the number 0137 would be interpreted as an octal or hex value rather than a decimal number. The suppression of leading zeros is not a difficult task, but it does require some additional code. It is not sufficient to merely remove all zeros, for then the number 0307 becomes 37.

One technique is to utilize a zero-suppression flag which is initially reset. Zeros are omitted as long as the flag remains reset. Then the flag is set when the first nonzero character is encountered. Subsequent zeros are not removed since the flag is set.

The necessary zero-suppression code has been included in the routine shown in Listing 8.10. Register E is used for the flag; it is initially reset. Then each character is checked with a CPI '1' instruction to see if it is an ASCII zero. If the value is not a zero, it is printed and the flag is set to FF hex. On the other hand, if the digit is a zero, the flag is checked. If it is found to be reset, the zero is not printed. Only three decimal characters can be produced from the original byte; consequently, just the first two need to be checked. If the value of the byte is zero, a single ASCII zero is printed.

The B, C, D, and E registers are utilized in the operations. Consequently, the original values are initially saved on the stack, then restored at the conclusion of the routine.

Duplicate the program shown in Listing 8.4, the ASCII-hex to binary routine. Keep one of the copies as a backup, then rename the other one HEXDEC.ASM. Remove the semicolon at the beginning of the line

```
;      CALL    DEC8
```

and remove the END directive at the end of the program. Add the lines given in Listing 8.10. Assemble the combination program, load it into memory, and start it up by branching to the address of START. We have coupled the 16-bit hex input program with the 8-bit decimal output program. Consequently, only the high-order byte will be converted to decimal. This is the

byte in the H register. Try the combined program with the following hex numbers.

```
>0
0000 0
>1
0001 0
>100
0100 1
>A00
0A00 10 (hex A is decimal 10)
>1000
1000 16 (10 hex is 16 decimal)
>FFFF
FFFF 255 (FF hex is 255 decimal)
```

This binary-to-decimal routine can be very useful at the CP/M systems level. Suppose that you want to save a program that starts at 100 hex and runs to 2736 hex. If the decimal routine is incorporated into a hexadecimal math routine of the system monitor, you have only to type

```
>H2800 100      (command)
2900 2700 39     (response)
```

The response of 39 is the decimal number of 256-byte blocks to be saved. Then you can give the CP/M command

```
A>SAVE 39  FILENAME.EXT
```

CONVERSION OF A 16-BIT BINARY NUMBER INTO FIVE ASCII DECIMAL CHARACTERS

In the previous section, we developed a routine to convert an 8-bit binary number into three ASCII-encoded decimal characters. We will now write a routine for converting a 16-bit binary number in HL into 5 ASCII-encoded decimal characters. This double-precision decimal number will range from zero to 65,535.

Duplicate the decimal-to-16-bit binary program in Listing 8.2. Remove the semicolon from the line

```
;      CALL  DBIN
```

and the END directive if you used one. Add the program shown in Listing 8.11 to the end.

Listing 8.11 Binary in HL to ASCII decimal.

```

; THIS PROGRAM IS DESIGNED TO RUN WITH
; THE SYSTEM MONITOR AND WITH THE
; PROGRAM SHOWN IN LISTING 8.2
;
; FEB 22, 79
;
; PRINT BINARY NUMBER IN H,L AS ASCII
; DECIMAL DIGITS, LEADING ZERO SUPPRESSED.
;
5055 0600      BIND:  MVI      B,0        ;LEADING 0 FLAG
5057 11F0D8    LXI      D,-10000    ;2'S COMPL
505A CD7550    CALL     SUBTR      ;10 THOUS
505D 1118FC    LXI      D,-1000
5060 CD7550    CALL     SUBTR      ;THOUS
5063 119CFF    LXI      D,-100
5066 CD7550    CALL     SUBTR      ;HUNDREDS
5069 11F6FF    LXI      D,-10
506C CD7550    CALL     SUBTR      ;TENS
506F 7D        MOV      A,L
5070 C630      ADI      '0'        ;ASCII BIAS
5072 C30658    JMP      OUTT      ;UNITS
;
; SUBTRACT POWER OF TEN AND COUNT
;
5075 0E2F      SUBTR:  MVI      C,'0'-1 ;ASCII COUNT
5077 0C        SUBT2:  INR      C
5078 19        DAD      D          ;ADD NEG NUMBER
5079 DA7750    JC       SUBT2      ;KEEP GOING
;
; ONE TOO MANY, ADD ONE BACK
;
507C 7A        MOV      A,D        ;COMPLEMENT
507D 2F        CMA
507E 57        MOV      D,A        ; D,E
507F 7B        MOV      A,E
5080 2F        CMA
5081 5F        MOV      E,A
5082 13        INX      D          ;AND
5083 19        DAD      D          ;ADD BACK
5084 79        MOV      A,C        ;GET COUNT
;
; CHECK FOR ZERO
;
5085 FE31      CPI      '1'        ;LESS THAN 1?
5087 D29150    JNC      NZERO      ;NO
508A 78        MOV      A,B        ;CHECK 0 FLAG
508B B7        ORA      A          ;SET?
508C 79        MOV      A,C        ;RESTORE
508D C8        RZ              ;SKIP LEADING 0
508E C30658    JMP      OUTT      ;INTERIOR ZERO
;
; SET FLAG FOR NON-ZERO CHARACTER
;
5091 06FF      NZERO:  MVI      B,0FFH ;SET 0 FLAG
5093 C30658    JMP      OUTT      ;PRINT IT
;
5096          END

```

This 16-bit version is similar to the 8-bit version of the previous section. This time we start with the subtraction of the decimal value 10,000 instead of 100. The number of subtractions is counted as before. When the result becomes negative, the last 10,000 is added back. The number of subtractions that was performed is the desired digit for the ten-thousandths position.

Since the 8080 CPU does not incorporate a 16-bit subtraction operation, the subtraction is obtained by adding the corresponding two's complement

```
LXI      D,-10000
. . .
. . .
DAD      D
```

The carry flag will be set for each addition (subtraction) except the last. The carry flag is then reset for the operation corresponding to the result becoming negative. The JC instruction in subroutine SUBTR causes the computer to loop the correct number of times. Suppose, for example, that the binary number in HL corresponds to the decimal number 32,128. This is the equivalent of the hexadecimal value 7D80. The two's complement of 10,000 is D8F0 hex. The sum of these two is

decimal	hexadecimal
32,128	7D80
-10,000	+D8F0
-----	-----
22,128	5670

Thus the addition of 7D80 and D8F0 hex is equivalent to subtracting 10,000 from 32,128.

The last subtraction that causes the result to become negative has to be undone. This could be accomplished by adding 10,000. However, the addition is accomplished in subroutine SUBTR which is also used to add back the 1,000, 100, and 10 for the equivalent steps of each decade. Therefore, we won't know, in general, which value to add. The solution is to obtain the necessary value from the two's complement of the two's complement for the current value. This two's complement is first obtained by complementing both the D and the E register to produce the one's complement. Then the DE register pair is incremented. Subroutine SUBTR is first called with DE set to -10,000, then to -1,000, -100, and -10. At this point, the units digit is contained in the L register.

This double-precision routine also incorporates instructions for suppressing leading zeros. The approach is similar to the one used in the previous section except that the H register is used for the zero flag.

Assemble the combination program, load it into memory, and start it up. Enter the following decimal numbers. The response will include both the hexadecimal and the decimal values of the input number.


```
>0
0000 0
>1
0001 1
>100
0064 100
>1024
0400 1024
>65535
FFFF 65535
```

At this point you may want to incorporate decimal numbers into the system monitor. When we incorporated an ASCII-input feature into the monitor we used the apostrophe to indicate this fact. It is customary to precede decimal numbers by a number sign. For example, the following input would indicate decimal input.

```
>H#1024 #200
```

CONVERSION OF AN 8-BIT BINARY NUMBER INTO TWO ASCII HEXADECIMAL CHARACTERS

The conversion of an 8-bit binary byte into two ASCII-encoded hexadecimal characters is an interesting exercise. The high-order four bits are represented by one hex character, and the low-order four bits are represented by the other hex character. Since the upper character is printed first, the upper four bits are rotated down to the lower position. These new lower four bits are converted to ASCII to produce the first character. Then the original low-order four bits are converted to ASCII to get the second character.

The nibble conversion appears to be straightforward. The upper four bits are zeroed by performing a masking AND with the value of 0F hex. The lower four bits are then converted to ASCII by the addition of an ASCII 0. If the result is in the range 0-9, then the conversion is complete. Otherwise, a binary 7 is added to the result, converting it to an ASCII-encoded letter of A through F.

To see why this conversion works, look at the ASCII table in Appendix A. The ASCII number 9 has a decimal value of 57. The ASCII letter A has a decimal value of 65. But the hexadecimal value of A follows the value of 9. Therefore, we need to add 7 to any valid hex number larger than 9 to convert it into the appropriate ASCII letter A through F.

The program shown in Listing 8.12 will convert an 8-bit binary number in the C register into two ASCII characters and send them to the console. Duplicate the program in Listing 8.5. Remove the external reference to subroutine OUTHX near the beginning.

```
OUTHX    EQU    MONIT+12H
```

Our new program will perform the same function. Also remove the final END directive if you used one. Copy the lines from Listing 8.12 on the end of the program. Assemble the combined program, load it into memory, and

start it up. Our monitor will still have to be in memory since we will need the I/O routines. This current version, Listing 8.12, with the built-in binary-to-hex routine, should respond exactly the same as the earlier version, Listing 8.5. The only difference is that we are converting binary to hex within the program rather than using a routine in the monitor.

Listing 8.12 Binary in C to ASCII hex

```

; THIS PROGRAM IS DESIGNED TO RUN WITH
; THE SYSTEM MONITOR AND WITH THE
; PROGRAM SHOWN IN LISTING 8.5
;
; JAN 18, 80
;
; ROUTINE TO OUTPUT 2 HEX CHARACTERS FROM C
; 8-BIT BINARY TO ASCII HEX CONVERSION
;
5043 79      OUTHX:  MOV     A,C      ;GET BYTE
5044 1F              RAR             ;ROTATE
5045 1F              RAR             ; FOUR
5046 1F              RAR             ; BITS TO
5047 1F              RAR             ; THE RIGHT
5048 CD4C50        CALL    HEX1      ;UPPER CHAR
504B 79              MOV     A,C      ;LOWER CHAR
;
504C E60F        HEX1:  ANI     0FH     ;LOW 4 BITS
504E C630        ADI     '0'     ;ASCII ZERO
5050 FE3A        CPI     '9'+1    ;0 TO 9
5052 DA0658        JC      OUTT      ;YES
5055 C607        ADI     7         ;CONVERT
5057 C30658        JMP     OUTT      ;A TO F
;
505A                      END

```

The algorithm used to convert the binary nibble to a hex character clearly demonstrates the technique. But there is a more efficient method for CPUs such as the 8080 and Z-80 that incorporate the decimal adjust accumulator (DAA) instruction. Change the second, third, fourth, and fifth lines of subroutine HEX1 so the subroutine looks like

```

HEX1:  ANI     0FH      (same)
        ADI     90H      (new)
        DAA              (new)
        ACI     40H      (new)
        DAA              (new)
        JMP     OUTT     (same)

```

Conversion of a 16-bit binary value into four hex characters is obtained by calling the 8-bit routine twice. For example, the HL register pair can be printed with the following routine.

```

OUTH:  MOV     C,H
        CALL    OUTHX
        MOV     C,L
        CALL    OUTHX

```

Conversion of a binary number to a string of ASCII-encoded BCD characters does not require a special routine. It is performed simply by calling the binary-to-hex routine OUTHX.

CONVERSION OF A 16-BIT BINARY NUMBER INTO SIX ASCII OCTAL CHARACTERS

A 16-bit binary number in the HL register pair can be converted into six ASCII-encoded octal characters by repeatedly shifting the double register to the left. We make use of the double-register add instruction DAD H. This instruction adds the register pair HL to itself. The operation is equivalent to a double-precision arithmetic shift left. All 16 bits are shifted left and a zero is moved into the lowest order bit. The carry flag is set if the original highest-order bit was a logical one. The carry bit is reset otherwise.

The routine is shown in Listing 8.13. As the bits of the double register are shifted out the high end, they are converted to the corresponding octal number in the accumulator. The largest 16-bit octal number is 177777; consequently, the first octal character (starting from the left) can only be a zero or a one. The remaining five characters can range from zero through 7. They are obtained from groups of three bits.

Listing 8.13 Binary in HL to ASCII octal.

```

; THIS PROGRAM IS DESIGNED TO RUN WITH
; THE SYSTEM MONITOR AND WITH THE
; PROGRAM SHOWN IN LISTING 8.6
;
; JAN 18, 80
;
; ROUTINE TO OUTPUT A 16-BIT BINARY
; VALUE IN H,L AS OCTAL CHARACTERS
;
5052 E5      OUTOCT: PUSH    H          ;SAVE VALUE
5053 C5              PUSH    B
5054 0605      MVI     B,5          ;5 CHAR
5056 AF              XRA     A          ;ZERO
5057 29              DAD     H          ;HIGH BIT
5058 CE30      ACI     '0'          ;ADDED IN
505A CD0658     CALL    OUTT         ;PRINT IT
505D 3E06      OCT2:  MVI     A,6      ;ROTATE 60Q
505F 29              DAD     H          ;CARRY
5060 17              RAL           ;ROTATE TO A
5061 29              DAD     H          ;AGAIN
5062 17              RAL           ;TO A
5063 29              DAD     H          ;3RD TIME
5064 17              RAL           ;TO A
5065 CD0658     CALL    OUTT         ;PRINT CHAR
5068 05              DCR     B          ;COUNT
5069 C25D50     JNZ     OCT2         ;5 TIMES
506C C1              POP     B
506D E1              POP     H
506E C9              RET
;
506F                      END

```

The first step shown in Listing 8.13 saves the HL and BC registers on the stack. This operation may not always be necessary. The XRA operation is used to zero the accumulator. It must be performed before the DAD H instruction since it resets the carry flag. The DAD instruction will set the carry flag if the high-order bit was a 1, or reset the flag if the high-order bit was a zero. The carry flag is then added to an ASCII zero and sent to the console.

The remaining five digits are generated in a loop starting at label OCT2. Register B is preloaded with the value of 5 to count the remaining digits. We need to transfer the current three high-order bits from the H register into the accumulator. This is accomplished by three DAD H instructions. After each one, the carry flag will reflect the state of the most recent high-order bit of H. After each DAD instruction, we perform a rotate accumulator instruction. This moves the carry bit into the low-order bit of A. After three such operations, the three low-order bits of the accumulator will contain the proper octal bit pattern for the appropriate character. But they are in binary form and we need to convert them to ASCII for printing.

The bit pattern for the ASCII zero is 011 0000. Notice that it contains zeros in the lower four bit positions. At the beginning of the OCT2 loop we preloaded the accumulator with a binary 6 which has a bit pattern of 000 0110. At the conclusion of the OCT2 loop, the three rotations will convert this binary 6 into a 60 octal which is equivalent to an ASCII zero. This effectively converts the three lower-order bits, shifted in from the carry flag, into ASCII-encoded octal.

The Z-80 version can be a little shorter if the instruction

```
DJNZ    OCT2
```

is used in place of

```
DCR     B
JNZ     OCT2
```

CONVERSION OF AN 8-BIT BINARY NUMBER INTO THREE ASCII OCTAL CHARACTERS

In the previous section we derived a subroutine for the conversion of a 16-bit binary number into ASCII characters. The conversion of an 8-bit binary number to octal will be considered here. We could use the H,L double register, as previously, to perform the necessary shifts. However, if the H,L register is needed for something else, such as a pointer to memory, then another method would be better.

The routine shown in Listing 8.14 performs the needed rotations in the accumulator. The original binary byte is in the C register. The byte is moved to the accumulator and two left circular rotate instructions are performed. This effectively moves the two high-order bits down to the two low-order

positions. It is equivalent to performing six right circular rotations. The remaining bits are zeroed with a logical AND 3 step. The ubiquitous ASCII zero is added, and the result is sent to the console.

The middle character is obtained by rotating the original byte to the right. A logical AND 7 isolates these low-order bits. The ASCII zero is added and the byte is sent to the console. The original byte is retrieved a third time. Now the three bits of the third character are properly positioned. Hence no rotation is needed. The masking AND operation is still needed, however. Finally, the ASCII zero is added prior to printing.

Type the program shown in Listing 8.14. Add the new program to the end of the octal-to-binary program shown in Listing 8.7. Assemble the combination, load it into memory, and branch to the beginning. Remember that the input requires exactly three octal characters. If less than three are used, an error message of a question mark will be printed. If more than three characters are typed, only the first three will be used.

Listing 8.14. 8-bit binary in C to ASCII

```

; THIS PROGRAM IS DESIGNED TO RUN WITH
; THE SYSTEM MONITOR AND WITH THE
; PROGRAM SHOWN IN LISTING 8.7
;
; JAN 22, 80
;
; ROUTINE TO OUTPUT AN 8-BIT BINARY
; VALUE AS THREE OCTAL CHARACTERS
;
5053 79      OCT:  MOV     A,C      ;GET IT
5054 07              RLC              ;2 HIGH BITS
5055 07              RLC
5056 E603      ANI      3          ;MASK
5058 CD6550     CALL     OCT3
505B 79      MOV     A,C      ;GET AGAIN
505C 0F              RRC              ;MIDDLE BITS
505D 0F              RRC
505E 0F              RRC
505F CD6350     CALL     OCT2
5062 79      MOV     A,C      ;RIGHT BITS
5063 E607      OCT2: ANI      7          ;3 BITS
5065 C630      OCT3: ADI      '0'      ;ASCII BIAS
5067 C30658     JMP     OUTT      ;PRINT
;
506A              END

```

CONVERSION OF A 16-BIT BINARY NUMBER TO SPLIT OCTAL

Some of the 8080 and Z-80 instructions can have either 8-bit or 16-bit operands. Typical 8-bit operations for the 8080 are

```

MVI     A,10
ADI      3
ANI      7

```

The 16-bit operations include

```
CALL    100H
JMP     5005H
LXI     H,0
```

But the 8-bit architecture of microcomputers means that 16-bit operands are stored as two consecutive bytes. Each byte can be represented as two hexadecimal characters. And the entire 16-bit value can be represented by a combination of all four of these hex characters. For example, the 16 bits

11110000 10101010

can be represented with the hex characters

F0AA

Alternately, the left byte can be represented by an F0 hex, and the right byte can be expressed as AA hex. There is no problem here since each hex character represents four bits, and both 8 and 16 are evenly divisible by 4.

Octal representation is more complex. In this case, each octal character represents three bits (or sometimes two). Since neither 8 nor 16 is evenly divisible by 3, a problem can occur. Consider the 16-bit value

1 111 010 011 101 010

It can be represented in the octal notation as

172352

This is the result that the program in Listing 8.13 would produce at the system console. The problem is that the 16 bits are actually stored in two adjacent 8-bit locations. If the bit pattern is grouped into 8-bit bytes, it looks like this.

11 110 100 11 101 010

In this arrangement, the two corresponding octal bytes are represented as

364 352

The result, which has been termed split octal or crazy octal, looks very different from the corresponding 16-bit octal value of 172352. The two octal bytes of split-octal notation are sometimes separated by a colon to distinguish the representation from the regular 16-bit octal.

364:352

The split-octal notation can be readily implemented, as shown in Listing 8.15. This program is adapted from the 8-bit octal-to-binary and binary-to-octal routines given in Listings 8.7 and 8.14. The first part takes two separate octal bytes and converts them to an 8-bit binary number. The second part converts the binary byte into two octal bytes. Each split-octal number is entered from the console as two groups of three characters. A space or colon can be used to separate the two parts.

Listing 8.15. Split-octal routines

```

; 6 OCTAL CHARACTERS SEPARATED BY A
; SPACE ARE ENTERED FROM THE CONSOLE.
; A 16-BIT BINARY NUMBER IS PRODUCED
; IN D,E. THIS IS RECONVERTED TO OCTAL
;
; THIS PROGRAM IS DESIGNED TO OPERATE
; WITH THE SYSTEM MONITOR AT 5800 HEX
;
; JAN 22, 80
;
5000      ORG      5000H
;
5800 =    MONIT   EQU      5800H
5806 =    OUTT    EQU      MONIT+6
580C =    INPLN   EQU      MONIT+0CH
580F =    GETCH   EQU      MONIT+0FH
5812 =    OUTHX   EQU      MONIT+12H
;
5000 3E0D      START: MVI      A,0DH      ;CARR RET
5002 CD0658      CALL      OUTT
5005 3E0A      MVI      A,0AH      ;LINE FEED
5007 CD0658      CALL      OUTT
500A CD0C58      CALL      INPLN      ;GET A LINE
500D CD2350      CALL      OCT88      ;6 OCT CHAR
5010 4A          MOV      C,D        ;FIRST
5011 CD1258      CALL      OUTHX      ;TO HEX
5014 4B          MOV      C,E        ;SECOND
5015 CD1258      CALL      OUTHX      ;TO HEX
5018 3E20      MVI      A,' '        ;BLANK
501A CD0658      CALL      OUTT
501D CD6850      CALL      OUT80      ;TO BINARY
5020 C30050      JMP      START      ;NEXT VALUE
;
; 6 SPLIT-OCTAL CHAR TO 16-BIT BINARY
;
5023 CD3250      OCT88: CALL      OCT8      ;FIRST
5026 51          MOV      D,C        ;SAVE
5027 CD0F58      CALL      GETCH      ;SPACE
502A DA5F50      JC      ERR3        ;ONLY 1 CHAR
502D CD3250      CALL      OCT8      ;SECOND
5030 59          MOV      E,C        ;SAVE
5031 C9          RET
;
; CONVERT ASCII-ENCODED OCTAL
; TO 8-BIT BINARY NUMBER IN C
;

```

```

5032 CD4C50      OCT8:  CALL      OCTIN      ;1ST CHAR
5035 FE04                CPI      4          ;FIRST
5037 D25E50                JNC      ERROR     ;TOO LARGE
503A 87                ADD      A          ;TIMES 2
503B 87                ADD      A          ;TIMES 4
503C 87                ADD      A          ;TIMES 8
503D 4F                MOV      C,A         ;SAVE BYTE
503E CD4C50      CALL      OCTIN      ;2ND CHAR
5041 B1                ORA      C          ;COMBINE
5042 87                ADD      A          ;TIMES 2
5043 87                ADD      A          ;TIMES 4
5044 87                ADD      A          ;TIMES 8
5045 4F                MOV      C,A         ;SAVE IN C
5046 CD4C50      CALL      OCTIN      ;3RD CHAR
5049 B1                ORA      C          ;COMBINE
504A 4F                MOV      C,A         ;SAVE IN C
504B C9                RET

;
; CONVERT INPUT CHARACTER 0-7 TO BINARY
;
504C CD0F58      OCTIN:  CALL      GETCH
504F DA5D50                JC      ERR2      ;NO CHAR
5052 D630                SUI      '0'       ;ASCII BIAS
5054 DA5D50                JC      ERR2      ;TOO SMALL
5057 FE08                CPI      8
5059 D25D50                JNC      ERR2      ;TOO LARGE
505C C9                RET

;
; PRINT ? ON IMPROPER INPUT
;
505D C1      ERR2:  POP      B          ;RAISE STACK
505E C1      ERROR: POP      B
505F C1      ERR3:  POP      B
5060 3E3F                MVI      A,'?'
5062 CD0658      CALL      OUTT
5065 C30050      JMP      START      ;TRY AGAIN

;
; 16-BIT BINARY IN D,E TO SPLIT OCTAL
;
5068 4A      OUT80:  MOV      C,D          ;FIRST BYTE
5069 CD7250      CALL      OCT          ;TO OCT
506C 3E3A      MVI      A,':'
506E CD0658      CALL      OUTT          ;SEPARATOR
5071 4B      MOV      C,E          ;SECOND

;
; ROUTINE TO OUTPUT AN 8-BIT BINARY
; VALUE AS THREE OCTAL CHARACTERS
;
5072 79      OCT:   MOV      A,C          ;GET IT
5073 07                RLC              ;2 HIGH BITS
5074 07                RLC
5075 E603      ANI      3              ;MASK
5077 CD8450      CALL      OCT3
507A 79      MOV      A,C          ;GET AGAIN
507B 0F                RRC              ;MIDDLE BITS
507C 0F                RRC
507D 0F                RRC
507E CD8250      CALL      OCT2

```



```
5081 79          MOV    A,C    ;RIGHT BITS
5082 E607      OCT2:  ANI    7    ;3 BITS
5084 C630      OCT3:  ADI    '0'  ;ASCII BIAS
5086 C30658    JMP     OUTT    ;PRINT
                    ;
5089          END
```

The input number is converted into a 16-bit binary number in the D,E register pair by calling the 8-bit routine twice. The hex value is printed out as usual, then the split-octal version. A colon in the middle separates the two halves.

Assemble the program and try it out.

```
>177 377  (a space separator)
7FFF 177:377
>100:200  (a colon separator)
4080 100:200
```

This completes the base-conversion routines. At this point, you may want to incorporate some of these routines into your system monitor.

CHAPTER NINE

Paper Tape and Magnetic Tape Routines

It is possible to encode complete programs, such as a BASIC interpreter, into ROM so that calculations, such as the square root of 19, can be performed as soon as the computer is turned on. But more complicated problems will require a source program. If the source program is used frequently, then it would be inconvenient to reenter the source program each time it is needed. One way to avoid this reentry problem is to save the source program somehow and then reload it into the computer when it is needed.

But BASIC is not the only computer language. Some tasks are more easily performed with other languages, such as Pascal or APL. Assembly language is useful for systems programming. A full text editor program has more features than the most complex BASIC interpreter. Thus, it is better not to have the BASIC interpreter in ROM. Instead, a small monitor program, such as the one developed in Chapter 6, can be placed in ROM. We can use this small monitor to load larger programs from an external medium.

The floppy disk is a convenient medium for saving and reloading programs. The cost, however, is greater than other storage media such as paper tape or magnetic tape. Even if a floppy-disk system is utilized for program storage, it might be wise to make backup copies on magnetic or paper tape.

The simplest storage method is to utilize the paper tape accessory available on some Teletype machines. With this approach, a separate computer I/O port is unnecessary. Furthermore, paper tapes can be read directly on the Teletype, without using a computer. The disadvantage of this method is that the transfer rate is low, since the Teletype operates at only ten characters per second.

A more complicated, but faster, method utilizes an ordinary magnetic tape machine designed for home recording. In this case a separate I/O port will usually be necessary, but the advantage is that the recording rate is higher than for paper tape. Common data transfer rates range from 30 to over 120 characters per second.

The frequency response of audio tape recorders is limited to a maximum of 10 to 20 kHz. But since the computer operates at 2 or 4 MHz, the signals from the computer cannot be directly copied onto tape.

One solution is to convert the computer's digital signals into sine waves that can be easily recorded. A digital-to-analog (D/A) circuit is used for this purpose. When the recorded program is subsequently played back into the computer, a separate analog-to-digital (A/D) circuit reverses the process. It converts the signal from a sine wave back into the digital form. The D/A and A/D circuits are combined on a printed circuit board with the usual parallel-to-serial converter for the I/O port.

THE CHECKSUM METHOD

Two separate tape-handling routines are given in this chapter; both may be used with paper tape or magnetic tape. They are both suitable for storing binary object programs, ASCII-encoded source programs, or just a set of numbers. The information is stored in a file consisting of a sequence of records. Each record contains a checksum that is used to detect errors.

Errors can be introduced at several places in the tape-recording and playback process. The proximity of AC power cords to audio signal lines can change the transmitted signal. Oxide layers may fall off the tape, or there may be a defective spot on the recording surface. If the recording and playback heads are dirty, they can incorrectly render the signal. The A/D conversion step, when the tape is played back, can also give rise to errors.

In addition to the data, each record stored on the tape contains the record length, the memory address of the record, and a checksum byte. The checksum byte is obtained by adding all of the data bytes in the record. When the tape is read back, the computer sums up the data and compares the result to the checksum value written on the tape at the end of the record. A discrepancy indicates an error.

Since an 8-bit checksum is used in both programs, there are 256 possible combinations. Any single load error in the record will be discovered by this method. In principle, it is possible that two errors in the same record will combine to produce the expected checksum value. In practice, however, this is not likely to be a problem. Double errors occur much less frequently than single errors. Furthermore, in a well-tuned system, single errors should be infrequent. They are most likely to be caused by low-quality tape, a dirty head, or a mistuned A/D converter circuit. Buy the best tape you can and clean the heads often. A routine that can be used for aligning the A/D circuit is incorporated in the second tape routine given later in this chapter.

AN ASCII-HEX TAPE PROGRAM

The tape program given in Listing 9.1 is based on an ASCII-encoded hexadecimal format. It can be used to produce paper tapes or magnetic tapes of

computer programs. It can even produce a tape of itself. The program is self-contained and assembled to run at 100 hex. No outside routines are required. An additional feature of this program is that it can punch readable labels on the leader of a paper tape. (Of course, this feature is not very useful for magnetic tape recordings.) The label routine is discussed in the next section of this chapter.

Listing 9.1. Hexadecimal tape routines.

```

; HEXMON: A MONITOR TO DUMP, LOAD, AND
;         VERIFY INTEL HEX CHECKSUM TAPES
;         WITH TAPE LABEL FOR HEADER
;
;         TITLE 'hexmon with tlabel'
;
0100      ORG      100H
;
;
;
;
0010 =    RLEN      EQU      16      ;RECORD LENGTH
;
0010 =    CSTAT     EQU      10H      ;CONSOLE STATUS
0011 =    CDATA     EQU      CSTAT+1 ;CONSOLE DATA
0001 =    CISK      EQU      1       ;IN MASK
0002 =    COMSK     EQU      2       ;OUT MASK
0006 =    PSTAT     EQU      6       ;PUNCH STATUS
0007 =    PDATA     EQU      PSTAT+1 ;PUNCH DATA
0001 =    PISK      EQU      1       ;PUNCH IN MASK
0080 =    POMSK     EQU      80H      ;PUNCH OUT MASK
;
000D =    CR        EQU      13      ;CARRAGE RETURN
000A =    LF        EQU      10      ;LINE FEED
007F =    DEL       EQU      127
0008 =    CTRH      EQU      8       ;^H CONSOLE BACKUP
0000 =    NNULS     EQU      0       ;CONSOLE NULLS
;
;
0100 C37D01 START:  JMP      CONTIN
;
; INPUT A BYTE FROM THE CONSOLE
;
0103 DB10      INPUTT: IN       CSTAT
0105 E601      ANI       CISK
0107 CA0301     JZ        INPUTT
010A DB11      IN       CDATA
010C E67F      ANI       7FH      ;STRIP PARITY
010E C9        RET
;
; OUTPUT A CHARACTER TO CONSOLE
;

```

```

010F F5      OUTT:  PUSH    PSW
0110 DB10    OUTW:  IN      CSTAT
0112 E602          ANI      COMSK
0114 CA1001          JZ      OUTW
0117 F1        POP      PSW
0118 D311          OUT      CDATA
011A C9        RET

; OUTPUT H,L TO CONSOLE
; 16-BIT BINARY TO HEX
;
011B 4C      OUTHL:  MOV     C,H      ;FETCH H
011C CD2001          CALL    OUTHX   ;PRINT IT
011F 4D        MOV     C,L      ;FETCH L, PRINT IT
;
; CONVERT A BINARY NUMBER TO TWO
; HEX CHARACTERS, AND PRINT THEM
;
0120 79      OUTHX:  MOV     A,C
0121 1F          RAR          ;ROTATE
0122 1F          RAR          ;UPPER
0123 1F          RAR          ;CHARACTER
0124 1F          RAR          ;TO LOWER
0125 CD2901          CALL    HEX1    ;OUTPUT UPPER
0128 79        MOV     A,C      ;OUTPUT LOWER
;
; OUTPUT A HEX CHARACTER
; FROM LOWER FOUR BITS
;
0129 E60F    HEX1:  ANI      0FH    ;TAKE 4 BITS
012B C690          ADI      144
012D 27        DAA          ;DAA TRICK
012E CE40          ACI      64
0130 27        DAA          ;ONCE AGAIN
0131 C30F01      JMP      OUTT
;
; CONVERT ASCII CHARACTER FROM CONSOLE
; TO 4 BINARY BITS
;
0134 D630    NIB:   SUI      '0'    ;ASCII BIAS
0136 D8        RC          ;< '0'
0137 FE17          CPI      'F'-'0'+1
0139 3F        CMC          ;INVERT
013A D8        RC          ;ERROR, > 'F'
013B FE0A          CPI      10
013D 3F        CMC          ;INVERT
013E D0        RNC          ;NUMBER IS 0-9
013F D607          SUI      'A'-'9'-1
0141 FE0A          CPI      10
0143 C9        RET          ;CHARACTER IS A-F
;
; INPUT H,L FROM CONSOLE
;
0144 D5      READHL:  PUSH    D
0145 C5        PUSH    B
0146 210000          LXI      H,0    ;START WITH 0
0149 CD0402      RDHL2:  CALL    GETCH

```

```

014C DA6801      JC      RDHL5      #END OF LINE
014F CD3401      CALL     NIB        #CONVERT TO BINARY
0152 DA5E01      JC      RDHL4      #NOT HEX
0155 29          DAD      H          #16-BIT
0156 29          DAD      H          # SHIFT LEFT
0157 29          DAD      H
0158 29          DAD      H
0159 B5          ORA      L          #COMBINE NEW
015A 6F          MOV      L,A
015B C34901      JMP      RDHL2      #NEXT

;
; CHECK FOR COMMA OR BLANK
; AT END OF ADDRESS
;
015E FEFC      RDHL4: CPI      ','-'0' #COMMA?
0160 CA6801      JZ      RDHL5      #YES, OK
0163 FEFO      CPI      ','-'0' #BLANK?
0165 C26B01      JNZ     ERROR      #NO
0168 C1          RDHL5: POP      B
0169 D1          POP      D
016A C9          RET

;
ERROR: MVI      A,'?' #IMPROPER INPUT
CALL     OUTT
JMP      START #TELL HOW AGAIN

;
; SEND CHRACTERS POINTED TO BY D,E
; UNTIL A BINARY ZERO IS FOUND
;
0173 1A          SENDM: LDAX     D      #NEXT BYTE
0174 B7          ORA      A          #SEE IF ZERO
0175 C8          RZ      #DONE
0176 CD0F01      CALL     OUTT
0179 13          INX      D
017A C37301      JMP      SENDM

;
CONTIN: LXI      SP,STACK
LXI      D,SIGN #MESSAGE
CALL     SENDM #SEND IT

;
RSTRT: LXI      SP,STACK
CALL     INPLN #GET A LINE
CALL     GETCH #INPUT THE TASK
CPI      'W' #DUMP
JZ      PDUMP
CPI      'R' #READ, NO AUTOSTART
JZ      FLOAD
CPI      'E' #LOAD AND EXECUTE
JZ      FLOAD
CPI      'V' #VERIFY
JZ      FLOAD
CPI      'G' #GO SOMEWHERE
JNZ     ERROR

#####
;

```

```

; JUMP TO ANOTHER PROGRAM
;
01A8 CD4401      CALL    READHL  ;JUMP ADDRESS
01AB E9          JPCHL:  PCHL    ;OK, GOODBYE
;
; INPUT A LINE FROM THE CONSOLE
; AND PUT IT INTO A BUFFER
;
01AC CDEE01      INPLN:  CALL    CRLF
01AF 3E3E        MVI     A,'>'  ;COMMAND PROMPT
01B1 CD0F01      CALL    OUTT    ;SEND TO CONSOLE
01B4 212406      INPL2:  LXI     H,IBUFF ;BUFFER ADDRESS
01B7 222106      SHLD    IBUFF   ;INITIALIZE POINTER
01BA 0E00        MVI     C,0     ;INITIALIZE COUNT
01BC CD0301      INPLI:  CALL    INPUTT ;CHAR FROM CONSOLE
01BF FE20        CPI     ' '     ;CONTROL CHAR?
01C1 DAE001      JC      INPLC   ;YES, GO PROCESS
01C4 FE7F        CPI     DEL     ;DELETE CHAR?
01C6 CAF801      JZ      INPLB   ;YES
01C9 FESB        CPI     'Z'+1  ;UPPER CASE?
01CB DAD001      JC      INPL3   ;NO
01CE E65F        ANI     5FH     ;MAKE UPPER
01D0 77          INPL3:  MOV     M,A ;PUT IN BUFFER
01D1 3E20        MVI     A,32    ;GET BUFFER SIZE
01D3 B9          CMP     C       ;TEST IF FULL
01D4 CAB001      JZ      INPLI   ;YES, LOOP
01D7 7E          MOV     A,M     ;RECALL CHARACTER
01D8 23          INX     H       ;INCR POINTER
01D9 0C          INR     C       ;AND INCR COUNT
01DA CD0F01      INPLE:  CALL    OUTT ;ECHO CHARACTER
01DD C3BC01      JMP     INPLI   ;GET NEXT CHAR
;
; PROCESS CONTROL CHARACTER
;
01E0 FE08        INPLC:  CPI     CTRH ;'H'?
01E2 CAF801      JZ      INPLB   ;YES
01E5 FE0D        CPI     CR      ;TEST IF RETURN
01E7 C2BC01      JNZ     INPLI   ;NO, IGNORE CHAR
;
; END OF INPUT LINE
;
01EA 79          MOV     A,C     ;LINE COUNT
01EB 322306      STA     IBUFC   ;SAVE
;
; CARRIAGE RETURN, LINE FEED
CRLF:  MVI     A,CR
       CALL    OUTT
       MVI     A,LF
;
; IF NULLS REQUIRED AFTER CR, LF
; USE REPEAT MACRO
;

```

```

                                IF      NNULS > 0 ;ASSEMBLE
                                CALL     OUTT
                                XRA      A          ;GET A NULL
                                REPT     NNULS-1
                                CALL     OUTT
                                ENDM
                                ENDIF          ;NULLS
                                ;
01F5 C30F01                    JMP      OUTT
                                ;
                                ; DELETE ANY PRIOR CHARACTER
                                ;
01F8 79                        INPLB:  MOV     A,C      ;CHAR COUNT
01F9 B7                        ORA      A          ;ZERO?
01FA CAB01                     JZ       INPLI      ;YES
01FD 2B                        DCX      H          ;BACK POINTER
01FE 0D                        DCR      C          ;AND COUNT
01FF 3E08                      MVI      A,CTRH     ;BACK CURSOR
0201 C3DA01                    JMP      INPLE      ;PRINT IT
                                ;
                                ; OBTAIN A CHARACTER FROM THE CONSOLE
                                ; BUFFER. SET CARRY IF EMPTY.
                                ;
0204 E5                        GETCH:  PUSH     H          ;SAVE REGS
0205 2A2106                    LHL      IBUFF      ;GET POINTER
0208 3A2306                    GETC2:  LDA      IBUFC     ;GET COUNT
020B D601                      SUI      1          ;DECR WITH CARRY
020D DA1802                    JC       GETC4      ;NO CHARACTERS
0210 322306                    STA      IBUFC     ;REPLACE COUNT
0213 7E                        MOV      A,M        ;GET CHARACTER
0214 23                        GETC3:  INX      H          ;INCR POINTER
0215 222106                    SHLD     IBUFF      ;REPLACE POINTER
0218 E1                        GETC4:  POP      H          ;RESTORE REGS
0219 C9                        RET              ;CARRY IF NO CHAR
                                ;
                                ; PUNCH A PAPER TAPE
                                ;
021A CD4401                    PDUMP:  CALL     READHL   ;START ADDRESS
021D DA6B01                    JC       ERROR      ;TOO FEW PARAM
0220 EB                        XCHG
0221 CD4401                    CALL     READHL   ;STOP ADDRESS
0224 EB                        XCHG
0225 13                        INX      D
0226 E5                        PUSH     H
0227 CD4401                    CALL     READHL   ;AUTOSTART ADDR
022A E3                        XTHL          ;PUT ON STACK
022B CD8502                    CALL     LEADR     ;PUNCH LEADER
022E CD8404                    CALL     LABEL    ;PUNCH LABEL
                                ;
                                ; START NEW RECORD, ZERO THE CHECKSUM
                                ; PUNCH CR, LF, 2 NULLS AND COLON
                                ;
0231 CDD002                    NEWREC: CALL     PCRLF   ;CR, LF, NULLS
                                ;
                                ; FIND THE RECORD LENGTH
                                ;

```



```

0234 7B      MOV     A,E      #COMPARE LOW STOP
0235 95      SUB     L        # TO LOW POINTER
0236 4F      MOV     C,A      #DIFFERENCE IN C
0237 7A      MOV     A,D      #COMPARE HIGH STOP
0238 9C      SBB     H        # TO HIGH POINTER
0239 47      MOV     B,A      #DIFFERENCE TO B
023A DA6B01  JC      ERROR    #IMPROPER, H,L > D,E
023D 3E10    MVI     A,RLEN   #FULL RECORD
023F C24C02  JNZ     NEW2
0242 B9      CMP     C        #COMPARE TO E-L
0243 DA4C02  JC      NEW2     #FULL RECORD LENGTH
0246 78      MOV     A,B      #ARE BOTH E-L AND
0247 B1      ORA     C        # D-E ZERO?
0248 CA6802  JZ      DONE     #YES, REC LENGTH = 0
024B 79      MOV     A,C      #SHORT RECORD
024C 4F      NEW2:  MOV     C,A  #RECORD LENGTH TO C
024D 0600    MVI     B,0      #ZERO THE CHECKSUM
024F CD9502  CALL    PNHEX    #PUNCH RECORD LENGTH
0252 CD9002  CALL    PUNHL    #PUNCH H/L
0255 AF      XRA     A
0256 CD9502  CALL    PNHEX    #PUNCH RECORD TYPE 0
0259 7E      PMEM:  MOV     A,M
025A CD9502  CALL    PNHEX    #PUNCH MEMORY BYTE
025D 23      INX     H        #INCR. MEMORY POINTER
025E 0D      DCR     C        #DECR RECORD LENGTH
025F C25902  JNZ     PMEM
0262 CD6703  CALL    CSUM     #PUNCH CHECKSUM
0265 C33102  JMP     NEWREC    #NEXT RECORD

;
; FINISHED, PUNCH LAST RECORD, RECORD
; LENGTH 00, THE START ADDRESS,
; AND A RECORD TYPE OF 01
;
0268 AF      DONE:  XRA     A
0269 47      MOV     B,A      #ZERO CHECKSUM
026A CD9502  CALL    PNHEX    #ZERO RECORD LEN.
026D E1      POP     H
026E CD9002  CALL    PUNHL    #AUTOSTART H/L
0271 7C      MOV     A,H      #CHECK FOR
0272 B5      ORA     L        # AUTOSTART
0273 3E00    MVI     A,0      #0 WITH CARRY
0275 CA7902  JZ      DON2     #NO AUTOSTART
0278 3C      INR     A
0279 CD9502  DON2:  CALL    PNHEX  #RECORD TYPE 1
027C CD6703  CALL    CSUM     #PUNCH CHECKSUM
027F CD8502  CALL    LEADR    #PUNCH TRAILER
0282 C38601  JMP     RSTR    #NEXT JOB

;
; PUNCH BLANK HEADER AND TRAILER
;
0285 AF      LEADR:  XRA     A
0286 063C    MVI     B,60     #TAPE NULLS
0288 CDB802  NLDR:  CALL    FOUT
028B 05      DCR     B
028C C28802  JNZ     NLDR
028F C9      RET
;

```

```

; PUNCH THE H,L REGISTER PAIR
;
0290 7C      PUNHL: MOV     A,H      ;FETCH H
0291 CD9502  CALL     PNHEX    ;PUNCH IT
0294 7D      MOV     A,L      ;GET L, PUNCH IT
;
; CONVERT A BINARY NUMBER TO TWO HEX
; CHARACTERS, PUNCH THEM, ADD TO CHECKSUM
;
0295 F5      PNHEX: PUSH     PSW      ;SAVE ON STACK
0296 80      ADD     B        ;ADD TO CHECKSUM.
0297 47      MOV     B,A      ;SAVE IT IN B
0298 F1      POP     PSW      ;RETRIEVE BYTE
0299 F5      PUSH     PSW
029A 1F      RAR
029B 1F      RAR              ;ROTATE UPPER
029C 1F      RAR
029D 1F      RAR              ;TO LOWER
029E CDA202  CALL     PHEX1    ;LEFT CHARACTER
02A1 F1      POP     PSW      ;RIGHT CHARACTER
;
; PUNCH A HEX CHARACTER FROM
; LOWER FOUR BITS
;
02A2 E60F    PHEX1: ANI     0FH      ;MASK UPPER 4 BITS
02A4 C690    ADI     144
02A6 27      DAA
02A7 CE40    ACI     64
02A9 27      DAA
02AA C3B802  JMP     POUT
;
; INPUT A HEX CHARACTER FROM TAPE
;
02AD CDC402  HEX:  CALL     PIN
02B0 D630    SUI     '0'
02B2 FE0A    CPI     10
02B4 D8      RC              ;0-9
02B5 D607    SUI     7        ;A-F
02B7 C9      RET
;
; OUTPUT A BYTE TO THE PUNCH
;
02B8 F5      POUT:  PUSH     PSW
02B9 DB06    POUTW: IN      PSTAT
02BB E680    ANI     PMSK
02BD C2B902  JNZ     POUTW
02C0 F1      POP     PSW
02C1 D307    OUT     PDATA
02C3 C9      RET
;
; INPUT A BYTE FROM PAPER TAPE
;
02C4 DB06    PIN:   IN      PSTAT
02C6 E601    ANI     PMSK
02C8 C2C472  JNZ     PIN
02CB DB07    IN      PDATA
02CD E67F    ANI     7FH      ;STRIP PARITY
02CF C9      RET
;

```

```

; PUNCH CR, LF, NULLS AND COLON
;
02D0 3E0D      PCRLF: MVI    A,CR
02D2 CDB802    CALL    FOUT
02D5 3E0A      MVI    A,LF
02D7 CDB802    CALL    FOUT
02DA AF        XRA     A
02DB CDB802    CALL    FOUT    ;TWO NULLS
02DE CDB802    CALL    FOUT
02E1 3E3A      MVI    A,':'    ;COLON
02E3 C3B802    JMP     FOUT
;
;
; ENTRY FOR LOAD, EXECUTE AND VERIFY
;
02E6 320006    FLOAD: STA     TASK
02E9 3E11      MVI    A,17    ;TAPE READER ON
02EB CDB802    CALL    FOUT
02EE CD4401    CALL    READHL  ;OFFSET
02F1 220106    SHLD    OFSET    ;SAVE IT
;
; PROCESS THE RECORD HEADING ON INPUT
;
02F4 CDC402    HEAD:  CALL    PIN    ;INPUT FROM TAPE
02F7 FE3A      CPI     ':'    ;COLON?
02F9 C2F402    JNZ     HEAD    ;NO, TRY AGAIN
02FC 0600      MVI     B,0     ;ZERO THE CHECKSUM
02FE CD3303    CALL    PHEX    ;RECORD LENGTH
0301 B7        ORA     A       ;IS IT ZERO?
0302 CA4403    JZ      ENDFL    ;YES, DONE
0305 4F        MOV     C,A     ;SAVE REC. LEN.
0306 CD2B03    CALL    TAPEHL   ;GET H/L
0309 EB        XCHG    ;ADDR TO D,E
030A 2A0106    LHLD    OFSET    ;GET OFFSET
030D 19        DAD     D       ;ADD
030E CD3303    LOOP:  CALL    PHEX ;INPUT DATA BYTE
0311 5F        MOV     E,A     ;SAVE BYTE
0312 3A0006    LDA     TASK    ;GET TASK
0315 FE56      CPI     'V'    ;SEE IF VERIFYING
0317 7B        MOV     A,E     ;MOVE BACK
0318 CA1C03    JZ      SKIP    ;JUMP IF VERIFYING
031B 77        MOV     M,A     ;DATA TO MEMORY
031C BE        SKIP:  CMP     M    ;CHECK MEMORY
031D C27603    JNZ     MERROR   ;BAD MEMORY
0320 23        INX     H       ;INCREMENT POINTER
0321 0D        DCR     C       ;DECR RECORD LEN
0322 C20E03    JNZ     LOOP    ;NOT YET ZERO
0325 CD6D03    CALL    CHECK    ;PROCESS CHECKSUM
0328 C3F402    JMP     HEAD    ;START NEXT RECORD
;
; INPUT H,L AND RECORD TYPE FROM TAPE
;
032B CD3303    TAPEHL: CALL    PHEX    ;READ H
032E 67        MOV     H,A     ;
032F CD3303    CALL    PHEX    ;READ L
0332 6F        MOV     L,A     ;READ RECORD TYPE
;
; CONVERT 2 CHAR FROM TAPE TO ONE BINARY
; WORD, STORE IN A AND ADD TO CHECKSUM

```

```

0333 CDAD02      $
                  PHEX:  CALL    HEX    $UPPER CHARACTER
0336 07          RLC
0337 17          RAL
                  $MOVE TO UPPER
0338 17          RAL
0339 17          RAL
                  $HALF
033A 5F          MOV     E,A    $SAVE IT
033B CDAD02      CALL    HEX    $LOWER CHARACTER
033E 83          ADD     E      $COMBINE BOTH
033F 5F          MOV     E,A    $SAVE IT
0340 80          ADD     B      $ADD TO CHECKSUM
0341 47          MOV     B,A    $SAVE IT
0342 7B          MOV     A,E    $RETRIEVE DATA
0343 C9          RET

$
$ ROUTINE TO CHECK FOR AUTOSTART
$
0344 CD2B03      ENDFL:  CALL    TAPEHL  $AUTOSTART ADDRESS
                  $AND RECORD TYPE
0347 F5          PUSH    PSW      $SAVE RECORD TYPE
0348 CD3303      CALL    PHEX    $INPUT CHECKSUM
034B CD6203      CALL    TOFF    $TAPE READER OFF
034E F1          POP     PSW      $RETRIEVE REC TYPE
034F FE01        CPI     1       $AUTOSTART?
0351 C2B601      JNZ     RSTRT    $NO
0354 3A0006      LDA     TASK    $CHECK TASK
0357 FE45        CPI     'E'     $EXECUTE?
0359 CAAB01      JZ      JPCHL    $YES, GO THERE
035C CD1B01      CALL    OUTHL    $NO, PRINT HL
035F C3B601      JMP     RSTRT    $NEXT TASK

$
$ TURN OFF TAPE READER
$
0362 3E13        TOFF:   MVI     A,19
0364 C3B802      JMP     FOUT

$
$ CALCULATE AND PUNCH THE CHECKSUM
$
0367 78          CSUM:   MOV     A,B    $CHECKSUM TO A
0368 2F          CMA     $ONE'S COMPLEMENT
0369 3C          INR     A    $TWO'S COMPLEMENT
036A C39502      JMP     PNHEX    $PUNCH CHECKSUM

$
$ SEE IF CHECKSUM IS CORRECT (ZERO)
$
036D CD3303      CHECK:  CALL    PHEX    $INPUT CHECKSUM
0370 AF          XRA     A
0371 80          ADD     B    $IS CHECKSUM ZERO?
0372 C8          RZ      $YES, RETURN

$
$ ERROR MESSAGES
$
0373 3E43        MVI     A,'C'    $CHECKSUM ERROR
0375 01          DB      1        $DB TRICK TO SKIP
0376 3E4D        MERROR: MVI     A,'M' $M FOR BAD MEMORY
0378 F5          PUSH    PSW
0379 CD6203      CALL    TOFF    $TAPE READER OFF

```

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037C F1          POP      PSW
037D CD0F01      CALL     OUTT      ;PRINT ERROR TYPE
0380 CD1B01      CALL     OUTH      ;PRINT H/L
0383 C38601      JMP      RSTRT

;
0386 0D0A          SIGN:  DB      CR,LF
0388 4865782070   DB      'Hex paper-tape program'
039E 0D0A0A       DB      CR,LF,LF
03A1 45202D206C   DB      'E - load and execute'
03B5 0D0A       DB      CR,LF
03B7 47202D2067   DB      'G - go to addresses given'
03D0 0D0A       DB      CR,LF
03D2 52202D2072   DB      'R - read tape into memory'
03EB 0D0A       DB      CR,LF
03ED 2020202028   DB      '      (with optional offset)'
0407 0D0A       DB      CR,LF
0409 56202D2076   DB      'V - verify tape against'
0420 206D656D6F   DB      ' memory',CR,LF
0429 57202D2077   DB      'W - write paper tape'
043D 2028616E64   DB      ' (and label)',CR,LF,' '
044F 2877697468   DB      ' (with optional autostart)'
0468 0D0A00       DB      CR,LF,0

046B 0D0A456E74LMESG: DB      CR,LF,'Enter leader message'
0481 0D0A00       DB      CR,LF,0

;
; PUNCH READABLE LABELS ON PAPER TAPE
;
0484 E5          LABEL:  PUSH     H
0485 D5          PUSH     D
0486 116B04       LXI      D,LMESG ;LABEL MESS.
0489 CD7301       CALL     SENDM   ;SEND IT
048C CDAC01       CALL     INPLN   ;GET A LINE
048F CD0402       LABL1:  CALL     GETCH ;GET CHARACTER
0492 DABF04       JC      LABL2    ;DONE ON CARRY
0495 DE20       SBI      20H      ;ASCII BIAS
0497 DABF04       JC      LABL1    ;< SPACE
049A FE3F       CPI      63
049C D28F04       JNC     LABL1    ;TOO BIG
049F 6F         MOV      L,A
04A0 5F         MOV      E,A
04A1 2600       MVI      H,0
04A3 1600       MVI      D,0
04A5 29         DAD      H        ;DOUBLE IT
04A6 29         DAD      H        ;TIMES 4
04A7 19         DAD      D        ;TIMES FIVE
04A8 EB       XCHG
04A9 21C504     LXI      H,TABL
04AC 19         DAD      D
04AD 0E05       MVI      C,5
04AF 7E       NEXTC:  MOV      A,M
04B0 CDB802     CALL     POUT
04B3 23       INX      H
04B4 0D       DCR      C
04B5 C2AF04     JNZ      NEXTC
04B8 AF       XRA      A
04B9 CDB802     CALL     POUT
04BC C38F04     JMP      LABL1    ;NEXT CHARACTER

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04BF CD8502	LABL2:	CALL	LEADR
04C2 D1		POP	D
04C3 E1		POP	H
04C4 C9		RET	
;			
04C5 0000000000	TABL:	DB	0, 0, 0, 0, 0 ; SPACE
04CA 0000CF00		DB	0, 0, 207, 207, 0 ; EXCL
04CF 0007000700		DB	0, 7, 0, 7, 0 ; "
04D4 28FE28FE28		DB	40, 254, 40, 254, 40 ; #
04D9 4689FF8972		DB	70, 137, 255, 137, 114 ; \$
04DE 462610C8C4		DB	70, 38, 16, 200, 196 ; %
04E3 6C92AC40A0		DB	108, 146, 172, 64, 160 ; &
04E8 0004030300		DB	0, 4, 3, 3, 0 ; '
04ED 003C428100		DB	0, 60, 66, 129, 0 ; (
04F2 0081423C00		DB	0, 129, 66, 60, 0 ;)
04F7 8850F85088		DB	136, 80, 248, 80, 136 ; *
04FC 08087E0808		DB	8, 8, 126, 8, 8 ; +
0501 0080703000		DB	0, 128, 112, 48, 0 ; ,
0506 0808080808		DB	8, 8, 8, 8, 8 ; -
050B 00C0C00000		DB	0, 192, 192, 0, 0 ; .
0510 4020100804		DB	64, 32, 16, 8, 4 ; /
0515 7EA189857E		DB	126, 161, 137, 133, 126 ; 0
051A 8482FF8080		DB	132, 130, 255, 128, 128 ; 1
051F C2A191898A		DB	194, 161, 145, 137, 134 ; 2
0524 4289898976		DB	66, 137, 137, 137, 118 ; 3
0529 0C0A89FF88		DB	12, 10, 137, 255, 136 ; 4
052E 6789898971		DB	103, 137, 137, 137, 113 ; 5
0533 7E89898972		DB	126, 137, 137, 137, 114 ; 6
0538 0101F90503		DB	1, 1, 249, 5, 3 ; 7
053D 7689898976		DB	118, 137, 137, 137, 118 ; 8
0542 468989897E		DB	70, 137, 137, 137, 126 ; 9
0547 00D8D80000		DB	0, 216, 216, 0, 0 ; :
054C 0080763600		DB	0, 128, 118, 54, 0 ; ;
0551 1028448200		DB	16, 40, 68, 130, 0 ; <
0556 2828282828		DB	40, 40, 40, 40, 40 ; =
055B 8244281000		DB	130, 68, 40, 16, 0 ; >
0560 0601B90906		DB	6, 1, 185, 9, 6 ; ?
0565 7E819D910E		DB	126, 129, 157, 145, 14 ;
056A FE090909FE		DB	254, 9, 9, 9, 254 ; A
056F 81FF898976		DB	129, 255, 137, 137, 118 ; B
0574 7E81818142		DB	126, 129, 129, 129, 66 ; C
0579 81FF81817E		DB	129, 255, 129, 129, 126 ; D
057E FF89898989		DB	255, 137, 137, 137, 137 ; E
0583 FF09090901		DB	255, 9, 9, 9, 1 ; F
0588 7E81919172		DB	126, 129, 145, 145, 114 ; G
058D FF080808FF		DB	255, 8, 8, 8, 255 ; H
0592 0081FF8100		DB	0, 129, 255, 129, 0 ; I
0597 6080817F01		DB	96, 128, 129, 127, 1 ; J
059C FF081422C1		DB	255, 8, 20, 34, 193 ; K
05A1 FF80808080		DB	255, 128, 128, 128, 128 ; L
05A6 FF020C02FF		DB	255, 2, 12, 2, 255 ; M
05AB FF023C40FF		DB	255, 2, 60, 64, 255 ; N
05B0 FF818181FF		DB	255, 129, 129, 129, 255 ; O
05B5 0509090906		DB	5, 9, 9, 9, 6 ; P
05BA 7E81A141BE		DB	126, 129, 161, 65, 190 ; Q
05BF FF19294986		DB	255, 25, 41, 73, 134 ; R
05C4 4689898972		DB	70, 137, 137, 137, 114 ; S
05C9 0101FF0101		DB	1, 1, 255, 1, 1 ; T

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05CE 7F8080807F      DB      127,128,128,128,127 ; U
05D3 0F30C0300F      DB      15, 48, 192,48, 15 ; V
05D8 7F8070807F      DB      127,128,112,128,127 ; W
05DD C3241824C3      DB      195,36, 24, 36, 195 ; X
05E2 0304F80403      DB      3, 4, 248,4 ,3 ; Y
05E7 C1A1918987      DB      193,161,145,137,135 ; Z
05EC 00FF818181      DB      0, 255,129,129,129 ; [
05F1 0408102040      DB      4, 8, 16, 32, 64 ; \
05F6 818181FF00      DB      129,129,129,255,0 ; ]
05FB 0C0201020C      DB      12, 2, 1, 2, 12 ; ^

0600          TASK:   DS      1          ;SAVE IT
0601 0000      OFFSET: DW      0          ;LOAD OFFSET
0603          DS      30          ;STACK SPACE

          STACK:
0621          IBUFF:  DS      2          ;BUFFER POINTER
0623          IBUFC:  DS      1          ;BUFFER COUNT
0624          IBUFF:  DS      20         ;INPUT BUFFER
          ;
0638          END

```

Symbols:

0011 CDATA	036D CHECK	0001 CIMSK	0002 COMSK
017D CONTIN	000D CR	01EE CRLF	0010 CSTAT
0367 CSUM	0008 CTRH	007F DEL	0279 DON2
0268 DONE	0344 ENDFL	016B ERROR	0208 GETC2
0214 GETC3	0218 GETC4	0204 GETCH	02F4 HEAD
0129 HEX1	02AD HEX	0623 IBUFC	0624 IBUFF
0621 IBUFF	01B4 INPL2	01D0 INPL3	01F8 INPLB
01E0 INPLC	01DA INPLE	01BC INPLI	01AC INPLN
0103 INPUTT	01AB JPCHL	0484 LABEL	048F LABL1
04BF LABL2	0285 LEADR	000A LF	046B LMSG
030E LOOP	0376 MERROR	024C NEW2	0231 NEWREC
04AF NEXTC	0134 NIB	0288 NLDR	0000 NNULS
0601 OFFSET	011B OUTHL	0120 OUTHX	010F OUTT
0110 OUTW	02D0 PCRLF	0007 PDATA	021A PDUMP
02A2 PHEX1	0333 PHEX	0001 PIMSK	02C4 PIN
02E6 PLOAD	0259 PMEM	0295 PNHEX	0080 POMSK
02B8 POUT	02B9 POUTW	0006 PSTAT	0290 PUNHL
0149 RDHL2	015E RDHL4	0168 RDHL5	0144 READHL
0010 RLEN	0186 RSTRT	0173 SENDM	0386 SIGN
031C SKIP	0621 STACK	0100 START	04C5 TABL
032B TAPEHL	0600 TASK	0362 TOFF	

This program generates tapes with a modified Intel format. A typical record is shown in Figure 9.1.

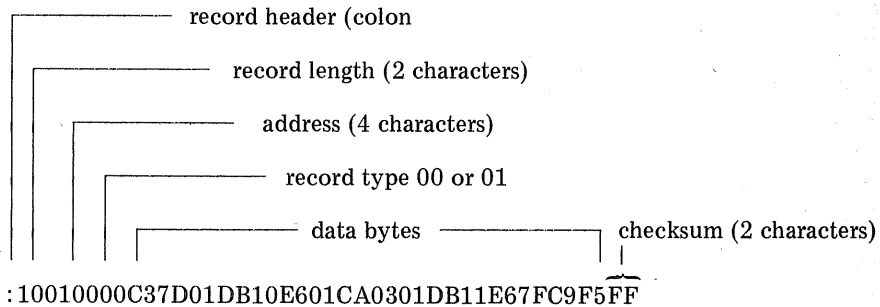


Figure 9.1. The hex tape format.

In this example, the record length is 10 hex, the address is 100 hex, the record type is 00, the first data byte is C3, the last data byte is F5 hex, and the checksum is FF hex. This is the format used by the CP/M assemblers ASM and MAC to generate HEX files.

Each record starts with a colon and is followed by the hex-encoded data. Since the data are encoded in ASCII, two bytes on the tape are needed to represent each original byte. Two hex characters, representing the record length, follow the header character. This hex value gives the actual number of data bytes contained in the record. It does not include the other characters in the record which designate the record address, the record type, and the checksum. A zero value for the record length is used for the last record to indicate the end of the file.

The record address, the address of the first byte in the record, comes next. This address is encoded into four hex characters, high-order byte first. The next item is the record type; it consists of two characters and can be 00 or 01. The value is usually 00, however; 01 is used for the end-of-file record for autostart tapes.

The data from memory are encoded next. Two bytes on the tape represent each data byte. The checksum byte is the last item in the record. It is formed by taking the two's complement of the sum of all the previous bytes in the record (in binary form). A carriage return, line feed, and optional nulls follow the checksum.

When the hex tape is loaded into the computer, the bytes within each record including the checksum are added together. The checksum byte is formed from the two's complement of the original sum. Since the sum of a number and its two's complement is zero, the total at this point should be zero. A nonzero result indicates an error.

The last record in the file has a record length of zero. This end-of-file record can indicate an autostart address in place of the usual record address. The computer can branch to this autostart address after the program is loaded. The record type in this case is 01—the end-of-file record.

Since the tape is written with an ASCII-encoded format, it is easy to read. Listing 9.2 shows the first part of the monitor made with the monitor itself.

Listing 9.2 A hex dump of the beginnings of the monitor.

```
:10010000C37D01DB10E601CA0301DB11E67FC9F5FF
:10011000DB10E602CA1001F1D311C94CCD20014D0C
:10012000791F1F1F1FCD290179E60FC69027CE40EA
:1001300027C30F01D630D8FE173FD8FE0A3FD0D6CE
```

The disadvantage of this format is that the tape takes twice as long to make and twice as long to read as a corresponding binary tape. A BASIC interpreter that loads in 20 minutes from a binary format would take 40 minutes to load from hex format.

You may want to reassemble the hex tape routine for some other memory location, or you may want to incorporate it into your system monitor. But wait until you've learned about the binary tape monitor shown later in this chapter before you do.

Type in the hex program, assemble it, and start it up by branching to the beginning. A list of commands will be printed as a guide to operation.

Hex paper-tape program:

E	load and execute
G	go to address given
R	read tape into memory (with optional offset)
V	verify tape against memory
W	write and label paper tape (with optional autostart)

Console input is buffered just as it is in our system monitor. In fact, you will notice that many of the monitor I/O routines have been duplicated in this tape program. To create a tape, type the letter W (for write), the start address, and an optional autostart address. Finish the line with a carriage return. Typing errors can be corrected as usual with a DEL or backspace key. When the statement "Enter leader message" appears, either type the characters that you want on the tape leader, or just type a carriage return to skip the title.

After the tape has been made, it should be verified. Type the letter V and a carriage return. If you have a Teletype with an automatic tape reader, the computer can turn it on at the beginning and turn it off at the end. This is accomplished by sending a control-Q at the beginning and a control-S at the end. Each entry on the tape will be compared to the corresponding value in memory. If a checksum or verify error is detected, the process will be terminated. The appropriate error message and the address of the error will appear. In the case of a checksum error, the address is not meaningful.

A tape can be loaded into memory by typing the letter R (for read) and the optional offset value. This offset is added to the record address, after the record address has been added into the checksum. An offset of 1000 hex will

load a program 4K bytes higher than the regular address. An offset of F000 hex will load the program 4K bytes lower. If you want, the computer will branch to the autostart address after the tape has been loaded; simply type an E (for execute) rather than an R.

If a leader message has been punched on the tape, it is not necessary to position the tape past this message. The loader routine is looking for a colon to indicate the start of a record. But the colon symbol will never appear in the label itself. There is a GO command so that you can easily leave the tape program. Type the letter G (GO) and the address.

A TAPE-LABELING ROUTINE

The assembly language instructions that punch readable labels on paper tape begin at LABEL and continue on down to TABL. The data used by this portion starts at TABL and goes down to TASK. The characters that are available include the complete set of ASCII characters from the blank (20 hex) through the underline (5F hex). The uppercase letters are included but the lowercase letters are not. One line of data in the source program is used for each character punched on the tape. The characters can be identified by the comment at the end of the line. The lines of data are arranged in sequence corresponding to the ASCII character set. The characters punched on the tape are generated in a five-by-eight matrix, with a row of blanks between the characters.

When the label subroutine is called, it first prints a message requesting input. In response, the user enters one line of characters and concludes the line with a carriage return. The message is then punched on the tape. Each ASCII character is obtained from the console input buffer as needed. The ASCII character is converted to binary by subtraction of an ASCII blank. The result is then used as a pointer to find the corresponding entry in the table. This is done by multiplying the binary value by 5 and adding it to the table address. The next five bytes of the table are then sent to the punch. The complete set of characters is shown in Figure 9.2.

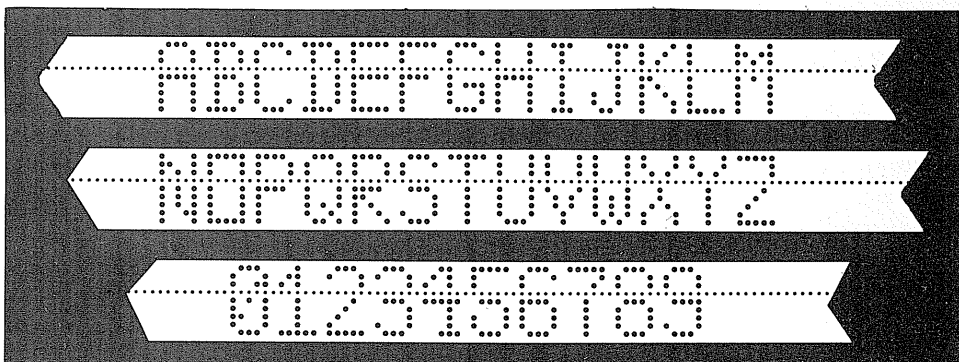


Figure 9.2. The set of letters and numbers produced by HEXMON.

The label subroutine with its necessary I/O routines can be removed from the tape program and used separately. It can be placed into high memory and called by another program such as a BASIC interpreter.

A BINARY TAPE MONITOR

The hexadecimal program given in the previous section is useful for paper tape. But a binary tape routine is much more suitable for magnetic tape. With a magnetic tape format, the tape cannot be visually inspected. Therefore, there is no advantage in coding the data in hexadecimal format.

Files are organized into records just as they are with the hex program. Each record starts with a record header, then continues with the record length, the address, the data, and the checksum. But the binary format is a bit different. As shown in Figure 9.3, there are three types of records: a header record, a data record, and an end-of-file record. The first record in the file is the file-header record. It begins with a 55-hex character. An optional filename appears next. The record header ends with a carriage-return character.

Header Record	55H	Filename	Carriage Return		
Data Record	3CH	Rec. Len.	Addr.	Data	Checksum
EOF Record	74H	Autostart Addr.		Checksum	

Figure 9.3. Three different record types are used with the binary tape format: A header record, one or more data records, and an end-of-file record.

The data record follows the header record. It starts with a 3C-hex header byte, a record-length byte, and two bytes giving the record address. The record address is written with the low-order byte first. The data bytes appear next, and then the checksum concludes the record.

With this format, the checksum byte consists of the sum of the data record bytes rather than the two's complement of the sum as used with the hex format. This checksum includes the record address and the data bytes, but it does not include the record length. The record length is not needed, since an incorrectly read record length will point to an incorrect byte that is to be used for the checksum.

The end-of-file record is four bytes long. It begins with a 74-hex character. It is followed by the autostart address, written as low byte, high byte. The fourth byte in this record is the checksum of the two-byte autostart address.

The routine given in Listing 9.3 is not a complete program. It is meant to be added to the end of the system monitor developed in Chapter 6. The

I/O and conversion routines of the monitor are used whenever possible. If you want to use it as a stand-alone program, you will have to include the necessary I/O routines. The addition of the tape program to the monitor will increase its size to one-and-a-half K bytes.

Add the new instructions to the end of the monitor, then change the monitor command-branch table for the letter T (tape)

DW TAPE #T

so that a command line starting with the letter T will cause a branch to the new tape routines.

Listing 9.3. Binary tape routines.

```

; LOCATIONS IN THE STACK AREA
;
57C6 =        FBUF     EQU        Ibuff+32 #FILENAME BUFF
57E6 =        OFFSET   EQU        FBUF+20H #LOAD OFFSET
57E8 =        TASK     EQU        OFFSET+2
57E9 =        LFLAG    EQU        TASK+1   #LOAD-ERROR FLAG
;
0055 =        SBYTE    EQU        55H     #SYNC BYTE
003C =        RHEAD    EQU        3CH     #RECORD HEADER
0074 =        EOF      EQU        74H     #END OF FILE
;
0006 =        PSTAT    EQU        6        #PUNCH STATUS
0007 =        PDATA    EQU        PSTAT+1 #PUNCH DATA
0001 =        PIMSK    EQU        1        #INPUT MASK
0080 =        POMSK    EQU        80H     #OUTPUT MASK
;
;
5BFA 210000    TAPE:    LXI        H,0
5BFD 22E657        SHLD        OFFSET   #ZERO OFFSET
5C00 CD2559        CALL        GETCH    #COMMAND
;
; TAPE-COMMAND PROCESSOR
;
5C03 FE45        CPI        'E'
5C05 CAD25C        JZ        TLOAD    #LOAD AND EXEC
5C08 FE4C        CPI        'L'
5C0A CAD25C        JZ        TLOAD    #LOAD
5C0D FE4D        CPI        'M'
5C0F CA805D        JZ        TMAKE    #MAKE TEST TAPE
5C12 FE4F        CPI        'O'
5C14 CACA5C        JZ        OFFST    #OFFSET LOAD
5C17 FE54        CPI        'T'
5C19 CA9A5D        JZ        TTEST    #TAPE TEST
5C1C FE56        CPI        'V'
5C1E CAD25C        JZ        TLOAD    #VERIFY TAPE/MEM
5C21 FE44        CPI        'D'        #DUMP TO TAPE
5C23 C2D459        JNZ        ERROR
;

```

```

; DUMP MEMORY TO TAPE IN 8-BIT BINARY FORMAT
;
5C26 CD8659      CALL    RDHLDE  ;ADDRESS LIMITS
5C29 E5          PUSH    H        ;START ADDR
5C2A CD9D59      CALL    READHL   ;AUTOSTART
5C2D E3          XTHL    ;SWITCH WITH H,L
5C2E CD885C      CALL    LEADR    ;TAPE LEADER
5C31 3E55        MVI     A,SBYTE  ;SYNC BYTE
5C33 CD935C      CALL    TOUT     ;
5C36 CD2559      TDMP:  CALL    GETCH  ;FILE-NAME CHAR
5C39 DA425C      JC      PD4      ;FILENAME END
5C3C CD935C      CALL    TOUT     ;SEND TO TAPE
5C3F C3365C      JMP     TDMP     ;NEXT CHAR
5C42 3E0D        PD4:  MVI     A,CR
5C44 CD935C      CALL    TOUT     ;PUT CR ON TAPE
5C47 3E3C        PD0:  MVI     A,RHEAD ;RECORD HEADER
5C49 CD935C      CALL    TOUT     ;PUT ON TAPE
5C4C 7B          MOV     A,E
5C4D 95          SUB     L
5C4E 3C          INR     A        ;RECORD LENGTH
5C4F 4F          MOV     C,A
5C50 CD935C      CALL    TOUT     ;PUT ON TAPE
5C53 7D          MOV     A,L
5C54 CD935C      CALL    TOUT     ;L TO TAPE
5C57 45          MOV     B,L      ;START CHECKSUM
5C58 7C          MOV     A,H
5C59 CD935C      CALL    TOUT     ;H TO TAPE
5C5C 7E          PD1:  MOV     A,M  ;GET DATA
5C5D CD935C      CALL    TOUT     ;SEND TO TAPE
5C60 0D          DCR     C        ;RECORD COUNT
5C61 CA685C      JZ      PD2      ;DONE
5C64 23          INX     H        ;BUMP POINTER
5C65 C35C5C      JMP     PD1      ;NEXT BYTE
;
; END OF RECORD
;
5C68 7B          PD2:  MOV     A,B  ;GET CHECKSUM
5C69 CD935C      CALL    TOUT     ;SEND IT
5C6C 7C          MOV     A,H
5C6D BA          CMP     D        ;END OF FILE?
5C6E CA755C      JZ      PD3      ;YES
5C71 23          INX     H
5C72 C3475C      JMP     PD0      ;NEXT RECORD
;
; END OF FILE
;
5C75 3E74        PD3:  MVI     A,EOF
5C77 CD935C      CALL    TOUT     ;SEND IT
5C7A E1          POP     H        ;AUTOSTART ADDR
5C7B 7D          MOV     A,L      ;LOW
5C7C CD935C      CALL    TOUT     ;SEND IT
5C7F 45          MOV     B,L      ;START CHECKSUM
5C80 7C          MOV     A,H      ;HIGH
5C81 CD935C      CALL    TOUT     ;SEND IT
5C84 78          MOV     A,B      ;CHECKSUM
5C85 CD935C      CALL    TOUT     ;SEND IT

```

```

$
$ MAKE A LEADER/TRAILER ON TAPE
$
5C88 AF      LEADR:  XRA      A      $GET A NULL
5C89 0648    MVI      B,72    $# OF NULLS
5C8B CD935C  NLDR:   CALL    TOUT    $SEND NULL
5C8E 05      DCR      B
5C8F C28B5C  JNZ      NLDR
5C92 C9      RET

$
$ OUTPUT BYTE TO TAPE, ADD TO CHECKSUM
$
5C93 F5      TOUT:   PUSH     PSW
5C94 80      ADD      B        $TO CHECKSUM
5C95 47      MOV      B,A      $PUT BACK
5C96 F1      POP      PSW
5C97 F5      POUT:   PUSH     PSW
5C98 DB06    POUTW:  IN       PSTAT $STATUS
5C9A E680    ANI      PMSK

$
$ NEXT LINE MAY NEED TO BE JZ POUTW
5C9C C2985C  JNZ      POUTW    $NOT READY
5C9F F1      POP      PSW
5CA0 D307    OUT      PDATA    $SEND BYTE
5CA2 C9      RET

$
$ INPUT BYTE FROM TAPE
$ ADD TO CHECKSUM
$
5CA3 CDB25C  TIN4:   CALL     PIN     $GET BYTE
5CA6 F5      PUSH     PSW
5CA7 80      ADD      B        $ADD TO CHECKSUM
5CA8 47      MOV      B,A      $PUT BACK
5CA9 F1      POP      PSW

$
$ SEND TO CONSOLE IF NOT A CONTROL CHARACTER
$
5CAA E67F    ANI      7FH
5CAC FE20    CPI      ' '
5CAE D8      RC        $CONTROL
5CAF D311    OUT      CDATA
5CB1 C9      RET

$
5CB2 DB06    PIN:    IN       PSTAT $STATUS
5CB4 E601    ANI      PMSK

$
$ NEXT LINE MAY NEED TO BE JZ PIN
5CB6 C2B25C  JNZ      PIN     $NOT READY
5CB9 DB07    IN       PDATA    $GET BYTE
5CBB C9      RET            $KEEP 8 BITS

$
$ LOOK FOR HEADER ON PAPER TAPE
$

```

```

5CB0 3E11      PIN4:  MVI    A,CTRQ  ;"Q
5CBE CD975C    CALL    POUT      ;TURN ON READER
5CC1 CDB25C    PIN5:  CALL    PIN     ;GET BYTE
5CC4 FE55      CFI      SBYTE     ;SYNC BYTE?
5CC6 C2C15C    JNZ     PIN5      ;NO, TRY AGAIN
5CC9 C9        RET

;
; LOAD A TAPE WITH 16-BIT OFFSET
;
5CCA 57        OFFST:  MOV     D,A      ;SAVE TASK
5CCB CD9D59    CALL    READHL   ;GET OFFSET
5CCE 22E657    SHLD    OFFSET    ;SAVE IT
5CD1 7A        MOV     A,D      ;RESTORE TASK

;
; LOAD/ VERIFY BINARY TAPE
;
5CD2 32E857    TLOAD:  STA      TASK    ;SAVE COMMAND
5CD5 21C657    LXI      H,FBUF   ;FILENAME BUFFER
5CD8 AF        XRA      A        ;GET A ZERO
5CD9 32E957    STA      LFLAG    ;RESET FLAG
5CDC CD2559    TLD1:   CALL    GETCH   ;READ FILENAME
5CDF DAE75C    JC       TLD5     ;END OF FILENAME
5CE2 77        MOV     M,A      ;PUT IN FBUF
5CE3 23        INX      H
5CE4 C3DC5C    JMP     TLD1      ;NEXT CHARACTER
5CE7 3E0D      TLD5:   MVI      A,CR
5CE9 32A657    STA      IBUFF
5CEC CDBC5C    CALL    PIN4      ;FIND HEADER
5CEF 21C657    LXI      H,FBUF   ;FILENAME BUFFER
5CF2 7E        MOV     A,M      ;1ST CHARACTER
5CF3 FE0D      CFI      CR
5CF5 CA1C5D    JZ       TLO      ;NO FILENAME
5CF8 11A657    LXI      D,IBUFF  ;INPUT BUFFER

;
; INPUT FILENAME FROM TAPE, PUT IN IBUF
;
5CFB CDA35C    TLD2:   CALL    TIN4    ;BYTE FROM TAPE
5CFE 12        STAX     D        ;PUT IN IBUFF
5CFF 13        INX      D
5D00 FE0D      CFI      CR
5D02 CA125D    JZ       TLD4      ;NO FILENAME
5D05 BE        CMP     M        ;COMP FILENAMES
5D06 23        INX      H
5D07 CAFB5C    JZ       TLD2      ;NEXT CHARACTER

;
; FILENAME ENTERED FROM CONSOLE
; DOESN'T MATCH NAME ON TAPE
;
5D0A 3E46      MVI      A,'F'    ;SET ERROR FLAG
5D0C 32E957    STA      LFLAG
5D0F C3FB5C    JMP     TLD2
5D12 AF        TLD4:   XRA      A
5D13 1B        DCX      D
5D14 12        STAX     D
5D15 3AE957    LDA      LFLAG    ;CHECK FLAG
5D18 B7        ORA      A        ;ZERO?
5D19 C2C05D    JNZ     FNERR     ;FILENAME ERROR

```

```

5D1C CDA35C      TL0:  CALL    TIN4      ;BYTE FROM TAPE
5D1F FE74        CPI      EOF          ;DONE
5D21 CA605D      JZ       EXEC         ;RECORD HEADER
5D24 FE3C        CPI      RHEAD        ;TRY AGAIN
5D26 C21C5D      JNZ      TL0          ;RECORD LENGTH
5D29 CDA35C      CALL     TIN4          ;PUT IN C
5D2C 4F          MOV      C,A          ;ADDR, LOW BYTE
5D2D CDA35C      CALL     TIN4          ;INTO E
5D30 5F          MOV      E,A          ;PUT IN CHECKSUM
5D31 47          MOV      B,A          ;ADDR, HIGH BYTE
5D32 CDA35C      CALL     TIN4          ;INTO D
5D35 57          MOV      D,A          ;GET LOAD OFFSET
5D36 2AE657      LHLD     OFFSET        ;ADD TO ADDRESS
5D39 19          DAD      D            ;GET TASK
5D3A 3AE857      LDA      TASK          ;PUT IN D
5D3D 57          MOV      D,A          ;DATA BYTE
5D3E CDA35C      TL1:  CALL     TIN4          ;SAVE IN E
5D41 5F          MOV      E,A          ;CHECK THE TASK
5D42 7A          MOV      A,D          ;VERIFYING?
5D43 FE56        CPI      'V'          ;GET BYTE AGAIN
5D45 7B          MOV      A,E          ;VERIFYING, SKIP
5D46 CA4A5D      JZ       SKIP         ;INTO MEMORY
5D49 77          MOV      M,A          ;IS IT THERE?
5D4A BE          CMP      M            ;NO
5D4B C2AE5D      JNZ      FERROR       ;INCR ADDRESS
5D4E 23          INX      H            ;RECORD COUNT
5D4F 0D          DCR      C            ;NEXT BYTE
5D50 C23E5D      JNZ      TL1

;
; END OF RECORD, GET CHECKSUM
;
5D53 48          MOV      C,B          ;CHECKSUM TO C
5D54 CDA35C      CALL     TIN4          ;TAPE CHECKSUM
5D57 B9          CMP      C            ;THE SAME?
5D58 CA1C5D      JZ       TL0          ;YES
5D5B 3E43        CSERR: MVI     A,'C'    ;ERROR
5D5D C3455A      JMP      ERR2

;
; END OF TAPE, GET AUTOSTART ADDRESS
; SEE IF EXECUTING
;
5D60 CDA35C      EXEC:  CALL     TIN4      ;START, LOW
5D63 6F          MOV      L,A          ;PUT IN L
5D64 47          MOV      B,A          ;START CHECKSUM
5D65 CDA35C      CALL     TIN4          ;START, HIGH
5D68 67          MOV      H,A          ;PUT IN H
5D69 48          MOV      C,B          ;GET SUM
5D6A CDA35C      CALL     TIN4          ;READ CHECKSUM
5D6D B9          CMP      C            ;SAME
5D6E C25B5D      JNZ      CSERR        ;NO
5D71 CDB45D      CALL     POFF         ;READER OFF
5D74 7A          MOV      A,D          ;CHECK TASK
5D75 FE45        CPI      'E'          ;EXECUTING?
5D77 CA7F5D      JZ       PCHLT        ;YES
5D7A 3E45        MVI     A,'E'        ;EXEC ADDRESS
5D7C C3455A      JMP      ERR2

```



```

;
; THE NEXT LABEL CAN BE PLACED AFTER
; THE LABEL CALLS/GO NEAR THE BEGINNING
;
5D7F E9      PCHLT:  PCHL
;
; MAKE BINARY TEST TAPE, EACH BYTE
; IS ONE LARGER THAN PREVIOUS BYTE
; WITH OVERFLOW, 00 IS AFTER FF
;
5D80 21F401  TMAKE:  LXI      H,500    ;ABORT CHECK
5D83 7A      TMAK2:  MOV      A,D      ;GET A BYTE
5D84 CD935C      CALL     TOUT      ;SEND TO TAPE
5D87 14      INR      D            ;INCREMENT IT
5D88 2B      DCX      H            ;DECR COUNT
5D89 7C      MOV      A,H
5D8A B5      ORA      L            ;SEE IF ZERO
5D8B C2835D      JNZ      TMAK2      ;NO
5D8E CD2558      CALL     INSTAT     ;TERMINATION?
5D91 CA805D      JZ       TMAKE      ;NO
5D94 CD1558      CALL     INPUTT     ;X FOR ABORT
5D97 C3805D      JMP      TMAKE      ;NO
;
; READ BINARY TEST TAPE
; EACH BYTE MUST BE ONE LARGER
; THAN THE PREVIOUS ONE
;
5D9A CDB25C      TTEST:  CALL     PIN      ;GET A BYTE
5D9D 57      MOV      D,A          ;SAVE IT
5D9E CDB25C      TTEST2: CALL     PIN      ;NEXT BYTE
5DA1 14      INR      D            ;INCR FIRST
5DA2 BA      CMP      D            ;SAME?
5DA3 CA9E5D      JZ       TTEST2     ;YES
5DA6 3E43      MVI     A,'C'       ;NO
5DA8 CD2A58      CALL     OUTT       ;C FOR ERROR
5DAB C39A5D      JMP      TTEST      ;START AGAIN
;
; TAPE ERROR, PRINT B AND ADDRESS
;
5DAE CDB45D      PERROR: CALL     POFF
5DB1 C3435A      JMP      ERRB
;
; TURN OFF TAPE READER
;
5DB4 3E13      POFF:   MVI     A,CTRS ;READER OFF
5DB6 C3935C      JMP      TOUT
;
; FILENAME ERROR, PRINT ACTUAL
; FILENAME ON TAPE
;
5DB9 205472793AEMESS: DB      ' Try: ',0
5DC0 CDB45D      FNERR:  CALL     POFF  ;READER ON
5DC3 11B95D      LXI     D,EMESS  ;ERROR MESSAGE
5DC6 CD3B59      CALL     SENDM     ;SEND IT
5DC9 11A657      LXI     D,IBUFF  ;FILE NAME
5DCC C33B59      JMP      SENDM     ;SEND IT TOO
;
5DCF          END

```

Symbols:

5B07	ADMP2	5B23	ADMP3	5B26	ADMP4	5B04	ADUMP
5AED	ALOD2	FFF7	AFOS	5AD5	ASCII	5B2C	ASCS
0008	BACKUP	5B4C	BIT2	5B4A	BITS	5A09	CALLS
0011	CDATA	0011	CDATA0	5A3E	CHEKM	5B09	CIN
5B58	COLD	5B06	COUT	000D	CR	59DC	CRHL
590F	CRLF	5D5B	CSERR	0010	CSTAT	0010	CSTATO
0008	CTRH	0011	CTRQ	0013	CTRS	0018	CTRX
007F	DEL	5945	DUMP	5948	DUMP2	594B	DUMP3
595E	DUMP4	5967	DUMP5	5DB9	EMESS	0074	EOF
5A45	ERR2	5A43	ERRB	59D4	ERROR	5A42	ERRP
001B	ESC	5D60	EXEC	57C6	FBUF	5A5D	FILL
5A66	FILL2	5A6C	FILL3	5A75	FILL4	5DC0	FNERR
5B0F	GCHAR	5939	GETC4	5925	GETCH	5A08	GO
59F5	HEX1	5991	HHLDE	5A7C	HLDEBC	5A8A	HLDECK
5B73	HMATH	57A5	IBUFC	57A6	IBUFF	57A3	IBUFFP
00DB	INC	5B0C	INLN	0001	INMSK	5B05	INPL2
5B1F	INPL3	5919	INPLB	5901	INPLC	5BFB	INPLE
5BDD	INPLI	5B00	INPLN	5B1B	INPUT2	5B15	INPUTT
5B25	INSTAT	5B3D	IPORT	5BA5	JERR	5B85	JUST
5B89	JUST2	5B92	JUST3	5C88	LEADR	000A	LF
57E9	LFLAG	5A0D	LOAD	5A10	LOAD2	5A33	LOAD3
5A30	LOAD4	5A37	LOAD6	5A96	MOVDN	5A93	MOVE
5AA0	MOVIN	5B78	MSIZE	59C4	NIB	5C8B	NLDR
5B6A	NPAGE	5CCA	OFFST	57E6	OFSET	0002	OMSK
5B5A	OFORT	5B00	ORGIN	5B2B	OUT2	5B39	OUT3
5B44	OUT4	00D3	OUTC	5B12	OUTH	59E4	OUTHEX
59DF	OUTH1	59EC	OUTHX	59E3	OUTLL	59E7	OUTSP
5B2A	OUTT	59B1	PASC2	59B3	PASC3	5976	PASCI
5D7F	PCHLT	5C47	PD0	5C5C	PD1	5C68	PD2
5C75	PD3	5C42	PD4	0007	PDATA	5DAE	PERROR
0001	PIMSK	5CB2	PIN	5CB0	PIN4	5CC1	PIN5
5DB4	POFF	00B0	POMSK	57A0	PORTN	5C97	POUT
5C98	POUTW	0006	PSTAT	5B63	PUTIO	59A2	RDHL2
59B7	RDHL4	59C1	RDHL5	59B9	RDHLD2	59B6	RDHLDE
599D	READHL	5A4E	REGS	5BB4	REPL	5BC1	REPL2
5BCC	REPL3	5B03	RESTR1	00C9	RETC	003C	RHEAD
0055	SBYTE	5AAD	SEAR2	5AB8	SEAR3	5ACF	SEAR4
5AC9	SEAR5	5AAA	SEARCH	593B	SENDM	5B4F	SIGNON
5D4A	SKIP	57A0	STACK	5B00	START	0009	TAB
5B9C	TABLE	5BFA	TAPE	57E8	TASK	5C36	TDMP
5CA3	TIN4	5D1C	TLO	5D3E	TL1	5C0C	TLD1
5CFB	TLD2	5D12	TLD4	5CE7	TLD5	5CD2	TLOAD
5D83	TMAK2	5D80	TMAKE	0018	TOP	5C93	TOUT
5A00	TSTOP	5D9A	TTEST	5D9E	TTEST2	5B02	VERM
5BD5	VERM2	5B13	VERM3	3B31	VERS	5B61	WARM
5A55	ZERO						

There are seven tape commands that can be given. The appropriate command letter must immediately follow the letter T. The first thing that should be done is to make a test tape. In fact, the test pattern should be recorded onto the beginning of each tape you own. Give the command

>TM

(tape make), and start recording. The computer will send a sequence of bytes, each being one larger than the previous one. When the maximum value of FF hex has been sent, the next byte will be a zero. Record the pattern for 15 to 30 seconds. Type a control-X to end the procedure.

The integrity of the whole tape-recording system can now be tested. Rewind the test section of the tape and play it back. Type a command of

>TT

(tape test). The computer will read a byte from the tape, increment the value, then read another byte. If the two values don't agree, then a letter C will be printed on the console. The process will then be repeated until you terminate it.

If the two values do agree, then the computer will increment the first byte again, read another byte, and compare the two. This process will be repeated over and over. Each byte on the tape will be compared to see that it is exactly one larger than the previous byte. If you can go through a one-hour cassette recording without a single error, then you have a reliable system.

You may have an adjustment on the A/D converter circuit that allows you to set the frequency of the phase-locked loop (PPL). The MITS audio cassette boards have this feature. Make a test tape at least 10 minutes long, then play it back. Adjust the PPL frequency until a stream of Cs appear on the console; then adjust the PPL frequency in the opposite direction. The Cs should not print. Continue adjusting the PPL in the opposite direction again until the Cs appear again. You have now bracketed the usable range of the PPL. Set the PPL adjustment halfway between these two extremes.

There are some other tests you can make while the test tape is playing. Try moving both the audio cables and the AC line cords around to see if certain positions will cause an error. You can also try tapping the tape recorder, the computer case, the boards in the computer, and so on to see how delicate the system is. Pretty soon you will know if you have a reliable tape storage system. Remember to run the test tape at least once a week.

To save data from the computer's memory, including the tape program itself, type

>TD<start> <stop> <autostart> <filename>

After the D (for dump), give the start address, the stop address, the required autostart address, and an optional filename. A filename is important on

magnetic tape to ensure that you are loading the right program. The auto-start address can be the system monitor address. CP/M programs can be saved on tape using the original filename. Load the program into memory with DDT, SID, or the program FETCH given in the next chapter. Branch to the tape program and give the command

```
>TD100 9AF 100 TAPE.ASM
```

The filename can include the decimal point and the file type.

Each time a new tape is made, it should be verified with the command

```
>TV<filename>
```

A tape can be loaded into memory, at its normal position by typing

```
>TL<filename>
```

At the conclusion of the load, the autostart address is printed on the console then control returns to the monitor. If an incorrect filename is entered, the load operation is aborted and the actual filename on the tape is printed on the console.

During the load operation, all printable characters are displayed on the console. If your console is a printer rather than a video console, you will have to remove this feature to prevent the computer from falling behind. In this case, take out the following three lines from subroutine POUTW.

```
CPI      ' '
RC
OUT      CDATA
```

It is not necessary to verify the load step because of the checksum feature. If the load step was completed, then the tape was correctly read into memory.

The E command can be used instead of the L command for loading data. In this case the computer will branch to the autostart address at the completion of the load. A BASIC interpreter could be saved with the autostart address set to the BASIC start address. BASIC will then automatically start up at the completion of the E load command. The O command is used to load a tape at an offset from its regular address.

While this binary format is designed for magnetic tape systems, it can be used for paper tape as well. If a tape is punched on a Teletype machine, there will be a strange sound. The reason is that binary, rather than ASCII characters, are being punched. The printout will also be meaningless. But when the resulting tape is read back, the operation is quiet, since the inputted characters are not echoed back on the Teletype.

CHAPTER TEN

Linking Programs to the CP/M Operating System

The system monitor we developed in Chapters 6 and 7 allows us to communicate with the computer through the console. But this program only provides the bare minimum of operations such as memory display, block move, hex addition and subtraction, and so on. Computers are capable of performing more complicated tasks such as decimal arithmetic, keeping business records, formatting text, and game playing. Computer languages, such as FORTRAN, COBOL, and Pascal, make these tasks easier. These languages will operate on programs (called source programs) that are written by the user.

As an example, a BASIC interpreter, which may be as large as 24K bytes, needs a user's source program for direction. An assembler needs a source file to generate the desired machine code. And, of course, a formatting program needs a work file to produce a finished file.

Because programs to perform these common tasks are so large, an efficient method of loading them into memory is needed. In addition, the output generated by these programs needs to be stored somewhere. Magnetic tape can be used for this purpose, but it tends to be slow. The floppy disk currently is a better medium. It is relatively inexpensive, and the recording medium, the diskette, can be removed. This means that backup copies can be easily generated. In addition, programs can be readily exchanged between users.

We wrote our system monitor to transfer data between the console and the computer proper. Likewise, we need a disk-operating system (DOS) to effect an orderly transfer of information between the disk and the computer. Several different floppy disk systems are available for the 8080 and the Z-80. The disk-operating system that is provided with the disk drives may be relatively primitive, or it may be very elaborate.

A very popular DOS available today for the 8080 and Z-80 is called CP/M. CP/M was initially developed for the 8080 S-100 buss and the 8-inch

soft-sectored floppy disk. It is now available for most of the other configurations, including the 5-inch floppies and the Winchester hard disk. Versions are supplied for computers that don't have an S-100 buss, such as the TRS-80.

CP/M is a software system that must be interfaced to each different computer configuration through a set of software interface routines. Once the interfacing is accomplished, the computer programs that run with CP/M become system independent.

The operating system integrates all of the common tasks. Before CP/M came along, each assembler and BASIC interpreter had to incorporate its own text editor. The user could then write and correct the source program with the built-in editor. But with the CP/M operating system, the editing can be performed separately from program execution. An independent system editor is used to create an ASCII source file. Then a processor program such as BASIC, FORTRAN, Pascal, an assembler, or a text-output formatter can be directed to utilize the source file. The results can be stored in a separate ASCII file on the disk.

It is possible to generate an assembly-language program with the system editor, then assemble it as we did when we developed the system monitor in Chapters 6 and 7. In this case we had to tailor the console input and output routines to the host computer. In particular, we included in the program the address of the console status and data ports, and the read-ready and write-ready status bits. The sense of the status flags was selected with a JZ command corresponding to an active-high flag. As a result of this approach, our system monitor is not portable. The monitor runs on your system, but it might not run on someone else's unless the I/O details are changed.

We approached a solution to this problem in Chapter 8, where we wrote some base-conversion routines. We did not have to write the I/O subroutines into each program because we utilized the ones in the monitor.

When we wrote the monitor, we placed five jump vectors at the beginning. These provided an easy access to the commonly used routines. While this technique greatly simplifies things, it has the disadvantage that three bytes must be set aside for each different entry point. Also, the programmer must keep track of which entry is used for which task.

A better approach is to have only a single entry address for all operations. When this special address is called by an external program, the values in the CPU registers indicate the desired operation and provide the data. The CP/M operating system utilizes this approach. All of the systems operations are performed by calling memory address 5. Up to 37 different operations can be performed in this way. Operations 1 through 11 allow interaction with the four logical peripherals named CONSOLE, LIST, PUNCH, and READER. They are summarized in Table 10.1. Operation 12 allows a program to determine the current CP/M version. The remaining function numbers are used for disk operations such as reading, writing, and head positioning.

The desired operation is selected by placing the proper function number into register C. Sixteen-bit data are transferred in the DE register.

Eight-bit data are transferred in Register E or the accumulator. For example, the console input status can be determined by placing the function number of 11 (decimal) in the C register, and calling address 5.

```
MVI    C,11
CALL   5
```

Table 10.1. CP/M I/O operations. The function number is placed into register C. Single bytes are in register E. Double bytes are in the D, E register pair.

Function number (in C)	Operation	Value sent	Value returned
1	read CONSOLE		char in A
2	write CONSOLE	char in E	
3	read READER		char in A
4	write PUNCH	char in E	
5	write LIST	char in E	
6	direct console I/O	FF (input; char (output)	char/stat in A
7	get I/O byte		IOBYTE in A
8	set I/O byte	IOBYTE in E	
9	print CONSOLE buffer	buffer address in D, E	
10	read CONSOLE buffer	buffer address in D, E	characters in buffer:
11	CONSOLE status		0 = not ready FF = ready

On return, the accumulator and register E contain the value of FF hex if the console is ready for input, or a zero if not. The byte in the console data register can then be read by calling address 5 with the value of 1 in register C. The byte that is read will be returned in the accumulator.

CP/M MEMORY ORGANIZATION

When CP/M is in operation, the main memory is divided into several regions. In order of decreasing memory, they are:

1. Basic Input/Output System (BIOS)
2. Basic Disk-Operating System (BDOS)
3. Console-Command Processor (CCP)
4. Transient-Program Area (TPA)
5. System parameter area

If the BIOS is especially tailored to a particular system, then it is called the customized BIOS or CBIOS. The BIOS and BDOS regions are collectively known as the Full Disk-Operating System (FDOS). The memory layout is shown in Figure 10.1.

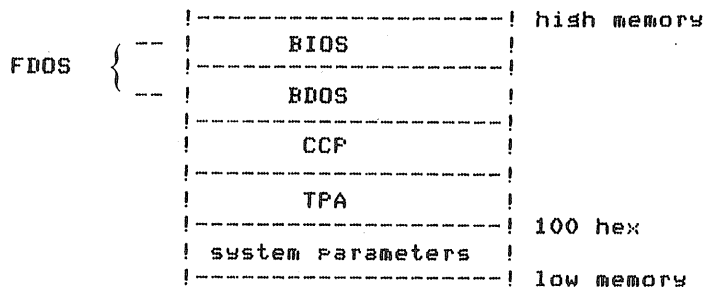


Figure 10.1 A memory map for CP/M.

BIOS contains the tailor-made routines for operation of all the peripheral devices such as the console, printer, disk drives, phone modem, and tape drives. BDOS has the hardware-independent routines for the disk operating system. The CCP handles the console commands. It contains the built-in routines such as DIR, LIST, and ERA. Separate programs such as PIP, DDT, and user-written programs execute in the TPA.

The lowest memory area contains several different items. The first is a warm-boot entry to BIOS. The first few entries are:

Address	Action	Purpose
0	JMP BIOS+3	warm start entry
3	IOBYTE	peripheral assignment
4	disk	current drive number
5	JMP BDOS+6	peripheral control
5C hex	FCB	command-line argument

CHANGING THE PERIPHERAL ASSIGNMENT

CP/M can interact with four logical peripheral devices. These are termed:

CON: console
 LST: list (printer)
 PUN: punch
 RDR: (tape) reader

Each of these four logical devices can be assigned to four different physical devices. The 16 different possible combinations can all be encoded into the IOBYTE located at memory address 3. The colon is part of the name; it is used when referring to peripheral devices. Disk filenames, on the other hand, are written without the colon.

The actual mapping of the logical devices into the desired physical devices must be accomplished in BIOS. Since there are so many different possibilities, it is not likely that the system supplied by your dealer will have

the IOBYTE features fully implemented. The CP/M logical console is probably mapped into your video terminal and the logical list device will be mapped into your printer. But the punch and reader might be mapped into your video terminal.

Even if you have only two peripherals, it may be useful to set up the IOBYTE feature. For example, suppose that you have both a video terminal and a printer such as a Decwriter or Teletype that has its own keyboard. Then either peripheral can be used for the console input and either can be used for the console output. The four physical console arrangements could correspond to:

IOBYTE	Input	Output
0	video	video (default)
1	video	printer
2	printer	printer
3	printer	video

Your customized BIOS (CBIOS) will set the default combination on a cold start. But any user program can change the IOBYTE to a new configuration. Also, the CP/M programs STAT and DDT can be used to alter the IOBYTE. The instructions in CBIOS will sample the IOBYTE and act accordingly.

Suppose that the IOBYTE is set to zero, and you load a BASIC interpreter. You develop a program that sends information to the console. The program will include statements like

```
. . .  
PRINT I, X(I), Y(I)  
. . .
```

The resulting output appears on the console video screen. After the program is debugged, you would like a hard-copy output of the program results. This is easily done if you have incorporated the IOBYTE feature. You can change the IOBYTE with the POKE command in the BASIC interpreter.

```
POKE 3, 1  
RUN
```

The POKE command will change the IOBYTE at address 3 from a zero to a 1. Console output will now appear at the printer when the BASIC program is run. Of course, console input has not changed; it still comes from the video terminal. At the conclusion of the run, the IOBYTE can be restored with another POKE command.

```
POKE 3, 0
```

As another example, suppose that you have a Teletype for your list device and it has a paper tape reader and punch. You can easily make BASIC

tapes and reload them using the IOBYTE features. POKE the IOBYTE to a value of 1 for punching a source tape. This will map the Teletype output into the logical console output. Give the BASIC commands

```
NULL 3
LIST
```

to make a tape of the source program.

Later, you can reload the tape into BASIC by setting the IOBYTE to a value of 3.

```
POKE 3, 3
```

Just put the tape into the reader and turn it on. With this configuration, the Teletype keyboard and tape reader perform the console input. But the video screen is used for console output. After the tape has been read, give the command

```
POKE 3, 0
```

from the Teletype keyboard to return to the console keyboard.

INCORPORATING THE IOBYTE INTO YOUR CBIOS

You will have to reassemble your CBIOS if you want to incorporate the IOBYTE feature. A sample CBIOS that uses the IOBYTE is given in Listing 5.1. This version additionally features such things as an interrupt-driven keyboard and connection to a telephone modem.

At the beginning of BIOS there are seven jump vectors that are used by other parts of CP/M.

JMP	INIT	!initialization
JMP	CONST	!console status
JMP	CONIN	!console input
JMP	CONOUT	!console output
JMP	LOUT	!list output
JMP	PUNCH	!punch
JMP	READR	!reader

Because of these fixed entry points, BIOS can be altered without having to alter any other part of CP/M. There are four regions of BIOS that need to be changed if the IOBYTE feature is incorporated into console routines. These are the routines for initialization, console status, console input, and console output. We have to set the IOBYTE to the default value in the initialization section of BIOS. Then, at the beginning of the three console routines, we have to read the IOBYTE at address 3, and branch to the appropriate subroutine.

In accordance with the step-by-step approach to programming we used in Chapter 6, we will not make all the changes at one time. The first alteration will be to the initialization and output routines.

Incorporating the IOBYTE into Output Routines

First locate the initialization region of BIOS. This area is referenced by the first jump instruction at the beginning of BIOS. Add the following instructions somewhere in the initialization routine.

```
MVI    A,0    ;set a zero
STA    3      ;SET IOBYTE
```

The safest places to put them are at the very beginning of the initialization section or at the end, just before the RET instruction. We could, of course, use an XRA A instruction rather than the MVI A,0 instruction shown above. This would reduce the size of BIOS by one byte. But if we later wanted BIOS to initialize the IOBYTE to 3 we would have to reassemble BIOS. With the MVI instruction, we can easily change the argument of zero to a 3 by using the system debugger.

Refer to the label START at the beginning of Listing 4.1 where there is a series of jump instructions.

```
      . . .
START:
      JMP     INIT      ;INITIALIZATION
      JMP     CONST     ;CONSOLE STATUS
      JMP     CONIN     ;CONSOLE INPUT
      JMP     CONOUT    ;CONSOLE OUTPUT
      . . .
```

Locate the address of the console-output routine. This can be found from the fourth jump instruction, JMP CONOUT in this case. We will now alter the console-output routine so that it will read the IOBYTE at memory address 3 and act accordingly. The upper six bits, which refer to the list, punch, and reader, are reset by performing a masking AND with the value of 3.

```
XXXX XX01  or  XXXX XX10  IOBYTE
      11              11  AND with 3
-----
0000 0001  or  0000 0010  IOBYTE
```

The two low-order bits then determine whether output is sent to the console or to the printer. If the resulting value is a 1 or a 2, then a branch is made to the printer-output routine. Otherwise, output goes to the video console. Printer output corresponds to the following IOBYTE bit patterns.

```

0000 0001  or  0000 0010  IOBYTE
      11          11  AND with 3
-----
0000 0001 = 1   0000 0010 = 2

```

The other two possible IOBYTE patterns correspond to console output.

```

0000 0000 = 0  or  0000 0011 = 3

```

Notice that parity is odd for printer output but parity is even for console output. Thus the BIOS code at this point is programmed to jump to the list-output routine if parity is odd.

```

;
; LOGICAL CONSOLE OUTPUT
;
CONOUT: LDA    IOBYTE  ;GET ASSIGNMENT
        ANI    3       ;MASK FOR CONSOLE
        JPO    LOUT    ;LIST OUTPUT
;
; VIDEO-OUTPUT ROUTINE
;
VIDEO: . . . (existing routine)
        . . .
;
; LIST-OUTPUT ROUTINE
;
LOUT:  . . . (existing routine)
        . . .

```

Assemble the new BIOS and try it out. We can use the system debugger DDT or SID to load the new CBIOS over the old one. The command is

```
A>DDT CBIOS.HEX
```

One word of caution: Since the debugger uses the routines in CBIOS, there may be a problem. A safer way to put the new CBIOS into place is to first load it somewhere else.

Use the hex arithmetic command of DDT to calculate the offset. Suppose that BIOS is assembled for the address DB00 hex and you want to load it temporarily at 100 hex. Then the command

```
H100 DB00
```

will give both the sum and difference of the two addresses. The difference is what we need. Load CBIOS with the indicated offset

```
ICBIOS.HEX
R(offset)
```

DDT will indicate the location of the end of BIOS. The move command can now be used to put BIOS into its proper place.

```
M100 2FF DE00
```

The second address will be the present end of BIOS. The new BIOS is now in place. If the debugger no longer works, there may be an error in BIOS or there may have been an error in the move command.

If everything appears to be all right, try out the IOBYTE feature. Use the S (set) command of the debugger to change the IOBYTE at address 3. Change the value of the IOBYTE from a zero to a 1.

```
S3
0003 00 1 (type a 1)
0004 00 . (type a decimal point)
```

The (logical) console output should now appear at the printer instead of the console. Notice that this is different from typing a control-P when the IOBYTE has a value of zero. In fact, if a control-P is typed at this time, each typed character should be printed twice. Return the logical console output to the console by changing the IOBYTE back to zero using DDT.

```
S3
0003 01 0 (type a 0)
0004 00 . (type a decimal point)
```

Output should return to the console.

If everything appears to be all right, you are still not finished. You have a working copy of BIOS in memory; now you must get a copy onto the system tracks of the disk. *Continue with this section if you want to write a permanent copy of the new BIOS onto the disk. Otherwise, go on to the second part of the alteration where you will add the IOBYTE feature to the console input routines.* Then come back to this section to save the completed BIOS. If you have a Lifeboat version of CP/M, you can easily copy the new version of BIOS to the disk. Just give the command

```
A>SAVEUSER
```

and the new BIOS will be copied to the system disk.

Another method of getting the new CBIOS on the disk system tracks is to use SYSGEN. The current version of CPM is loaded into memory with the DDT command

```
A>DDT CPMXX.COM
```

where XX refers to the memory size. Then move the working version of BIOS down to the proper SYSGEN position using the DDT move command. Alternately, the HEX file of CBIOS could be copied from disk into memory.

The SYSGEN location for BIOS should be given in your CP/M documentation. Perform a warm start with a control-C, and then give the command

```
A>SYSGEN
```

Answer the first question about where to get the system by typing just a carriage return. The second question asks where to put the system. Give the appropriate drive name, A, B, etc. The new BIOS will now be copied to disk.

Incorporating the IOBYTE into Input Routines.

We are now ready to implement the second part of the console IOBYTE feature. This will allow the logical console input to be obtained from either of two keyboards. One of these keyboards will be the video terminal; the other will be the printer. If you don't have a second keyboard, go on to the next section.

Locate the console status and the console input routines. These are found from the second and third entries of the jump table of BIOS. Your present console-input routine may be coded in one of two ways. One method is straight-forward. The input routine has a status check independent of the regular BIOS status routine.

```
;  
; CONSOLE INPUT ROUTINE  
;  
CONIN: IN      CSTAT  ;GET STATUS  
        ANI      CIMSK ;MASK FOR INPUT  
        JZ       CONIN ;LOOP UNTIL READY  
        . . .
```

The other method uses the BIOS status routine.

```
;  
; CONSOLE INPUT ROUTINE  
;  
CONIN: CALL     CONST  ;GET STATUS  
        JZ       CONIN ;LOOP UNTIL READY  
        . . .
```

Although either method can be altered to include the IOBYTE feature, the former method will be demonstrated here. We will need two separate input routines. One is for the video screen and the other is for the printer or other keyboard. Our new console input routine might look like this.

```
;  
; LOGICAL CONSOLE INPUT  
;  
CONIN: LDA      IOBYTE ;GET ASSIGNMENT  
        ANI      2      ;MASK FOR LIST  
        JNZ      LISTIN ;LIST INPUT
```

```
;  
; VIDEO INPUT  
;  
VIDIN: IN      CSTAT    ;GET STATUS  
       ANI      CIMSK    ;MASK FOR INPUT  
       JZ       VIDIN    ;LOOP UNTIL READY  
       IN      CDATA    ;GET DATA  
       ANI      7FH      ;MASK PARITY  
       RET  
  
;  
; INPUT FROM PRINTER  
;  
LISTIN: IN      LSTAT    ;GET STATUS  
        ANI      LIMSK    ;MASK FOR INPUT  
        JZ       LISTIN   ;LOOP UNTIL READY  
        IN      CDATA    ;GET DATA  
        ANI      7FH      ;MASK PARITY  
        RET
```

The third jump statement at the beginning of BIOS should branch to the label CONIN. The IOBYTE at memory address 3 is read. All bits but bit 1 (the second bit) are zeroed with the ANI 2 command. List input corresponds to an IOBYTE of 2 or 3. The logical AND with 2 and either value will produce the result of 2.

0000 0010	or	0000 0011	IOBYTE
10		10	AND with 2
-----		-----	
0000 0010		0000 0010	= 2

The JNZ instruction will then cause a branch to the list-input routine. Otherwise, program flow will continue on to the console-input routine.

A similar construction can be used for the console status routine.

```
;  
; LOGICAL CONSOLE-INPUT STATUS  
;  
CONST: LDA      IOBYTE    ;GET ASSIGNMENT  
        ANI      2        ;MASK FOR LIST  
        JNZ      LISTST    ;LIST  
  
;  
; INPUT FROM VIDEO  
;  
VSTAT: IN      CSTAT    ;CHECK STATUS  
        ANI      CIMSK    ;MASK FOR INPUT  
        RZ              ;NO READY  
        MVI      A,0FFH    ;SET FOR READY  
        RET  
  
;  
; INPUT FROM LIST  
;  
LISTST: IN      LSTAT    ;CHECK STATUS  
        ANI      LIMSK    ;MASK FOR INPUT  
        RZ              ;NOT READY  
        MVI      A,0FFH    ;SET FOR READY  
        RET
```

Assemble the new version of BIOS and try it out as we did in the previous section. Load the debugger, then use it to change the IOBYTE at address 3. First, change the IOBYTE to a value of 3. This will assign the logical console input to the printer (or other alternate keyboard) and logical console output to the video screen. As soon as you make the change, all further input must come from the printer. Use the debugger to change the IOBYTE to a value of 2. Now logical console input must come from the printer, and logical console output will appear at the printer. Finally, change the IOBYTE back to the value of zero. Console input and output should both go through the video terminal.

USING STAT TO CHANGE THE IOBYTE

The CP/M program called STAT can be used to symbolically change the IOBYTE. STAT can also be used to determine the current value of the IOBYTE. Each of the four logical devices CON: (console), RDR: (reader), PUN: (punch), and LST: (list) can be assigned to four different physical devices.

Logical device	Physical device			
	1	2	3	4
CON: console	TTY:	CRT:	BAT:	UC1:
RDR: reader	TTY:	PTP:	UR1:	UR2:
PUN: punch	TTY:	PTP:	UP1:	UP2:
LST: list	TTY:	CRT:	LPT:	UL1:

The first column represents the four logical peripherals. The remaining entries on each line represent the four physical devices. You can easily change these names in STAT to something more descriptive. Load STAT into memory with the debugger.

```
DDT STAT.COM
```

Then dump the first few lines.

```
D100 16F
```

You will see the names of the logical peripherals and the physical peripherals encoded in ASCII. You can now change any of the names to something else. You might want to choose the names

```
CRT:
LST:
LPT:
LCR:
```


for the four console devices. These four names correspond to the IOBYTE values of 0 through 3. After you change the names with the debugger, return to CP/M and save the altered STAT. If the IOBYTE is currently set to zero and you type the command

```
A>STAT CON:=LST:
```

STAT will change the IOBYTE to a value of 1 and console output will appear at the printer. The IOBYTE can be set back to zero with the command

```
A>STAT CON:=CRT:
```

If you have other peripherals, such as a phone modem, these can also be incorporated into IOBYTE. The logical punch can then be sent to the modem, the printer, or the console. A disk file can be sent over the phone modem with the command

```
A>STAT FUN:=B:CPMIO.ASM
```

where CPMIO.ASM is a disk file on drive B. As you can see, there is room for a lot of imagination.

A ROUTINE TO GO ANYWHERE IN MEMORY

The assembly language program shown in Listing 10.1 can be used to branch to any location in memory. Executable programs in CP/M are usually designed to be run starting at address 100 hex, since this is where programs are loaded by CP/M. There are times, however, when it is desirable to assemble a program for operation at some other location. The system monitor developed in Chapter 6 is one such program. If this monitor is to be located in ROM, then it must be placed above the CP/M operating system. A location of F000 hex would be ideal. But there is no easy way to get to the monitor from the CP/M system. If the GO routine is located on disk drive A, then we have only to give the CP/M command

```
A>GO F000
```

and a branch will occur to the address F000 hex.

The GO program demonstrates several of the I/O features available with CP/M. The branch address given as an argument on the above command line is read from a region of memory called the file-control block (FCB). The address of the FCB is 5C hex but the ASCII-encoded address starts at 5D hex. The input address, F000 in this example, is a valid hexadecimal number; it is to be converted from ASCII into a 16-bit binary number. The result is placed into the CPU program counter so that the computer will branch to the desired address. The address format is free-form, and leading zeros are

Listing 10.1 A Program to go anywhere in memory.

```

; (date goes here)
;
;          TITLE    'GO (Jump anywhere) '
;
; USAGE: TYPE GO F800 TO JUMP TO F800 HEX
;
0100      ORG        100H
;
0005 =     BDOS      EQU      5          ;DOS ENTRY POINT
005C =     FCB       EQU      5CH        ;FILE CONTROL BLOCK
0009 =     PBUF      EQU      9          ;PRINT BUFFER
000A =     RDBUF     EQU      10         ;READ CONSOLE BUFFER
000D =     CR        EQU      0DH        ;CARRIAGE RETURN
000A =     LF        EQU      0AH        ;LINE FEED
;
; START:
0100 215D00      LXI      H,FCB+1 ;GET ARGUMENT IF ANY
0103 7E          MOV     A,M        ;FIRST BYTE
0104 FE20        CPI      ' '        ;BLANK?
0106 CA3B01      JZ       ERROR      ;NO ARGUMENT
0109 229B01      AGAIN:  SHLD     RBUF  ;SAVE POINTER
010C CD1001      CALL     READHL     ;GET ADDRESS
010F E9          PCHL      ;GO TO ADDRESS
;
; CONVERT ASCII-HEX CHARACTERS
; TO 16-BIT BINARY NUMBER IN H,L
;
0110 210000      READHL: LXI      H,0      ;START WITH 0
0113 CD6301      RDHL2:  CALL     GETCH   ;GET A BYTE
0116 FE20        CPI      ' '        ;END?
0118 C8          RZ           ;YES
0119 CD2801      CALL     NIB         ;TO BINARY
011C DA3801      JC       RDHL4      ;NOT HEX
011F 29          DAD      H          ;TIMES 2
0120 29          DAD      H          ;TIMES 4
0121 29          DAD      H          ;TIMES 8
0122 29          DAD      H          ;TIMES 16
0123 B5          ORA      L          ;COMBINE NEW
0124 6F          MOV     L,A         ;PUT BACK
0125 C31301      JMP      RDHL2      ;NEXT
;
; CONVERT ASCII TO BINARY
;
0128 D630      NIB:      SUI      '0'      ;ASCII BIAS
012A D8          RC          ; < 0
012B FE17      CPI      'F'-'0'+1
012D 3F          CMC
012E D8          RC          ; > F
012F FE0A      CPI      10
0131 3F          CMC
0132 D0          RNC          ;A NUMBER 0-9
0133 D607      SUI      'A'-'9'-1
0135 FE0A      CPI      10
0137 C9          RET
;

```

```

; BLANK AT END OF LINE IS OK
; ELSE AN ERROR
;
0138 FEFO      RDHL4: CPI      ' ' '0'
013A C8        RZ
;
; IMPROPER ARGUMENT, TRY AGAIN
;
013B 117501    ERROR: LXI      D,MESG  ;POINT TO MESSAGE
013E CD5901    CALL     PRINT  ;SEND IT
0141 119D01    LXI      D,RBUF  ;INPUT BUFFER
0144 CD5E01    CALL     READB   ;GET A LINE
0147 1600      MVI      D,0
0149 3A9E01    LDA      RBUF  ;BUFFER LENGTH
014C 5F        MOV      E,A
014D 219F01    LXI      H,RBUF
0150 19        DAD      D      ;PAST BUFFER
0151 3620      MVI      M,' '  ;PUT IN BLANK
0153 219F01    LXI      H,RBUF
0156 C30901    JMP      AGAIN  ;TRY AGAIN
;
; PRINT CHARACTERS UNTIL $ IS FOUND
;
0159 0E09      PRINT: MVI      C,PBUF  ;SET FOR PRINT
015B C30500    JMP      BDOS
;
; INPUT A LINE FROM CONSOLE
;
015E 0E0A      READB: MVI      C,RDBUF ;READ INPUT BUFFER
0160 C30500    JMP      BDOS
;
; GET A CHARACTER FROM THE INPUT BUFFER
;
0163 E5        GETCH: PUSH     H
0164 2A9B01    LHL      RBUF  ;GET POINTER
0167 7E        MOV      A,M    ;GET NEXT CHAR
0168 23        INX      H      ;INCREMENT POINTER
0169 229B01    SHLD     RBUF  ;SAVE POINTER
016C FE61      CPI      'Z'+7  ;UPPER CASE?
016E DA7301    JC      GETC2   ;NO
0171 E65F      ANI      5FH    ;MAKE UPPER CASE
0173 E1        GETC2: POP      H
0174 C9        RET
;
MSG:
0175 474F206572 DB      'GO error. Input '
0185 7468652061 DB      'the address again.'
0197 0D0A2A24   DB      CR,LF,'*%'
;
019B 9F01      RBUF: DW      RBUF  ;BUFFER POINTER
019D 0A        RBUFM: DB      10   ;MAX SIZE
019E           RBUFL: DS      1    ;ACTUAL SIZE
019F           RBUF: DS      1    ;INPUT BUFFER
;
01A0           END

```

unnecessary. If more than four characters are entered, only the last four are used. Thus, all of the following are valid.

0	F000
900	PF800
6000	

If no argument is given to the GO command, or if an invalid hexadecimal address is entered, then an error message is printed. This step uses the console string-output feature, selected with the function code of 9 in register C. The DE register pair is loaded with a pointer to the string location in memory. A dollar sign (\$) is used to indicate the end of the string. In subroutine SENDM of Chapter 6, a binary zero is used for this purpose since it requires less code.

The user can retype the desired address after the error message has been printed. This time, however, the program reads the input string data in a different way. The console string-input operation is selected by loading the C register with the function number of 10. If the new string is a valid hex number, it is converted to a 16-bit binary number. The computer then jumps to this address. If the input is still invalid, the error routine is repeated again.

During the input operation, the usual CP/M commands are available for error correction. For example, the most recently typed character can be deleted by pressing the DEL key. A control-R will reprint the current line in its corrected form. A control-U cancels the entire line so that it can be retyped. If Version 2 of CP/M is being used, then the backspace character, control-H, can also be used for correcting errors. Finally, a control-C can be entered to abort the entire program. This returns control to the CP/M operating system.

Enter the GO program in Listing 10.1. Assemble it and try it out. GO is a universal program; it will work on any system. If you have a monitor located in memory, use GO to branch to it; if not, you can still try out the GO program. Type just the command of GO without an argument. An error message should be printed. Type some characters, then delete some of them with the DEL key. The deleted characters will be printed a second time. Reprint the line with a control-R to see the correct version. Finally return to CP/M by giving the address of zero.

GO 0

A control-C can also be used to return to CP/M.

A LIST ROUTINE WITH DATE AND TIME

In Chapter 7 we developed a monitor routine for sending data to a separate list device. When this routine is activated with a control-P command, the output appears at both the console and the printer. CP/M has a similar

arrangement. A control-P command will activate the list device, too. Output is then sent to both the console and the printer.

But the console and list routines are entirely separate in CP/M. Output can therefore be sent specifically to the list device and it will not appear on the console. In CP/M I/O operations, a function number of 2 corresponds to console output, and a function number of 5 corresponds to list output. If memory address 5 is called with a value of 2 in the C register, then the byte in the E register will be displayed on the system console. On the other hand, if a function number of 5 is placed in the C register, then the byte in register E will appear on the list device. The byte in the E register can be sent to the punch by loading a function number of 4 into the C register.

This complexity may seem unnecessary, since the list device can be turned on by typing a control-P. If the command

```
A>TYPE <filename>
```

were given, then the file would be sent to both the console and the printer. The disadvantage of this method is that the TYPE command line will appear on the printer output. Also, when the listing is finished, the new prompt of A> will be printed on the listing.

The CP/M utility program PIP can be used to send a disk file specifically to the list device. The command is

```
A>PIP LST:=<filename>[T8]
```

The argument T8, embedded in brackets, will expand the ASCII tab character to 8-column fields. PIP, however, does not automatically eject a new page when a form feed is encountered.

The LIST program in Listing 10.2 can be used to send an ASCII disk file to the printer, too. It will automatically expand the ASCII tab character. Furthermore, when a form-feed character is encountered, LIST will add the correct number of lines to the end of the page. At the end of the disk file, additional line feeds are issued to finish the page. This will ensure that the printer will start the next task on a new page. If the file contains an odd number of pages, then an extra blank page is added to the end. Without this feature you will have to refold about half of the output.

If your computer keeps track of the date and time, LIST can print current values at the top of the first page. The name of the disk file is also printed on this line.

LIST is a very small program, requiring only 1K bytes of memory. It was derived from the program called DUMP in the CP/M *Interface Guide*. LIST bears only a passing resemblance to DUMP, however. DUMP is designed to convert binary files to ASCII-hex characters and display them on the console. LIST, on the other hand, prints ASCII files directly with no conversion. Since the CP/M BDOS is used for all I/O and disk operations, LIST will operate with all standard CP/M systems.

Listing 10.2. List an ASCII disk file.

```

; SEND ASCII DISK FILE TO LIST
; PUT DATE AND TIME AT TOP OF PAGE
; ENTIRE FILE LOADS INTO MEMORY FIRST
; FORMFEEDS ADDED WITH F ARGUMENT
; EXTRA PAGE ADDED TO MAKE TOTAL EVEN
; UNLESS A P OPTION IS GIVEN
;
; USAGE:
;     LIST <filename>
;     LIST <filename> F (add form feeds)
;     LIST <filename> P (no extra page)
;     LIST <filename> n (skip n lines)
;
; (date goes here)
;
TITLE    'List an ASCII disk file.'
;
0100      ORG      100H
0005 =    BDOS     EQU      5      ;DOS ENTRY POINT
0001 =    CONS     EQU      1      ;READ CONSOLE
0005 =    TYPEF     EQU      5      ;LIST OUTPUT
0009 =    PBUF      EQU      9      ;PRINT CONSOLE BUFFER
000B =    BRKF      EQU     11      ;KILL? (TRUE IF CHAR)
000F =    OPENF     EQU     15      ;FILE OPEN
0014 =    READF     EQU     20      ;READ FUNCTION
000D =    CR        EQU     0DH     ;CARRIAGE RETURN
000A =    LF        EQU     0AH     ;LINE FEED
001A =    EOF       EQU     1AH     ;END OF FILE
0009 =    TAB       EQU      9      ;^I
000C =    FORMFD    EQU     0CH     ;FORM FEED
003A =    LINES     EQU     58      ;LINES/PAGE
0042 =    LMAX      EQU     66      ;MAX LINES
;
005C =    FCB       EQU     5CH     ;FILE CONTROL BLOCK
0080 =    BUFF      EQU     80H     ;DISK BUFFER ADDR
;
; FILE-CONTROL BLOCK DEFINITIONS
;
005D =    FCBFN     EQU     FCB+1   ;FILE NAME
0068 =    FCBRL     EQU     FCB+12  ;CURRENT REEL #
007C =    FCBRCR    EQU     FCB+32  ;NEXT REC #(0-127)
;
; TIME AND DATE FROM A COMPU/TIME BOARD
;
00C4 =    ADATA     EQU     0C4H     ;PORT A DATA
00C5 =    ACONT     EQU     ADATA+1  ;PORT A CONTROL
00C7 =    BCONT     EQU     ADATA+3  ;PORT B CONTROL
00C6 =    BDATA     EQU     ADATA+2  ;PORT B DATA
;
; SAVE OLD STACK AND SET UP A NEW ONE
;
0100 210000  START:  LXI      H,0
0103 39      DAD      SP
0104 22E004  SHLD     OLDSP    ;SAVE STACK
0107 310005  LXI      SP,STACK
010A 111E04  LXI      D,RULES
010D CD3E02  CALL     PRINT    ;HOW TO ABORT

```

```

;
; HOW MANY LINES TO SKIP BEFORE STARTING?
;
0110 210000          LXI      H,0
0113 016D00          LXI      B,6DH    ;3RD ARGUMENT
0116 0A             SKIP2: LDAX    B      ;GET CHARACTER
0117 FE20            CPI      ' '      ;BLANK AT END
0119 CA4001          JZ       SKIP3     ;DONE
011C FE46            CPI      'F'      ;NEED FORM FEEDS?
011E CA3C01          JZ       FORM      ;YES
0121 FE50            CPI      'P'      ;EXTRA PAGE?
0123 CA3601          JZ       NOPAGE     ;NO
0126 D630            SUI      'O'      ;REMOVE ASCII BIAS
;
; CONVERT ASCII DECIMAL TO BINARY IN H,L
;
0128 54             MOV      D,H      ;DUPLICATE
0129 5D             MOV      E,L      ;H,L IN D,E
012A 29             DAD      H      ;TIMES 2
012B 29             DAD      H      ;TIMES 4
012C 19             DAD      D      ;TIMES 5
012D 29             DAD      H      ;TIMES 10
012E 5F             MOV      E,A
012F 1600            MVI      D,0
0131 19             DAD      D      ;ADD NEW BYTE
0132 03             INX      B      ;INCR POINTER
0133 C31601          JMP      SKIP2     ;NEXT
;
0136 32D904          NOPAGE: STA     PFLAG ;NO EXTRA PAGE
0139 C33F01          JMP      ZERO
;
013C 32D804          FORM:  STA     FFLAG ;SET FOR FORM FEEDS
013F AF             ZERO:  XRA      A      ;RESET COUNT
0140 22DA04          SKIP3: SHLD    SKIPB ;SAVE BINARY CNT
;
; READ AS MUCH AS POSSIBLE INTO MEMORY
;
0143 CDB302          CALL    SETUP    ;SET UP INPUT FILE
0146 3E80            MVI      A,80H
0148 32DE04          STA      IBP      ;SET POINTER TO 80H
014B 32D304          STA      TIME2    ;SET 1ST PASS
;
014E 2ADA04          LHL      SKIPB    ;HOW MANY LINES?
0151 7C             MAIN6: MOV      A,H
0152 B5             ORA      L      ;H,L = 0?
0153 CA6401          JZ       MAIN5    ;NO SKIP
0156 E5             MAIN7: PUSH    H
0157 CD4302          CALL    GNB      ;NEXT BYTE
015A E1             POP      H
015B FE0D            CPI      CR
015D C25601          JNZ      MAIN7    ;LOOK FOR CR
0160 2B             DCX      H      ;DECR COUNT
0161 C35101          JMP      MAIN6
;
0164 AF             MAIN5: XRA      A
0165 32D504          STA      FULL     ;RESET FLAG
0168 CD4302          MAIN2: CALL    GNB ;GET A BYTE
016B E5             PUSH    H

```

```

016C 2ADC04      LHL D    BUFPF    #MEMORY POINTER
016F 77          MOV      M,A      #PUT BYTE IN
0170 23          INX      H
0171 22DC04      SHLD     BUFPF    #SAVE POINTER
0174 47          MOV      B,A
0175 3EFF        MVI      A,OFFH
0177 BD          CMP      L        #L=0?
0178 C28B01      JNZ      MAIN4    #NO
; CHECK FDOS
017B 3A0700      LDA      7        #FDOS
017E D40A        SUI      10       #CCP -1
0180 BC          CMP      H        #TOO BIG?
0181 D28B01      JNC      MAIN4    #NO
0184 3E1A        MVI      A,EOF
0186 77          MOV      M,A      #PUT IN MEMORY
0187 32D504      STA      FULL     #SET FOR FULL
018A 47          MOV      B,A
018B 78          MAIN4: MOV     A,B    #GET BYTE
018C E1          POP      H
018D FE1A        CPI      EOF
018F C26801      JNZ      MAIN2    #NO
;
; CHECK FOR EOF AT END
;
0192 2ADC04      LHL D    BUFPF    #GET POINTER
0195 2B          DCX      H
0196 3E1A        MVI      A,EOF
0198 BE          CMP      M        #EOF?
0199 CAA101      JZ       MAIN3    #YES
019C 23          INX      H
019D 77          MOV      M,A      #PUT IN EOF
019E 22DC04      SHLD     BUFPF
;
01A1 CD7C02      MAIN3: CALL     RESET #POINTER
;
; PUT TIME AT START OF LISTING
; REMOVE FORMFEED IF FIRST
;
01A4 CD5D03      CALL     CLOCK    #GET TIME
01A7 3AD804      LDA      FFLAG    #FORMFEEDS?
01AA B7          ORA      A
01AB C4F601      CNZ      TWOLN    #YES
01AE CD5F02      CALL     GETB     #GET BYTE
01B1 FE0C        CPI      FORMFD   #FORMFEED
01B3 C2BC01      JNZ      GLOP2    #NO
01B6 CDF601      CALL     TWOLN    #SEND 2 LF
;
01B9 CD5F02      GLOP:  CALL     GETB     #GET NEXT BYTE
01BC 47          GLOP2: MOV      B,A    #SAVE BYTE
01BD CDFD02      CALL     TABO     #PRINT BYTE
01C0 78          MOV      A,B      #GET BYTE AGAIN
01C1 FE0A        CPI      LF       #END OF LINE?
01C3 C2B901      JNZ      GLOP     #NO
01C6 3AD604      LDA      LCOUNT  #GET COUNT
01C9 3C          INR      A        #INCREMENT IT
01CA 32D604      STA      LCOUNT  #SAVE IT
01CD FE42        CPI      LMAX     #TOO MANY?
01CF D43202      CNC      NPAGE    #YES, RESET
01D2 3AD804      LDA      FFLAG    #FORM FEEDS?

```



```

01D5 B7          ORA      A
01D6 CAB901      JZ       GLOOP    ;NO
01D9 3AD604      LDA      LCOUNT  ;GET COUNT
01DC FE3A        CPI      LINES    ;END OF PAGE?
01DE DAB901      JC       GLOOP    ;NO
01E1 CD1B02      CALL     FILL      ;NEW PAGE
01E4 CDF601      CALL     TWOLN
01E7 C3B901      JMP      GLOOP

;
; CHECK FOR ABORT, ANY KEY PRESSED
;
01EA E5          ABORT:  PUSH     H          ;SAVE
01EB D5          PUSH     D
01EC C5          PUSH     B
01ED 0E0B        MVI      C,BRKF  ;CONSOLE READY?
01EF CD0500      PCHAR2: CALL     BDOS
01F2 C1          POP      B          ;RESTORE
01F3 D1          POP      D
01F4 E1          POP      H
01F5 C9          RET

;
01F6 060A        TWOLN:  MVI      B,LF    ;TWO LINES
01F8 3AD604      LDA      LCOUNT
01FB 3C          INR      A          ;ADD 2 TO
01FC 3C          INR      A          ;COUNT
01FD 32D604      STA      LCOUNT
0200 CD0302      OUTT2:  CALL     OUTT    ;DOUBLE OUTPUT
;
0203 78          OUTT:   MOV      A,B    ;OUTPUT FROM B
;
; SEND CHARACTER FROM A TO LIST
;
0204 E5          PCHAR:  PUSH     H
0205 D5          PUSH     D
0206 C5          PUSH     B          ;SAVED
0207 0E05        MVI      C,TYPEF ;LIST
0209 5F          MOV      E,A
020A FE0C        CPI      FORMFD  ;FORMFEED?
020C C2EF01      JNZ      PCHAR2  ;PRINT BYTE
;
; FILL OUT PAGE AFTER FORMFEED
;
020F CD1B02      CALL     FILL
0212 060A        MVI      B,LF    ;FOR FORMFEED
0214 CD0302      CALL     OUTT
0217 C1          POP      B
0218 D1          POP      D
0219 E1          POP      H
021A C9          RET

;
; FILL OUT END OF PAGE
;
021B 3AD604      FILL:   LDA      LCOUNT ;LINE COUNT
021E 4F          MOV      C,A
021F CD3202      CALL     NPAGE    ;INCR PAGE
0222 3E42        MVI      A,LMAX
0224 91          SUB      C
0225 D8          RC          ;TOO BIG

```

```

0226 C8          RZ
0227 4F          MOV     C,A
0228 060A        MVI     B,LF
022A CD0302     FILL2:  CALL    OUTT      ;SEND LF
022D 0D          DCR     C
022E C22A02     JNZ     FILL2
0231 C9          RET

;
; RESET LINE COUNT, INCREMENT PAGES
;
0232 AF          NPAGE:  XRA     A          ;GET A ZERO
0233 32D604      STA     LCOUNT ;LINE COUNT
0236 3AD704      LDA     PAGES  ;PAGE COUNT
0239 3C          INR     A
023A 32D704      STA     PAGES
023D C9          RET

;
; SEND MESSAGE TO CONSOLE
;
023E 0E09        PRINT:  MVI     C,PBUF
0240 C30500      JMP     BDOS

;
; GET NEXT BYTE FROM DISK BUFFER
;
0243 3ADE04      GNB:    LDA     IBF
0246 FE80        CPI     80H
0248 C24F02      JNZ     READ

;
; READ ANOTHER BUFFER
;
024B CDDA02      CALL    DISKR
024E AF          XRA     A

;
; READ THE BYTE AT BUFF+REG A
;
024F 5F          READ:   MOV     E,A
0250 1600        MVI     D,0
0252 3C          INR     A
0253 32DE04      STA     IBF

; POINTER IS INCREMENTED
; SAVE THE CURRENT FILE ADDRESS
0256 E5          PUSH    H
0257 218000      LXI     H,BUFF
025A 19          DAD     D
025B 7E          MOV     A,M

; BYTE IS IN THE ACCUMULATOR
; RESTORE FILE ADDRESS AND INCREMENT
025C E1          POP     H
025D 23          INX     H
025E C9          RET

;
; GET A BYTE FROM MEMORY BUFFER
;
025F E5          GETB:   PUSH    H
0260 2ADC04      LHLD    BUFFP
0263 7E          MOV     A,M
0264 23          INX     H
0265 22DC04      SHLD    BUFFP

```

```

0268 E1          POP      H
0269 E67F        ANI      7FH      ;STRIP PARITY
026B FE1A        CPI      EOF
026D C0          RNZ
026E F1          POP      PSW      ;RAISE STACK
;
026F 3AD504      LDA      FULL     ;CHECK FLAG
0272 B7          ORA      A        ;ZERO?
0273 C8E02       JZ       FINIS     ;YES, DONE
0276 CD7C02      CALL     RESET     ;POINTER
0279 C36401      JMP      MAIN5     ;GET MORE
;
; RESET MEMORY POINTER
;
027C E5          RESET:  PUSH     H
027D 210005      LXI      H,BUFFER
0280 22DC04      SHLD     BUFFP
0283 E1          POP      H
0284 C9          RET
;
0285 110204      NONAME: LXI      D,MES1 ;POINT TO MESSAGE
0288 CD3E02      FINI3:  CALL     PRINT
028B C3AE02      JMP      ABOR2
;
; NORMAL END OF OF LISTING
;
028E 32D404      FINIS:  STA      EOFFL  ;SET EOF FLAG
;
0291 CD1B02      CALL     FILL      ;OUT PAGE
;
; ADD AN EXTRA PAGE IF THERE IS AN ODD NUMBER
; AND P FLAG IS NOT SET
;
0294 3AD904      LDA      PFLAG
0297 B7          ORA      A        ;ZERO?
0298 C2AE02      JNZ      ABOR2     ;NO
029B 3AD704      LDA      PAGES    ;HOW MANY?
029E E601        ANI      1        ;ODD?
02A0 CAAE02      JZ       ABOR2     ;NO
;
; ADD BLANK PAGE TO MAKE EVEN
;
; (CAN WE CALL FILL?)
02A3 0642        MVI      B,LMAX   ;LINES
02A5 3E0A        EPAGE:  MVI      A,LF
02A7 CD0402      CALL     PCHAR
02AA 05          DCR      B
02AB C2A502      JNZ      EPAGE
;
ABOR2:
ABOR3:
02AE 2AE004      LHLD     OLDDSP    ;OLD STACK POINTER
02B1 F9          SPHL
02B2 C9          RET
;
; SETUP FILE AND OPEN FOR INPUT
;

```

```

02B3 115C00  SETUP: LXI      D,FCB
02B6 0E0F      MVI      C,OPENF
02B8 CD0500      CALL     BDOS

;
; CHECK FOR ERRORS
;
02BB FEFF      CPI      255
02BD CAC502      JZ       BADOPN ;NO GOOD

;
; OPEN IS OK
;
02C0 AF        XRA      A
02C1 327C00      STA     FCBCR
02C4 C9         RET

;
; BAD OPEN
;
02C5 215D00  BADOPN: LXI      H,FCBFN ;1ST CHAR
02C8 7E      MOV      A,M      ;GET IT
02C9 FE20      CPI      ' '    ;FILE NAME?
02CB CA8502      JZ       NONAME ;NO
02CE 213F24      LXI      H,'? '$ ;SET UP FOR PRINT
02D1 226800      SHLD     FCBRL ;USE INPUT FILENAME
02D4 115D00      LXI      D,FCBFN ;FILENAME
02D7 C38802      JMP      FINI3 ;QUIT

;
; READ DISK FILE RECORD
;
02DA E5        DISKR: PUSH     H
02DB D5        PUSH     D
02DC C5        PUSH     B
02DD 115C00      LXI      D,FCB
02E0 0E14      MVI      C,READF
02E2 CD0500      CALL     BDOS
02E5 C1        POP      B
02E6 D1        POP      D
02E7 E1        POP      H
02E8 B7        ORA      A      ;CHECK FOR ERRS
02E9 C8        RZ           ;OK

; MAY BE EOF
02EA FE01      CPI      1
02EC CAF502      JZ       FEND   ;EOF

;
02EF 111104      LXI      D,MES2
02F2 C3AE02      JMP      ABOR3

;
; FOUND DISK EOF
;
02F5 2ADC04  FEND:  LHLD     BUFPF ;GET POINTER
02F8 361A      MVI      M,EOF ;PUT IN 1A
02FA C3A101      JMP      MAIN3

;
; TAB COUNTER ROUTINE
; JUMP HERE WITH BYTE IN B
;

```

```

02FD 78      TABO:  MOV    A,B      ;GET BYTE
02FE FE20    CPI     ' '          ;CONTROL CHAR?
0300 DA1E03  JC      TABCR        ;YES
0303 CD0903  CALL    TABN         ;INCR COUNTER
0306 C30302  JMP     OUTT         ;SEND BYTE
;
; INCREMENT TAB COUNTER
; MAKE MODULO 8
;
0309 3AD204  TABN:  LDA     TABC     ;GET TAB COUNT
030C 3C      INR     A             ;INCREMENT IT
030D E607    ANI     7            ;MODULO 8
030F 32D204  STA     TABC         ;SAVE IT
0312 C9      RET
;
; READ THE BYTE AFTER ABORT
;
0313 CD1B02  DONE:  CALL    FILL     ;OUT PAGE
0316 0E01    MVI     C,CONS        ;READ CONSOLE
0318 CD0500  CALL    BDOS
031B C3AE02  JMP     ABOR3         ;RETURN
;
; IF CARRIAGE RETURN THEN ZERO COUNT
;
031E FE0D    TABCR: CPI     CR
0320 C23103  JNZ     TABI         ;NOT CR
0323 CDEA01  CALL    ABORT
0326 0F      RRC
0327 DA1303  JC      DONE         ;QUIT
032A AF      XRA     A            ;GET A ZERO
032B 32D204  STA     TABC         ;SET TO ZERO
032E C30302  JMP     OUTT         ;SEND CR
;
; CHECK FOR TAB (CONTROL-I)
;
0331 FE09    TABI:  CPI     TAB
0333 C24003  JNZ     TFORM        ;NOT TAB
0336 CD5803  TAB2:  CALL    BLANK    ;SEND A BLANK
0339 CD0903  CALL    TABN         ;INCR TAB COUNT
033C C23603  JNZ     TAB2         ;MORE
033F C9      RET                 ;NO PRINT
;
; CHECK FOR FORMFEED
;
0340 FE0C    TFORM: CPI     FORMFD
0342 C20302  JNZ     OUTT         ;NO
0345 3AD804  LDA     FFLAG        ;FORM FEED OPTION?
0348 B7      ORA     A
0349 C25403  JNZ     TFOR2        ;OTHER CONTROL
034C 060A    MVI     B,LF
034E CD0302  CALL    OUTT
0351 C31B02  JMP     FILL         ;NORMAL FORMFEED
0354 F1      TFOR2: POP     PSW     ;RESTORE STACK
0355 C3B901  JMP     GLOOP        ;NEXT BYTE
;
; SEND A BLANK
;

```

```

0358 3E20      BLANK: MVI      A,' '
035A C30402    JMP      PCHAR  ;SEND IT
;
035D DBC4      CLOCK: IN      ADATA  ;BOARD PRESENT?
035F FEFF      CPI      OFFH
0361 C8        RZ          ;NO
0362 3AD304    LDA      TIME2  ;PASS?
0365 B7        ORA      A      ;ZERO?
0366 C8        RZ          ;NOT 1ST
0367 AF        XRA      A
0368 32D304    STA      TIME2  ;SET 1ST
036B 21DE03    LXI      H,MON
036E CDA703    CALL     DATE   ;GET IT
0371 21ED03    LXI      H,HOUR
0374 CDC003    CALL     TIME
0377 21D703    LXI      H,PDATE ;POINT DATE/TIME
037A CD8A03    CALL     SEND
037D AF        XRA      A      ;GET A ZERO
037E 326900    STA      FCB+13 ;NAME END
0381 215D00    LXI      H,FCBFN ;NAME START
0384 CD8A03    CALL     SEND  ;SHOW
0387 21FF03    LXI      H,SCRLF
;
; SEND MESSAGE TO LIST
;
038A 7E        SEND: MOV     A,M   ;GET BYTE
038B B7        ORA      A      ;ZERO AT END
038C C8        RZ          ;DONE
038D CD0402    CALL     PCHAR  ;SEND CHARACTER
0390 23        INX      H      ;INCREMENT POINTER
0391 C38A03    JMP      SEND
;
; READ A DIGIT
;
0394 7A        RDIGIT: MOV    A,D   ;SELECT DIGIT
0395 D3C4      OUT     ADATA
0397 DBC4      IN      ADATA  ;RESET INTERRUPT
0399 DBC5      DWAIT: IN      ACONT ;DIGIT PRESENT?
039B E680      ANI     80H
039D CA9903    JZ      DWAIT  ;LOOP UNTIL READY
03A0 DBC4      IN      ADATA  ;READ A DIGIT
03A2 E60F      ANI     0FH    ;MASK
03A4 F630      ORI     30H    ;CONVERT TO ASCII
03A6 C9        RET
;
;READ-DATE ROUTINE
;
03A7 AF        DATE:  XRA      A      ;DATE DISPLAY MODE
03A8 D3C6      OUT     BDATA
03AA 4F        MOV     C,A      ;THIS IS DATE
;
; READ FOUR DIGITS
;
03AB 1600      READ4: MVI     D,0   ;SELECT FIRST DIGIT
03AD CD9403    RD4:  CALL     RDIGIT ;DELAY ONE DIGIT SCAN
03B0 CDCD03    CALL     RSDIG  ;READ & STORE DIGIT
03B3 7A        MOV     A,D
03B4 FE20      CPI     20H    ;TWO DIGITS DONE?

```

```

03B6 C2BA03          JNZ     SKIP     ;SKIP A PLACE
03B9 23              INX     H         ;SKIP : OR /
03BA FE40            SKIP:  CPI     40H
03BC C2AD03          JNZ     RD4      ;GET ANOTHER DIGIT
03BF C9              RET

;
; READ TIME & READ AND STORE DIGIT
;
03C0 3E40            TIME:  MVI     A,40H ;TIME DISPLAY MODE
03C2 D3C6            OUT     BDATA
03C4 0E01            MVI     C,1      ;THIS IS TIME
03C6 CDAB03          CALL    READ4    ;GET 4 DIGITS
03C9 23              INX     H         ;SKIP COLON
03CA CDCD03          CALL    RSDIG
03CD CD9403          RSDIG: CALL    RDIGIT
03D0 77              MOV     M,A      ;STORE BYTE
03D1 23              INX     H         ;INCR POINTER
03D2 7A              MOV     A,D
03D3 C610            ADI     10H
03D5 57              MOV     D,A
03D6 C9              RET

;
; STORAGE AREA
;
PDATE:
03D7 0D0A446174      DB         CR,LF,'Date '
03DE 78782F          MON:      DB         'xx/' ;MONTH
03E1 78782F          DB         'xx/' ;DAY
03E4 3830            DB         '80' ;YEAR
03E6 202054696D      DB         ' Time '
03ED 78783A          HOUR:     DB         'xx:' ;HOURS
03F0 78783A          DB         'xx:' ;MINUTES
03F3 7878            DB         'xx' ;SECONDS
03F5 2020204669      DB         ' File: ',0
03FF 0D0A00          SCRLF:    DB         CR,LF,0
0402 0D0A4E6F20MES1: DB         CR,LF,'No file name$'
0411 0D0A446973MES2: DB         CR,LF,'Disk error$'
041E 0D0A            RULES:    DB         CR,LF
0420 50726F6772      DB         'Program to list ASCII files'
043B 0D0A204F70      DB         CR,LF,' Options:'
0446 202863686F      DB         ' (choose one)',CR,LF
0455 2020462061      DB         ' F adds form feeds',CR,LF
046A 2020502073      DB         ' P skips extra even page'
0483 2061742065      DB         ' at end',CR,LF
048C 2020446563      DB         ' Decimal number skips '
04A3 6C696E6573      DB         'lines at beginings',CR,LF,LF
04B8 2050726573      DB         ' Press any key to abort.'
04D0 0A24            DB         LF,'$'
04D2 00              TABC:     DB         0 ;TAB COUNTER
04D3 80              TIME2:    DB         80H ;PASS
04D4 FF              EOFL:     DB         OFFH ;EOF FLAG
04D5 00              FULL:     DB         0 ;FULL FLAG
04D6 02              LCOUNT:  DB         2 ;LINE COUNT
04D7 00              PAGES:    DB         0 ;PAGE COUNT
04D8 00              FFLAG:    DB         0 ;FORMFEED FLAG
04D9 00              PFLAG:    DB         0 ;EXTRA-PAGE FLAG
04DA 0000            SKIPB:    DW         0 ;LINES TO SKIP
04DC 0005            BUFFF:    DW         BUFFER ;POINTER
04DE                IBF:       DS         2 ;INPUT BUFF POINTER

```

```

      $
      $      STACK AREA
04E0      OLDSP: DS      2      $OLD STACK
04E2      DS      30      $STACK SPACE
      STACK:
0500      BUFFER: DS      1      $NEW STACK
      $      $MEMORY BUFFER
0501      END

```

LIST can be executed by the command

```
A>LIST <filename> <optional argument>
```

The CP/M system copies LIST into memory at 100 hex and branches to it. The first step is to save the incoming stack pointer and set up a new one. The clock routine is executed next. The routine shown in Listing 10.2 is written for a Computime R clock board, but the program can be altered to accommodate other methods of timekeeping. The first step of the clock routine is to see if there is a clock board in the computer. One of the clock ports, at address ADATA, is read. If there is no port at this I/O address, the computer will read a value of FF hex. This will harmlessly terminate the subroutine with a return instruction.

If a clock board is present, then the first line of the printer output will appear in the form

```
Date 06/15/80 Time 13:18:33  FILE: <filename>
```

The next step is to see if one of the three optional arguments was given after the filename. These arguments are:

F	(add form feeds)
P	(no extra page at end)
decimal number	(skip lines at beginning)

The letter F is used to insert form feeds every 58 lines of the listing. The command looks like this.

```
A>LIST SORT.PAS F
```

This feature is useful for listing BASIC, FORTRAN, Pascal, or assembly-language source programs. If this argument is selected, the proper number of line feeds is generated as the end of the page is approached. This step causes the printer to skip over the fold in the paper. Also, any form feeds that are encountered are ignored.

If the letter P is given for the argument, then no extra blank page is generated at the end. This argument can be used to save paper when several one-page files are printed.

Another possible argument to LIST is a decimal number. In this case, the argument tells how many lines of the file are to be skipped. For example, the command

```
A>LIST LINFIT.FOR 500
```

will skip the first 500 lines and start the listing with line 501. Use this option if you want to print the last part of a long file but don't want to wait for the first part to be printed.

At this point, the disk directory is searched for the requested filename. This filename is retrieved from the file-control block at address 5C hex. If the requested filename can't be found in the directory, then the filename is printed on the console along with a question mark. LIST is then aborted. If no filename was entered, an error message stating this fact appears on the console. LIST is aborted in this case also. LIST could have been programmed to handle input errors the way that the GO routine does. Then, instead of aborting, LIST would ask for the filename to be entered again. The addition of this feature is left as an exercise for the reader.

If the filename exists in the directory, then the requested disk file is read. The proper number of lines are skipped over if the second argument of the command line was a valid decimal number. At this point, the disk file is read into memory. The FDOS address located at address 7 is checked to see how much memory is available. The entire file will be copied into memory if there is room. A check is made to see if the disk end-of-file character is encountered before the available memory is filled.

In either case, the date and time of day are printed first. Then the data in memory are printed. The first character is ignored if it is an ASCII form feed. This will prevent a page eject immediately after the date and time. The ASCII tab character is properly expanded by the routine TABO. The number of lines is counted. When a form-feed character is encountered, the proper number of line feeds is issued to fill out the page. If the F argument was given, the form feeds will be automatically issued.

LIST can be aborted at any time during the printing by pressing any console key. The console is checked for this after each carriage return. The CP/M program DUMP is set up a little differently. The disk data are read into a 128-byte buffer, rather than into the memory area above 100 hex. Using a small buffer has the advantage that programs can be stored in memory during the DUMP operation and they will not be erased. But, in return, there is a lot of disk activity. The disk must be accessed every 128 bytes.

COPY A DISK FILE INTO MEMORY

If you have programmed one of the tape routines given in Chapter 8, then you can make backup copies of your disk files. But you have to first copy the disk file into memory. The copy step can be performed with the debugger DDT or SID.

A>SID <filename>

This command loads the debugger at address 100 hex and branches to it. The debugger relocates itself into high memory, then copies the requested disk file into memory starting at 100 hex. The address of the end of the disk file in memory is printed in hexadecimal. This address can be used in conjunction with the memory map given in Appendix B to determine the number of 256-byte blocks in the file. For example, if DDT gives a value of 13AF, then the disk file occupies 19 (decimal) blocks of 256 bytes.

When the file has been copied into memory, the G command in the debugger can be used to branch to the tape routine. Then the SAVE command can be given to make a copy on tape. The process can be reversed by loading the file into memory from tape. Branch to address zero to restart CP/M. Finally, give the SAVE command

A>SAVE XX <filename>

where XX is the decimal number of 256-byte blocks to be saved.

This procedure can be simplified by using the FETCH program given in Listing 10.3. FETCH uses CP/M for all I/O and disk operations, so it should work with all standard CP/M systems. There are, however, 2 items that need to be customized. Fetch is initially loaded into memory at 100 hex. It then automatically relocates itself to higher memory. The relocation address is chosen to be F400 hex in Listing 10.3. You may have to change it to some other address if this region is not available. The address is defined by the label ORIGIN in the source program. After FETCH copies the requested disk file into memory, it branches to your tape routine. This address, defined by the label MONIT, is chosen to be F000 hex in Listing 10.3 MONIT should be changed to your tape address.

Listing 10.3. Copy a disk file into memory.

```

; (date goes here)
;
TITLE    'Copy a disk file into memory.'
;
; THIS PROGRAM RELOCATES ITSELF TO HIGH MEMORY THEN
; COPIES A DISK FILE TO MEMORY STARTING AT 100 HEX.
; ASCII AND COM FILES ARE CORRECTLY HANDLED.
; GIVE A THIRD ARGUMENT OF B FOR OTHER BINARY FILES.
; A 1A EOF CHARACTER IS PUT AT THE END ASCII FILES.
; THE LAST ADDRESS AND DECIMAL BLOCK SIZE ARE GIVEN.
; FINALLY A JUMP IS MADE TO THE ADDRESS OF MONIT.
;
; QUITS IF NO READ-WRITE MEMORY AT NEW LOCATION
;
F000 =    MONIT    EQU        0F000H    ;GO HERE WHEN DONE
F400 =    ORIGIN   EQU        0F400H    ;RELOCATE FETCH HERE
;
0100 =    BUFFER   EQU        100H      ;START MEMORY BUFFER
0005 =    BDOS     EQU        5         ;DOS ENTRY POINT

```

```

0002 =      TYPEF      EQU      2      ;CONSOLE OUTPUT
0009 =      PBUF       EQU      9      ;PRINT CONSOLE BUFFER
000F =      OPENF      EQU      15     ;FILE OPEN
0014 =      READF      EQU      20     ;READ FUNCTION
000D =      CR         EQU      0DH    ;CARRIAGE RETURN
000A =      LF         EQU      0AH    ;LINE FEED
001A =      EOF        EQU      1AH    ;END OF FILE
;
005C =      FCB        EQU      5CH    ;FILE CONTROL BLOCK
0080 =      BUFF       EQU      80H    ;INPUT DISK BUFFER ADDR
;
;
; FILE CONTROL BLOCK DEFINITIONS
;
005D =      FCBFN      EQU      FCB+1  ;FILE NAME
0065 =      FCBFT      EQU      FCB+9  ;FILE TYPE
0068 =      FCBRL      EQU      FCB+12 ;CURRENT REEL #
007C =      FCBCR      EQU      FCB+32 ;NEXT REC # (0-127)
;
0100      ORG         100H
;
; SAVE OLD STACK AND SET UP NEW STACK
;
0100 210000  BEGIN:  LXI      H,0      ;ZERO HL
0103 39      DAD      SP          ;ADD IN STACK
0104 22AEF5  SHLD     OLDSP      ;SAVE STACK
0107 31C8F5  LXI      SP,STACK  ;DEFINE NEW STACK
010A 210001  LXI      H,BUFFER
010D 22A9F5  SHLD     BUFFP     ;MEMORY POINTER
;
; BLOCK MOVE REST OF PROGRAM
;
0110 112A01  LXI      D,OLDST  ;OLD START
0113 2100F4  LXI      H,START  ;NEW START
0116 01AC01  LXI      B,IBP-START ;LENGTH
0119 1A      LOOP:  LDAX     D      ;GET BYTE
011A 77      MOV      M,A      ;MOVE TO NEW
011B BE      CMP      M      ;CHECK MEMORY
011C C20000  JNZ      O      ;QUIT, BAD
011F 23      INX      H      ;INCREMENT
0120 13      INX      D      ;POINTERS
0121 0B      DCX      B      ;DECR COUNT
0122 78      MOV      A,B      ;SEE IF DONE
0123 B1      ORA      C      ;ALL MOVED?
0124 C21901  JNZ      LOOP     ;NO
0127 C300F4  JMP      START    ;DONE
;
;ORIGINAL START OF PROGRAM
;
OLDST:
;
F400      ORG         ORIGIN
;
F400 C346F4  START:  JMP      MAIN  ;FINAL START
F403 CD0BF4  FINIS:  CALL     CRLF
F406 2AAEF5  LHL      OLDSP     ;ORIGINAL STACK
F409 F9      SPHL
F40A C9      RET

```

```

F40B 3E0D      ;
F40D CD12F4    CRLF:  MVI    A,CR
F410 3E0A      CALL    PCHAR
                   MVI    A,LF
;
; OUTPUT A CHARACTER FROM A
;
F412 E5        PCHAR:  PUSH    H
F413 D5        PUSH    D
F414 C5        PUSH    B          ;SAVED
F415 0E02      MVI    C,TYPEF
F417 5F        MOV     E,A
F418 CD0500    CALL    BDOS
F41B C1        POP     B
F41C D1        POP     D
F41D E1        POP     H          ;RESTORED
F41E C9        RET
;
; CARRIAGE RET, LINE FEED AND PRINT
;
F41F CD0BF4    PRINTC: CALL    CRLF
;
; PRINT BUFFER UNTIL $ FOUND
;
F422 E5        PRINT:  PUSH    H
F423 0E09      MVI    C,PBUF
F425 CD0500    CALL    BDOS
F428 E1        POP     H
F429 C9        RET
;
; GET NEXT BYTE FROM DISK BUFFER
;
F42A 3AACF5    GNB:    LDA     IBP
F42D FE80      CPI     80H
F42F C236F4    JNZ     GO
;
; READ ANOTHER BUFFER
;
F432 CD35F5    CALL    DISKR
F435 AF        XRA     A
;
; READ THE BYTE AT BUFF+REG A
;
F436 5F        GO:    MOV     E,A
F437 1600      MVI    D,0
F439 3C        INR     A
F43A 32ACF5    STA     IBP
; POINTER IS INCREMENTED
; SAVE THE CURRENT FILE ADDRESS
F43D E5        PUSH    H
F43E 218000    LXI     H,BUFF
F441 19        DAD     D
F442 7E        MOV     A,M
; BYTE IS IN THE ACCUMULATOR
; RESTORE FILE ADDRESS AND INCREMENT
F443 E1        POP     H
F444 23        INX     H
F445 C9        RET

```

```

;
MAIN:
;
; READ BYTES FROM DISK AND PUT IN MEMORY
;
F446 CDD6F4      CALL    SETUP    ;SET UP INPUT FILE
F449 3E80        MVI      A,80H
F44B 32ACF5      STA      IBP      ;BUFFER POINTER TO 80H
;
F44E CD2AF4      MAIN2:  CALL    GNB      ;GET A BYTE
F451 E5          PUSH    H
F452 2AA9F5      LHLD    BUFPF      ;MEMORY POINTER
F455 77          MOV     M,A        ;PUT BYTE IN
F456 23          INX     H
F457 22A9F5      SHLD    BUFPF      ;SAVE POINTER
F45A 47          MOV     B,A
F45B 3EFF        MVI      A,0FFH
F45D BD          CMP     L          ;L=0?
F45E C26AF4      JNZ     MAIN4      ;NO
F461 3A0700      LDA     7          ;FDOS
F464 D60A        SUI     10        ;CCF -1
F466 BC          CMP     H          ;TOO BIG?
F467 DA2FF5      JC      TOOBIG    ;WON'T FIT
;
F46A E1          MAIN4:  POP     H
F46B 3AABF5      LDA     BFLAG      ;BINARY FILE?
F46E B7          ORA     A
F46F C24EF4      JNZ     MAIN2      ;YES
F472 78          MOV     A,B        ;GET BYTE
F473 FE1A        CFI     EOF
F475 C24EF4      JNZ     MAIN2      ;NO
F478 2AA9F5      LHLD    BUFPF      ;POINTER
F47B 2B          MAIN5:  DCX     H
F47C 118AF5      DONE:  LXI     D,MESA
F47F CD22F4      CALL    PRINT
F482 CDBDF4      CALL    OUTHL      ;PRINT IT
F485 1199F5      LXI     D,MESB
F488 CD22F4      CALL    PRINT
;
; CONVERT FILE LENGTH TO DECIMAL K
;
F48B 7C          MOV     A,H
F48C 2600        MVI     H,0        ;LEADING 0 FLAG
F48E 1664        MVI     D,100
F490 0E2F        HM3:   MVI     C,'0'-1
F492 0C          HM2:   INR     C
F493 92          SUB     D          ;100/10
F494 D292F4      JNC     HM2        ;STILL PLUS
F497 82          ADD     D          ;ADD BACK
F498 47          MOV     B,A        ;SAVE REMAINDER
F499 79          MOV     A,C        ;GET 100S/TENS
;
; SUPPRESS LEADING ZEROS
;
F49A FE31        CPI     '1'        ;LESS THAN 1?
F49C D2A5F4      JNC     HM4        ;NO
F49F 7C          MOV     A,H        ;CHECK FLAG
F4A0 B7          ORA     A          ;ZERO?

```

```

F4A1 79          MOV     A,C      ;RESTORE BYTE
F4A2 CAAAF4      JZ       HM5     ;IF LEADING 0
F4A5 CD12F4      HM4:    CALL    PCHAR ;1ST, 2ND DIGIT
F4A8 26FF        MVI     H,OFFH   ;SET FLAG
F4AA 7A          HM5:    MOV     A,D
F4AB D65A        SUI     90       ;100 TO 10
F4AD 57          MOV     D,A
F4AE 78          MOV     A,B
F4AF D290F4      JNC     HM3      ;ONCEMORE
F4B2 C630        ADI     '0'      ;ASCII BIAS
F4B4 CD12F4      CALL    PCHAR   ;3RD DIGIT
F4B7 CD0BF4      CALL    CRLF
F4BA C300F0      JMP     MONIT    ;DONE

;
; CONVERT BINARY IN H,L TO ASCII HEX
;
F4BD 4C          OUTHL:  MOV     C,H
F4BE CDC2F4      CALL    OUTHX
F4C1 4D          MOV     C,L
F4C2 79          OUTHX:  MOV     A,C
F4C3 1F          RAR
F4C4 1F          RAR
F4C5 1F          RAR
F4C6 1F          RAR
F4C7 CDCBF4      CALL    HEX1
F4CA 79          MOV     A,C
F4CB E60F        HEX1:  ANI     OFH ;OUTPUT HEX BYTE
F4CD C690        ADI     90H
F4CF 27          DAA      ;INTEL DAA TRICK
F4D0 CE40        ACI     40H
F4D2 27          DAA
F4D3 C312F4      JMP     PCHAR

;
; SETUP FILE AND OPEN FOR INPUT
; CHECK FOR BINARY FILE
;
F4D6 AF          SETUP:  XRA     A      ;ZERO
F4D7 32ABF5      STA     BFLAG   ;NOT BINARY FILE
F4DA 2A6500      LHLD    FCBFT   ;FILE TYPE
F4DD 7D          MOV     A,L      ;1ST CHAR
F4DE FE43        CPI     'C'
F4E0 C200F5      JNZ     BINCH    ;NO
F4E3 7C          MOV     A,H      ;SECOND CHAR
F4E4 FE4F        CPI     'O'
F4E6 C200F5      JNZ     BINCH    ;NO
F4E9 3E1A        OPN2:  MVI     A,EOF ;SET FLAG
F4EB 32ABF5      STA     BFLAG

;
; SETUP FILE AND OPEN FOR INPUT
;
F4EE 115C00      OPN3:  LXI     D,FCB
F4F1 0E0F        MVI     C,OPENF
F4F3 CD0500      CALL    BDOS

;
; CHECK FOR ERRORS
;
F4F6 FEFF        CPI     255
F4F8 CA0EF5      JZ      BADOPN   ;NO GOOD

```

```

;
; OPEN IS OK
;
F4FB AF          XRA      A
F4FC 327C00      STA      FCBCR
F4FF C9          RET

;
; B FOR THIRD ARGUMENT MEANS BINARY FILE
;
BINCH: LXI      H,6DH
F500 216D00      MOV      A,M      ;GET THIRD ARGUMENT
F503 7E          ANI      57H      ;LOWER TO UPPER
F504 E657        CPI      'B'
F506 FE42        JNZ      OPN3      ;NOT BINARY
F508 C2EEF4      JMP      OPN2      ;BINARY
F50B C3E9F4

;
; BAD OPEN
;
BADOPN: LXI     H,FCBFN ;1ST CHAR
F50E 215D00      MOV      A,M      ;GET IT
F511 7E          CPI      ' '      ;FILE NAME?
F512 FE20        JZ       NONAME    ;NO
F514 CA26F5      LXI      H,'?#'   ;SET UP FOR PRINT
F517 213F24      SHLD     FCBRL     ;USE INPUT FILENAME
F51A 226800      LXI      D,FCBFN   ;FILENAME
F51D 115D00      CALL     PRINT
F520 CD22F4      JMP      FINIS     ;QUIT
F523 C303F4

;
NONAME: LXI      D,MES1 ;POINT TO MESSAGE
F526 1162F5      CALL     PRINTC
F529 CD1FF4      JMP      FINIS
F52C C303F4

;
TOOBIG: LXI     D,MES4
F52F 117AF5      CALL     NONAM2
F532 C329F5

;
; READ DISK FILE RECORD
;
DISKR: PUSH      H
F535 E5          PUSH     D
F536 D5          PUSH     B
F537 C5          LXI      D,FCB
F538 115C00      MVI      C,READF
F53B 0E14        CALL     BDOS
F53D CD0500      POP      B
F540 C1          POP      D
F541 D1          POP      H
F542 E1          ORA      A
F543 B7          ;CHECK FOR ERRS
F544 C8          ;OK
RZ

;
; MAY BE EOF
;
F545 FE01        CPI      1
F547 CA53F5      JZ       FEND      ;EOF

;
; INCORRECT FILE NAME
;
F54A 116FF5      LXI      D,MES2
F54D CD1FF4      CALL     PRINTC
F550 C303F4      JMP      FINIS

```

```

;
; FOUND DISK EOF
;
F553 2AA9F5 FEND:  LHL  BUFP  ;GET POINTER
F556 3AABF5      LDA  BFLAG ;COM FILE?
F559 B7         ORA  A
F55A C27BF4     JNZ  MAIN5  ;YES
F55D 361A       MVI  M,EOF  ;PUT EOF
F55F C37CF4     JMP  DONE
;
; STORAGE AREA
;
F562 4E6F206669MES1: DB  'No file name$'
F56F 4469736B20MES2: DB  'Disk error$'
F57A 46696C6520MES4: DB  'File is too big$'
F58A 4C61737420MESA: DB  'Last address: $'
F599 2068657820MESB: DB  ' hex, Blocks: $'
F5A9 0001      BUFP:  DW  BUFFER ;POINTER
;
F5AB          BFLAG:  DS   1      ;BINARY FLAG
F5AC          IBF:    DS   2      ;INPUT BUFP POINTER
;
; STACK AREA
;
F5AE          OLDSF:  DS   2      ;OLD STACK
F5B0          DS      24      ;STACK SPACE
;
F5C8          STACK:
;
END

```

One of the advantages of FETCH is that it is considerably smaller than DDT or SID. In addition, the decimal number of blocks to be saved and the last address of the program are given. FETCH is executed just like the debugger.

A>FETCH <filename>.<extension>

The CP/M system loads FETCH at 100 hex and then branches to it. The instructions at the beginning of FETCH are used to relocate the rest of the program into a preselected memory area. A jump is then made to the relocated FETCH.

FETCH loads the selected disk file into memory starting at 100 hex. An ASCII file is copied up to the 1A end-of-file mark. Typical extension names include the following.

ASM	(assembly language)
PAS	(Pascal)
FOR	(FORTRAN)
BAS	(BASIC)
HEX	(hex-encoded binary)
TEX	(text formatter)
LIB	(library)
MAC	(assembly language)

Executable binary files will have a file extension of COM; the entire file will be copied in this case. If a nonexecutable binary file is loaded, an additional argument of B (for binary) must be given.

FETCH SORT.REL B

Examples of executable binary files are

REL	(relocatable)
INT	(intermediate)

Relocatable files generated by the Microsoft assembler, and the FORTRAN, COBOL, and BASIC compiler are of this type. Intermediate files are produced by CBASIC.

After the disk file is loaded, FETCH prints two numbers. One number is the memory address of the end of the file expressed in hex. The other number is the size of the file. The number of 256-byte blocks is printed, in decimal.

Type up the program given in the listing. Assemble it and load it into memory with the debugger

A>DDT FETCH.HEX

The debugger will load the move routine, the first part of FETCH, into memory at 100 hex. The main part of the program, however, will be loaded at the address of ORIGIN, 0F400 hex in this case. Use the debugger to move the main part of FETCH back down to the beginning of the user area.

MF400 F5FF 12A

Now, return to the CP/M system with a control-C and save the combination of the move program and the main part of FETCH.

A>SAVE 2 FETCH.COM

FETCH is now ready for use.

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APPENDIX A

The ASCII Character Set

The ASCII character set is listed in numerical order with the corresponding decimal, hexadecimal, and octal values. The control characters are indicated with a caret (^). For example, the horizontal tab (HT) is formed with a control-I.

decim	hex	octal							
=====									
NUL	0	00	000	@	Null	@	64	40	100
SOH	1	01	001	A	Start of heading	A	65	41	101
STX	2	02	002	B	Start of text	B	66	42	102
ETX	3	03	003	C	End of text	C	67	43	103
EOT	4	04	004	D	End of transmission	D	68	44	104
ENQ	5	05	005	E	Enquiry	E	69	45	105
ACK	6	06	006	F	Acknowledge	F	70	46	106
BEL	7	07	007	G	Bell	G	71	47	107
=====									
BS	8	08	010	H	Backspace	H	72	48	110
HT	9	09	011	I	Horizontal tab	I	73	49	111
LF	10	0A	012	J	Line feed	J	74	4A	112
VT	11	0B	013	K	Vertical tab	K	75	4B	113
FF	12	0C	014	L	Form feed	L	76	4C	114
CR	13	0D	015	M	Carriage return	M	77	4D	115
SO	14	0E	016	N	Shift out	N	78	4E	116
SI	15	0F	017	O	Shift in	O	79	4F	117
=====									
DLE	16	10	020	P	Data link escape	P	80	50	120
DC1	17	11	021	Q	Device control 1	Q	81	51	121
DC2	18	12	022	R	Device control 2	R	82	52	122
DC3	19	13	023	S	Device control 3	S	83	53	123
DC4	20	14	024	T	Device control 4	T	84	54	124
NAK	21	15	025	U	Negative acknowledge	U	85	55	125
SYN	22	16	026	V	Synchronous idle	V	86	56	126
ETB	23	17	027	W	End transmission block	W	87	57	127
=====									
CAN	24	18	030	X	Cancel	X	88	58	130
EM	25	19	031	Y	End of medium	Y	89	59	131
SUB	26	1A	032	Z	Substitute	Z	90	5A	132
ESC	27	1B	033	[	Escape	[	91	5B	133
FS	28	1C	034	\	File separator	\	92	5C	134
GS	29	1D	035	]	Group separator	]	93	5D	135
RS	30	1E	036	^	Record separator	^	94	5E	136
US	31	1F	037	_	Unit separator	_	95	5F	137

=====				
SP	32	20	040	Space
!	33	21	041	
"	34	22	042	
#	35	23	043	
\$	36	24	044	
%	37	25	045	
&	38	26	046	
'	39	27	047	
=====				
(	40	28	050	
)	41	29	051	
*	42	2A	052	
+	43	2B	053	
,	44	2C	054	
-	45	2D	055	
.	46	2E	056	
/	47	2F	057	
=====				
0	48	30	060	
1	49	31	061	
2	50	32	062	
3	51	33	063	
4	52	34	064	
5	53	35	065	
6	54	36	066	
7	55	37	067	
=====				
8	56	38	070	
9	57	39	071	
:	58	3A	072	
;	59	3B	073	
<	60	3C	074	
=	61	3D	075	
>	62	3E	076	
?	63	3F	077	
=====				

=====			
`	96	60	140
a	97	61	141
b	98	62	142
c	99	63	143
d	100	64	144
e	101	65	145
f	102	66	146
g	103	67	147
=====			
h	104	68	150
i	105	69	151
j	106	6A	152
k	107	6B	153
l	108	6C	154
m	109	6D	155
n	110	6E	156
o	111	6F	157
=====			
p	112	70	160
q	113	71	161
r	114	72	162
s	115	73	163
t	116	74	164
u	117	75	165
v	118	76	166
w	119	77	167
=====			
x	120	78	170
y	121	79	171
z	122	7A	172
{	123	7B	173
|	124	7C	174
}	125	7D	175
~	126	7E	176
DEL	127	7F	177 Delete
=====			

APPENDIX B

A 64K Memory Map

The 8080 and Z-80 microprocessors can directly address 64K bytes of memory. The memory area is mapped out in the chart that follows. Each entry represents a 256-byte block. The high-order byte of the address is given in hex then in octal. For example, the first entry of the second column is:

20	040	32
----	-----	----

This represents an address range of 2000 to 2FFF hex, or 040-000 to 040-777 octal. The third column gives the decimal number of 1K blocks. The fourth column is the decimal number of 256-byte blocks starting at the address 100 hex. As an example, suppose that a CP/M program runs from 100 hex to 3035 hex. The 30 hex entry in the table shows that the program contains 48 decimal blocks of 256-byte size. The program can be saved with the CP/M command:

A>SAVE 48 filename

As another example, if you have two, 16K memory boards starting at address zero, then your top of memory is located at address 7FFF hex.

Hex	Oct	K	B1	Hex	Oct	K	B1	Hex	Oct	K	B1	Hex	Oct	K	B1
00	000	0		20	040	32		40	100	64		60	140	96	
01	001	1		21	041	33		41	101	65		61	141	97	
02	002	2		22	042	34		42	102	66		62	142	98	
03	003	1	3	23	043	9	35	43	103	17	67	63	143	25	99
04	004	4		24	044	36		44	104	68		64	144	100	
05	005	5		25	045	37		45	105	69		65	145	101	
06	006	6		26	046	38		46	106	70		66	146	102	
07	007	2	7	27	047	10	39	47	107	18	71	67	147	26	103
08	010	8		28	050	40		48	110	72		68	150	104	
09	011	9		29	051	41		49	111	73		69	151	105	
0A	012	10		2A	052	42		4A	112	74		6A	152	106	
0B	013	3	11	2B	053	11	43	4B	113	19	75	6B	153	27	107
0C	014	12		2C	054	44		4C	114	76		6C	154	108	
0D	015	13		2D	055	45		4D	115	77		6D	155	109	
0E	016	14		2E	056	46		4E	116	78		6E	156	110	
0F	017	4	15	2F	057	12	47	4F	117	20	79	6F	157	28	111
10	020	16		30	060	48		50	120	80		70	160	112	
11	021	17		31	061	49		51	121	81		71	161	113	
12	022	18		32	062	50		52	122	82		72	162	114	
13	023	5	19	33	063	13	51	53	123	21	83	73	163	29	115
14	024	20		34	064	52		54	124	84		74	164	116	
15	025	21		35	065	53		55	125	85		75	165	117	
16	026	22		36	066	54		56	126	86		76	166	118	
17	027	6	23	37	067	14	55	57	127	22	87	77	167	30	119
18	030	24		38	070	56		58	130	88		78	170	120	
19	031	25		39	071	57		59	131	89		79	171	121	
1A	032	26		3A	072	58		5A	132	90		7A	172	122	
1B	033	7	27	3B	073	15	59	5B	133	23	91	7B	173	31	123
1C	034	28		3C	074	60		5C	134	92		7C	174	124	
1D	035	29		3D	075	61		5D	135	93		7D	175	125	
1E	036	30		3E	076	62		5E	136	94		7E	176	126	
1F	037	8	31	3F	077	16	63	5F	137	24	95	7F	177	32	127

Hex	Oct	K	B1	Hex	Oct	K	B1	Hex	Oct	K	B1	Hex	Oct	K	B1
80	200		128	A0	240		160	C0	300		192	E0	340		224
81	201		129	A1	241		161	C1	301		193	E1	341		225
82	202		130	A2	242		162	C2	302		194	E2	342		226
83	203	33	131	A3	243	41	163	C3	303	49	195	E3	343	57	227
84	204		132	A4	244		164	C4	304		196	E4	344		228
85	205		133	A5	245		165	C5	305		197	E5	345		229
86	206		134	A6	246		166	C6	306		198	E6	346		230
87	207	34	135	A7	247	42	167	C7	307	50	199	E7	347	58	231
88	210		136	A8	250		168	C8	310		200	E8	350		232
89	211		137	A9	251		169	C9	311		201	E9	351		233
8A	212		138	AA	252		170	CA	312		202	EA	352		234
8B	213	35	139	AB	253	43	171	CB	313	51	203	EB	353	59	235
8C	214		140	AC	254		172	CC	314		204	EC	354		236
8D	215		141	AD	255		173	CD	315		205	ED	355		237
8E	216		142	AE	256		174	CE	316		206	EE	356		238
8F	217	36	143	AF	257	44	175	CF	317	52	207	EF	357	60	239
90	220		144	B0	260		176	D0	320		208	F0	360		240
91	221		145	B1	261		177	D1	321		209	F1	361		241
92	222		146	B2	262		178	D2	322		210	F2	362		242
93	223	37	147	B3	263	45	179	D3	323	53	211	F3	363	61	243
94	224		148	B4	264		180	D4	324		212	F4	364		244
95	225		149	B5	265		181	D5	325		213	F5	365		245
96	226		150	B6	266		182	D6	326		214	F6	366		246
97	227	38	151	B7	267	46	183	D7	327	54	215	F7	367	62	247
98	230		152	B8	270		184	D8	330		216	F8	370		248
99	231		153	B9	271		185	D9	331		217	F9	371		249
9A	232		154	BA	272		186	DA	332		218	FA	372		250
9B	233	39	155	BB	273	47	187	DB	333	55	219	FB	373	63	251
9C	234		156	BC	274		188	DC	334		220	FC	374		252
9D	235		157	BD	275		189	DD	335		221	FD	375		253
9E	236		158	BE	276		190	DE	336		222	FE	376		254
9F	237	40	159	BF	227	48	191	DF	337	56	223	FF	377	64	255

APPENDIX C

The 8080 Instruction Set (Alphabetic)

The 8080 instruction set is listed alphabetically with the corresponding hexadecimal code. The following representations apply.

nn 8-bit argument
nnnn 16-bit argument

Hex		Mnemonic		Hex		Mnemonic
CE	nn	ACI	nn	2F		CMA
8F		ADC	A	3F		CMC
88		ADC	B	BF		CMP A
89		ADC	C	B8		CMP B
8A		ADC	D	B9		CMP C
8B		ADC	E	BA		CMP D
8C		ADC	H	BB		CMP E
8D		ADC	L	BC		CMP H
8E		ADC	M	BD		CMP L
87		ADD	A	BE		CMP M
80		ADD	B	D4	nnnn	CNC nnnn
81		ADD	C	C4	nnnn	CNZ nnnn
82		ADD	D	F4	nnnn	CP nnnn
83		ADD	E	EC	nnnn	CPE nnnn
84		ADD	H	FE	nn	CPI nn
85		ADD	L	E4	nnnn	CPO nnnn
86		ADD	M	CC	nnnn	CZ nnnn
C6	nn	ADI	nn	27		DAA
A7		ANA	A	09		DAD B
A0		ANA	B	19		DAD D
A1		ANA	C	29		DAD H
A2		ANA	D	39		DAD SP
A3		ANA	E	3D		DCR A
A4		ANA	H	05		DCR B
A5		ANA	L	0D		DCR C
A6		ANA	M	15		DCR D
E6	nn	ANI	nn	1D		DCR E
CD	nnnn	CALL	nnnn	25		DCR H
DC	nnnn	CC	nnnn	2D		DCR L
FC	nnnn	CM	nnnn	35		DCR M

Hex	Mnemonic	Hex	Mnemonic
0B	DCX B	43	MOV B,E
1B	DCX D	44	MOV B,H
2B	DCX H	45	MOV B,L
3B	DCX SP	46	MOV B,M
F3	DI	4F	MOV C,A
FB	EI	48	MOV C,B
76	HLT	49	MOV C,C
DB nn	IN nn	4A	MOV C,D
3C	INR A	4B	MOV C,E
04	INR B	4C	MOV C,H
0C	INR C	4D	MOV C,L
14	INR D	4E	MOV C,M
1C	INR E	57	MOV D,A
24	INR H	50	MOV D,B
2C	INR L	51	MOV D,C
34	INR M	52	MOV D,D
03	INX B	53	MOV D,E
13	INX D	54	MOV D,H
23	INX H	55	MOV D,L
33	INX SP	56	MOV D,M
DA nnnn	JC nnnn	5F	MOV E,A
FA nnnn	JM nnnn	58	MOV E,B
C3 nnnn	JMP nnnn	59	MOV E,C
D2 nnnn	JNC nnnn	5A	MOV E,D
C2 nnnn	JNZ nnnn	5B	MOV E,E
F2 nnnn	JP nnnn	5C	MOV E,H
EA nnnn	JPE nnnn	5D	MOV E,L
E2 nnnn	JPO nnnn	5E	MOV E,M
CA nnnn	JZ nnnn	67	MOV H,A
3A nnnn	LDA nnnn	60	MOV H,B
0A	LDAX B	61	MOV H,C
1A	LDAX D	62	MOV H,D
2A nnnn	LHLD nnnn	63	MOV H,E
01 nnnn	LXI B, nnnn	64	MOV H,H
11 nnnn	LXI D, nnnn	65	MOV H,L
21 nnnn	LXI H, nnnn	66	MOV H,M
31 nnnn	LXI SP, nnnn	6F	MOV L,A
7F	MOV A,A	68	MOV L,B
78	MOV A,B	69	MOV L,C
79	MOV A,C	6A	MOV L,D
7A	MOV A,D	6B	MOV L,E
7B	MOV A,E	6C	MOV L,H
7C	MOV A,H	6D	MOV L,L
7D	MOV A,L	6E	MOV L,M
7E	MOV A,M	77	MOV M,A
47	MOV B,A	70	MOV M,B
40	MOV B,B	71	MOV M,C
41	MOV B,C	72	MOV M,D
42	MOV B,D	73	MOV M,E

Hex		Mnemonic	Hex		Mnemonic
74		MOV M,H	CF		RST 1
75		MOV M,L	D7		RST 2
3E	nn	MVI A, nn	DF		RST 3
06	nn	MVI B, nn	E7		RST 4
0E	nn	MVI C, nn	EF		RST 5
16	nn	MVI D, nn	F7		RST 6
1E	nn	MVI E, nn	FF		RST 7
26	nn	MVI H, nn	C8		RZ
2E	nn	MVI L, nn	9F		SBB A
36	nn	MVI M, nn	98		SBB B
00		NOP	99		SBB C
B7		ORA A	9A		SBB D
B0		ORA B	9B		SBB E
B1		ORA C	9C		SBB H
B2		ORA D	9D		SBB L
B3		ORA E	9E		SBB M
B4		ORA H	DE	nn	SBI nn
B5		ORA L	22	nnnn	SHLD nnnn
B6		ORA M	F9		SPHL
F6	nn	ORI nn	32	nnnn	STA nnnn
D3	nn	OUT nn	37		STC
E9		PCHL	02		STAX B
C1		POP B	12		STAX D
D1		POP D	97		SUB A
E1		POP H	90		SUB B
F1		POP PSW	91		SUB C
C5		PUSH B	92		SUB D
D5		PUSH D	93		SUB E
E5		PUSH H	94		SUB H
F5		PUSH PSW	95		SUB L
17		RAL	96		SUB M
1F		RAR	D6	nn	SUI nn
D8		RC	EB		XCHG
C9		RET	AF		XRA A
07		RLC	A8		XRA B
F8		RM	A9		XRA C
D0		RNC	AA		XRA D
C0		RNZ	AB		XRA E
F0		RP	AC		XRA H
E8		RPE	AD		XRA L
E0		RPO	AE		XRA M
0F		RRC	EE	nn	XRI nn
C7		RST 0	E3		XTHL

APPENDIX D

The 8080 Instruction Set

(Numeric)

The 8080 instruction set is listed alphabetically with the corresponding hexadecimal code. The following representations apply.

nn 8-bit argument
nnnn 16-bit argument

Hex	Mnemonic	Hex	Mnemonic
00	NOP	1E nn	MVI E, nn
01 nnnn	LXI B, nnnn	1F	RAR
02	STAX B	20	(not used)
03	INX B	21 nnnn	LXI H, nnnn
04	INR B	22 nnnn	SHLD nnnn
05	DCR B	23	INX H
06 nn	MVI B, nn	24	INR H
07	RLC	25	DCR H
08	(not used)	26 nn	MVI H, nn
09	DAD B	27	DAA
0A	LDAX B	28	(not used)
0B	DCX B	29	DAD H
0C	INR C	2A nnnn	LHLD nnnn
0D	DCR C	2B	DCX H
0E nn	MVI C, nn	2C	INR L
0F	RRC	2D	DCR L
10	(not used)	2E nn	MVI L, nn
11 nnnn	LXI D, nnnn	2F	CMA
12	STAX D	30	(not used)
13	INX D	31 nnnn	LXI SP, nnnn
14	INR D	32 nnnn	STA nnnn
15	DCR D	33	INX SP
16 nn	MVI D, nn	34	INR M
17	RAL	35	DCR M
18	(not used)	36 nn	MVI M, nn
19	DAD D	37	STC
1A	LDAX D	38	(not used)
1B	DCX D	39	DAD SP
1C	INR E	3A nnnn	LDA nnnn
1D	DCR E	3B	DCX SP

Hex	Mnemonic	Hex	Mnemonic
3C	INR A	6D	MOV L,L
3D	DCR A	6E	MOV L,M
3E nn	MVI A, nn	6F	MOV L,A
3F	CMC	70	MOV M,B
40	MOV B,B	71	MOV M,C
41	MOV B,C	72	MOV M,D
42	MOV B,D	73	MOV M,E
43	MOV B,E	74	MOV M,H
44	MOV B,H	75	MOV M,L
45	MOV B,L	76	HLT
46	MOV B,M	77	MOV M,A
47	MOV B,A	78	MOV A,B
48	MOV C,B	79	MOV A,C
49	MOV C,C	7A	MOV A,D
4A	MOV C,D	7B	MOV A,E
4B	MOV C,E	7C	MOV A,H
4C	MOV C,H	7D	MOV A,L
4D	MOV C,L	7E	MOV A,M
4E	MOV C,M	7F	MOV A,A
4F	MOV C,A	80	ADD B
50	MOV D,B	81	ADD C
51	MOV D,C	82	ADD D
52	MOV D,D	83	ADD E
53	MOV D,E	84	ADD H
54	MOV D,H	85	ADD L
55	MOV D,L	86	ADD M
56	MOV D,M	87	ADD A
57	MOV D,A	88	ADC B
58	MOV E,B	89	ADC C
59	MOV E,C	8A	ADC D
5A	MOV E,D	8B	ADC E
5B	MOV E,E	8C	ADC H
5C	MOV E,H	8D	ADC L
5D	MOV E,L	8E	ADC M
5E	MOV E,M	8F	ADC A
5F	MOV E,A	90	SUB B
60	MOV H,B	91	SUB C
61	MOV H,C	92	SUB D
62	MOV H,D	93	SUB E
63	MOV H,E	94	SUB H
64	MOV H,H	95	SUB L
65	MOV H,L	96	SUB M
66	MOV H,M	97	SUB A
67	MOV H,A	98	SBB B
68	MOV L,B	99	SBB C
69	MOV L,C	9A	SBB D
6A	MOV L,D	9B	SBB E
6B	MOV L,E	9C	SBB H
6C	MOV L,H	9D	SBB L

Hex			Mnemonic			Hex			Mnemonic		
9E			SBB	M		CF			RST	1	
9F			SBB	A		D0			RNC		
A0			ANA	B		D1			POP	D	
A1			ANA	C		D2	nnnn		JNC	nnnn	
A2			ANA	D		D3	nn		OUT	nn	
A3			ANA	E		D4	nnnn		CNC	nnnn	
A4			ANA	H		D5			PUSH	D	
A5			ANA	L		D6	nn		SUI	nn	
A6			ANA	M		D7			RST	2	
A7			ANA	A		D8			RC		
A8			XRA	B		D9			(not used)		
A9			XRA	C		DA	nnnn		JC	nnnn	
AA			XRA	D		DB	nn		IN	nn	
AB			XRA	E		DC	nnnn		CC	nnnn	
AC			XRA	H		DD			(not used)		
AD			XRA	L		DE	nn		SBI	nn	
AE			XRA	M		DF			RST	3	
AF			XRA	A		E0			RPO		
B0			ORA	B		E1			POP	H	
B1			ORA	C		E2	nnnn		JPO	nnnn	
B2			ORA	D		E3			XTHL		
B3			ORA	E		E4	nnnn		CPO	nnnn	
B4			ORA	H		E5			PUSH	H	
B5			ORA	L		E6	nn		ANI	nn	
B6			ORA	M		E7			RST	4	
B7			ORA	A		E8			RPE		
B8			CMP	B		E9			PCHL		
B9			CMP	C		EA	nnnn		JPE	nnnn	
BA			CMP	D		EB			XCHG		
BB			CMP	E		EC	nnnn		CPE	nnnn	
BC			CMP	H		ED			(not used)		
BD			CMP	L		EE	nn		XRI	nn	
BE			CMP	M		EF			RST	5	
BF			CMP	A		F0			RP		
C0			RNZ			F1			POP	PSW	
C1			POP	B		F2	nnnn		JP	nnnn	
C2	nnnn		JNZ	nnnn		F3			DI		
C3	nnnn		JMP	nnnn		F4	nnnn		CP	nnnn	
C4	nnnn		CNZ	nnnn		F5			PUSH	PSW	
C5			PUSH	B		F6	nn		ORI	nn	
C6	nn		ADI	nn		F7			RST	6	
C7			RST	0		F8			RM		
C8			RZ			F9			SPHL		
C9			RET			FA	nnnn		JM	nnnn	
CA	nnnn		JZ	nnnn		FB			EI		
CB			(not used)			FC	nnnn		CM	nnnn	
CC	nnnn		CZ	nnnn		FD			(not used)		
CD	nnnn		CALL	nnnn		FE	nn		CPI	nn	
CE	nn		ACI	nn		FF			RST	7	

APPENDIX E

The Z-80 Instruction Set (Alphabetic)

The Zilog Z-80 instruction set is listed alphabetically with the corresponding hexadecimal values. The following representations apply.

nn 8-bit arguments
nnnn 16-bit arguments
dd 8-bit signed displacement
* instructions common to the 8080

Hex	Mnemonic	Hex	Mnemonic
8E	* ADC A,(HL)	19	* ADD HL,DE
DD 8Edd	ADC A,(IX+dd)	29	* ADD HL,HL
FD 8Edd	ADC A,(IY+dd)	39	* ADD HL,SP
8F	* ADC A,A	DD 09	ADD IX,BC
88	* ADC A,B	DD 19	ADD IX,DE
89	* ADC A,C	DD 29	ADD IX,IX
8A	* ADC A,D	DD 39	ADD IX,SP
8B	* ADC A,E	FD 09	ADD IY,BC
8C	* ADC A,H	FD 19	ADD IY,DE
8D	* ADC A,L	FD 29	ADD IY,IY
CE nn	* ADC A, nn	FD 39	ADD IY,SP
ED 4A	ADC HL,BC	A6	* AND (HL)
ED 5A	ADC HL,DE	DD A6dd	AND (IX+dd)
ED 6A	ADC HL,HL	FD A6dd	AND (IY+dd)
ED 7A	ADC HL,SP	A7	* AND A
86	* ADD A,(HL)	A0	* AND B
DD 86dd	ADD A,(IX+dd)	A1	* AND C
FD 86dd	ADD A,(IY+dd)	A2	* AND D
87	* ADD A,A	A3	* AND E
80	* ADD A,B	A4	* AND H
81	* ADD A,C	A5	* AND L
82	* ADD A,D	E6 nn	* AND nn
83	* ADD A,E	CB 46	BIT 0,(HL)
84	* ADD A,H	DD CBdd46	BIT 0,(IX+dd)
85	* ADD A,L	FD CBdd46	BIT 0,(IY+dd)
C6 nn	* ADD A, nn	CB 47	BIT 0,A
09	* ADD HL,BC	CB 40	BIT 0,B

Hex	Mnemonic		Hex	Mnemonic	
CB 41	BIT	0,C	CB 68	BIT	5,B
CB 42	BIT	0,D	CB 69	BIT	5,C
CB 43	BIT	0,E	CB 6A	BIT	5,D
CB 44	BIT	0,H	CB 6B	BIT	5,E
CB 45	BIT	0,L	CB 6C	BIT	5,H
CB 4E	BIT	1,(HL)	CB 6D	BIT	5,L
DD CBdd4E	BIT	1,(IX+dd)	CB 76	BIT	6,(HL)
FD CBdd4E	BIT	1,(IY+dd)	DD CBdd76	BIT	6,(IX+dd)
CB 4F	BIT	1,A	FD CBdd76	BIT	6,(IY+dd)
CB 48	BIT	1,B	CB 77	BIT	6,A
CB 49	BIT	1,C	CB 70	BIT	6,B
CB 4A	BIT	1,D	CB 71	BIT	6,C
CB 4B	BIT	1,E	CB 72	BIT	6,D
CB 4C	BIT	1,H	CB 73	BIT	6,E
CB 4D	BIT	1,L	CB 74	BIT	6,H
CB 56	BIT	2,(HL)	CB 75	BIT	6,L
DD CBdd56	BIT	2,(IX+dd)	CB 7E	BIT	7,(HL)
FD CBdd56	BIT	2,(IY+dd)	DD CBdd7E	BIT	7,(IX+dd)
CB 57	BIT	2,A	FD CBdd7E	BIT	7,(IY+dd)
CB 50	BIT	2,B	CB 7F	BIT	7,A
CB 51	BIT	2,C	CB 78	BIT	7,B
CB 52	BIT	2,D	CB 79	BIT	7,C
CB 53	BIT	2,E	CB 7A	BIT	7,D
CB 54	BIT	2,H	CB 7B	BIT	7,E
CB 55	BIT	2,L	CB 7C	BIT	7,H
CB 5E	BIT	3,(HL)	CB 7D	BIT	7,L
DD CBdd5E	BIT	3,(IX+dd)	DC nnnn	* CALL	C, nnnn
FD CBdd5E	BIT	3,(IY+dd)	FC nnnn	* CALL	M, nnnn
CB 5F	BIT	3,A	D4 nnnn	* CALL	NC, nnnn
CB 58	BIT	3,B	CD nnnn	* CALL	nnnn
CB 59	BIT	3,C	C4 nnnn	* CALL	NZ, nnnn
CB 5A	BIT	3,D	F4 nnnn	* CALL	P, nnnn
CB 5B	BIT	3,E	EC nnnn	* CALL	PE, nnnn
CB 5C	BIT	3,H	E4 nnnn	* CALL	PO, nnnn
CB 5D	BIT	3,L	CC nnnn	* CALL	Z, nnnn
CB 66	BIT	4,(HL)	3F	* CCF	
DD CBdd66	BIT	4,(IX+dd)	BE	* CP	(HL)
FD CBdd66	BIT	4,(IY+dd)	DD BEdd	CP	(IX+dd)
CB 67	BIT	4,A	FD BEdd	CP	(IY+dd)
CB 60	BIT	4,B	BF	* CP	A
CB 61	BIT	4,C	B8	* CP	B
CB 62	BIT	4,D	B9	* CP	C
CB 63	BIT	4,E	BA	* CP	D
CB 64	BIT	4,H	BB	* CP	E
CB 65	BIT	4,L	BC	* CP	H
CB 6E	BIT	5,(HL)	BD	* CP	L
DD CBdd6E	BIT	5,(IX+dd)	FE nn	* CP	nn
FD CBdd6E	BIT	5,(IY+dd)	ED A9	CPD	
CB 6F	BIT	5,A	ED B9	CPDR	

Hex	Mnemonic		Hex	Mnemonic	
ED A1	CPI		13	* INC	DE
ED B1	CPIR		1C	* INC	E
2F	* CPL		24	* INC	H
27	* DAA		23	* INC	HL
35	* DEC	(HL)	DD 23	INC	IX
DD 35dd	DEC	(IX+dd)	FD 23	INC	IY
FD 35dd	DEC	(IY+dd)	2C	* INC	L
3D	* DEC	A	33	* INC	SP
05	* DEC	B	ED AA	IND	
0B	* DEC	BC	ED BA	INDR	
0D	* DEC	C	ED A2	INI	
15	* DEC	D	ED B2	INIR	
1B	* DEC	DE	E9	* JP	(HL)
1D	* DEC	E	DD E9	JP	(IX)
25	* DEC	H	FD E9	JP	(IY)
2B	* DEC	HL	DA nnnn	* JP	C, nnnn
DD 2B	DEC	IX	FA nnnn	* JP	M, nnnn
FD 2B	DEC	IY	D2 nnnn	* JP	NC, nnnn
2D	* DEC	L	C3 nnnn	* JP	nnnn
3B	* DEC	SP	C2 nnnn	* JP	NZ, nnnn
F3	* DI		F2 nnnn	* JP	P, nnnn
10 dd	DJNZ	dd	EA nnnn	* JP	PE, nnnn
FB	* EI		E2 nnnn	* JP	PO, nnnn
E3	* EX	(SP),HL	CA nnnn	* JP	Z, nnnn
DD E3	EX	(SP),IX	38 dd	JR	C, dd
FD E3	EX	(SP),IY	18 dd	JR	dd
08	EX	AF,AF'	30 dd	JR	NC, dd
EB	* EX	DE,HL	20 dd	JR	NZ, dd
D9	EXX		28 dd	JR	Z, dd
76	* HALT		02	* LD	(BC),A
ED 46	IM	0	12	* LD	(DE),A
ED 56	IM	1	77	* LD	(HL),A
ED 5E	IM	2	70	* LD	(HL),B
ED 78	IN	A,(C)	71	* LD	(HL),C
DB nn	* IN	A,(nn)	72	* LD	(HL),D
ED 40	IN	B,(C)	73	* LD	(HL),E
ED 48	IN	C,(C)	74	* LD	(HL),H
ED 50	IN	D,(C)	75	* LD	(HL),L
ED 58	IN	E,(C)	36 nn	* LD	(HL), nn
ED 60	IN	H,(C)	DD 77dd	LD	(IX+dd),A
ED 68	IN	L,(C)	DD 70dd	LD	(IX+dd),B
34	* INC	(HL)	DD 71dd	LD	(IX+dd),C
DD 34dd	INC	(IX+dd)	DD 72dd	LD	(IX+dd),D
FD 34dd	INC	(IY+dd)	DD 73dd	LD	(IX+dd),E
3C	* INC	A	DD 74dd	LD	(IX+dd),H
04	* INC	B	DD 75dd	LD	(IX+dd),L
03	* INC	BC	DD 36ddnn	LD	(IX+dd), nn
0C	* INC	C	FD 77dd	LD	(IY+dd),A
14	* INC	D	FD 70dd	LD	(IY+dd),B

Hex	Mnemonic		Hex	Mnemonic	
FD 71dd	LD	(IY+dd),C	4B	* LD	C,E
FD 72dd	LD	(IY+dd),D	4C	* LD	C,H
FD 73dd	LD	(IY+dd),E	4D	* LD	C,L
FD 74dd	LD	(IY+dd),H	0E nn	* LD	C, nn
FD 75dd	LD	(IY+dd),L	56	* LD	D,(HL)
FD 36ddnn	LD	(IY+dd), nn	DD 56dd	LD	D,(IX+dd)
32 nnnn	* LD	(nnnn),A	FD 56dd	LD	D,(IY+dd)
ED 43nnnn	LD	(nnnn),BC	57	* LD	D,A
ED 53nnnn	LD	(nnnn),DE	50	* LD	D,B
22 nnnn	* LD	(nnnn),HL	51	* LD	D,C
DD 22nnnn	LD	(nnnn),IX	52	* LD	D,D
FD 22nnnn	LD	(nnnn),IY	53	* LD	D,E
ED 73nnnn	LD	(nnnn),SP	54	* LD	D,H
0A	* LD	A,(BC)	55	* LD	D,L
1A	* LD	A,(DE)	16 nn	* LD	D, nn
7E	* LD	A,(HL)	ED 5Bnnnn	LD	DE, (nnnn)
DD 7Edd	LD	A,(IX+dd)	11 nnnn	* LD	DE, nnnn
FD 7Edd	LD	A,(IY+dd)	5E	* LD	E,(HL)
3A nnnn	* LD	A, (nnnn)	DD 5Edd	LD	E,(IX+dd)
7F	* LD	A,A	FD 5Edd	LD	E,(IY+dd)
78	* LD	A,B	5F	* LD	E,A
79	* LD	A,C	58	* LD	E,B
7A	* LD	A,D	59	* LD	E,C
7B	* LD	A,E	5A	* LD	E,D
7C	* LD	A,H	5B	* LD	E,E
ED 57	LD	A,I	5C	* LD	E,H
7D	* LD	A,L	5D	* LD	E,L
3E nn	* LD	A, nn	1E nn	* LD	E, nn
ED 5F	LD	A,R	66	* LD	H,(HL)
46	* LD	B,(HL)	DD 66dd	LD	H,(IX+dd)
DD 46dd	LD	B,(IX+dd)	FD 66dd	LD	H,(IY+dd)
FD 46dd	LD	B,(IY+dd)	67	* LD	H,A
47	* LD	B,A	60	* LD	H,B
40	* LD	B,B	61	* LD	H,C
41	* LD	B,C	62	* LD	H,D
42	* LD	B,D	63	* LD	H,E
43	* LD	B,E	64	* LD	H,H
44	* LD	B,H	65	* LD	H,L
45	* LD	B,L	26 nn	* LD	H, nn
06 nn	* LD	B, nn	2A nnnn	* LD	HL, (nnnn)
ED 4Bnnnn	LD	BC, (nnnn)	21 nnnn	* LD	HL, nnnn
01 nnnn	* LD	BC, nnnn	ED 47	LD	I,A
4E	* LD	C,(HL)	DD 2Annnn	LD	IX, (nnnn)
DD 4Edd	LD	C,(IX+dd)	DD 21nnnn	LD	IX, nnnn
FD 4Edd	LD	C,(IY+dd)	FD 2Annnn	LD	IY, (nnnn)
4F	* LD	C,A	FD 21nnnn	LD	IY, nnnn
48	* LD	C,B	6E	* LD	L,(HL)
49	* LD	C,C	DD 6Edd	LD	L,(IX+dd)
4A	* LD	C,D	FD 6Edd	LD	L,(IY+dd)

Hex	Mnemonic		Hex	Mnemonic	
6F	*	LD L,A	F5	*	PUSH AF
68	*	LD L,B	C5	*	PUSH BC
69	*	LD L,C	D5	*	PUSH DE
6A	*	LD L,D	E5	*	PUSH HL
6B	*	LD L,E	DD E5		PUSH IX
6C	*	LD L,H	FD E5		PUSH IY
6D	*	LD L,L	CB 86		RES 0,(HL)
2E nn	*	LD L, nn	DD CBdd86		RES 0,(IX+dd)
ED 4F		LD R,A	FD CBdd86		RES 0,(IY+dd)
ED 7Bnnnn		LD SP, (nnnn)	CB 87		RES 0,A
F9	*	LD SP,HL	CB 80		RES 0,B
DD F9		LD SP,IX	CB 81		RES 0,C
FD F9		LD SP,IY	CB 82		RES 0,D
31 nnnn	*	LD SP, nnnn	CB 83		RES 0,E
ED A8		LDD	CB 84		RES 0,H
ED B8		LDDR	CB 85		RES 0,L
ED A0		LDI	CB 8E		RES 1,(HL)
ED B0		LDIR	DD CBdd8E		RES 1,(IX+dd)
ED 44		NEG	FD CBdd8E		RES 1,(IY+dd)
00	*	NOP	CB 8F		RES 1,A
B6	*	OR (HL)	CB 88		RES 1,B
DD B6dd		OR (IX+dd)	CB 89		RES 1,C
FD B6dd		OR (IY+dd)	CB 8A		RES 1,D
B7	*	OR A	CB 8B		RES 1,E
B0	*	OR B	CB 8C		RES 1,H
B1	*	OR C	CB 8D		RES 1,L
B2	*	OR D	CB 96		RES 2,(HL)
B3	*	OR E	DD CBdd96		RES 2,(IX+dd)
B4	*	OR H	FD CBdd96		RES 2,(IY+dd)
B5	*	OR L	CB 97		RES 2,A
F6 nn	*	OR nn	CB 90		RES 2,B
ED BB		OTDR	CB 91		RES 2,C
ED B3		OTIR	CB 92		RES 2,D
ED 79		OUT (C),A	CB 93		RES 2,E
ED 41		OUT (C),B	CB 94		RES 2,H
ED 49		OUT (C),C	CB 95		RES 2,L
ED 51		OUT (C),D	CB 9E		RES 3,(HL)
ED 59		OUT (C),E	DD CBdd9E		RES 3,(IX+dd)
ED 61		OUT (C),H	FD CBdd9E		RES 3,(IY+dd)
ED 69		OUT (C),L	CB 9F		RES 3,A
D3 nn	*	OUT (nn),A	CB 98		RES 3,B
ED AB		OUTD	CB 99		RES 3,C
ED A3		OUTI	CB 9A		RES 3,D
F1	*	POP AF	CB 9B		RES 3,E
C1	*	POP BC	CB 9C		RES 3,H
D1	*	POP DE	CB 9D		RES 3,L
E1	*	POP HL	CB A6		RES 4,(HL)
DD E1		POP IX	DD CBddA6		RES 4,(IX+dd)
FD E1		POP IY	FD CBddA6		RES 4,(IY+dd)

Hex	Mnemonic		Hex	Mnemonic	
CB A7	RES	4,A	DD CBdd16	RL	(IX+dd)
CB A0	RES	4,B	FD CBdd16	RL	(IY+dd)
CB A1	RES	4,C	CB 17	RL	A
CB A2	RES	4,D	CB 10	RL	B
CB A3	RES	4,E	CB 11	RL	C
CB A4	RES	4,H	CB 12	RL	D
CB A5	RES	4,L	CB 13	RL	E
CB AE	RES	5,(HL)	CB 14	RL	H
DD CBddAE	RES	5,(IX+dd)	CB 15	RL	L
FD CBddAE	RES	5,(IY+dd)	17	*	RLA
CB AF	RES	5,A	CB 06	RLC	(HL)
CB A8	RES	5,B	DD CBdd06	RLC	(IX+dd)
CB A9	RES	5,C	FD CBdd06	RLC	(IY+dd)
CB AA	RES	5,D	CB 07	RLC	A
CB AB	RES	5,E	CB 00	RLC	B
CB AC	RES	5,H	CB 01	RLC	C
CB AD	RES	5,L	CB 02	RLC	D
CB B6	RES	6,(HL)	CB 03	RLC	E
DD CBddB6	RES	6,(IX+dd)	CB 04	RLC	H
FD CBddB6	RES	6,(IY+dd)	CB 05	RLC	L
CB B7	RES	6,A	07	*	RLCA
CB B0	RES	6,B	ED 6F	RLD	
CB B1	RES	6,C	CB 1E	RR	(HL)
CB B2	RES	6,D	DD CBdd1E	RR	(IX+dd)
CB B3	RES	6,E	FD CBdd1E	RR	(IY+dd)
CB B4	RES	6,H	CB 1F	RR	A
CB B5	RES	6,L	CB 18	RR	B
CB BE	RES	7,(HL)	CB 19	RR	C
DD CBddBE	RES	7,(IX+dd)	CB 1A	RR	D
FD CBddBE	RES	7,(IY+dd)	CB 1B	RR	E
CB BF	RES	7,A	CB 1C	RR	H
CB B8	RES	7,B	CB 1D	RR	L
CB B9	RES	7,C	1F	*	RRA
CB BA	RES	7,D	CB 0E	RRC	(HL)
CB BB	RES	7,E	DD CBdd0E	RRC	(IX+dd)
CB BC	RES	7,H	FD CBdd0E	RRC	(IY+dd)
CB BD	RES	7,L	CB 0F	RRC	A
C9	*	RET	CB 08	RRC	B
D8	*	RET C	CB 09	RRC	C
F8	*	RET M	CB 0A	RRC	D
D0	*	RET NC	CB 0B	RRC	E
C0	*	RET NZ	CB 0C	RRC	H
F0	*	RET P	CB 0D	RRC	L
E8	*	RET PE	0F	*	RRCA
E0	*	RET PO	ED 67	RRD	
C8	*	RET Z	C7	*	RST 0
ED 4D		RETI	CF	*	RST 8
ED 45		RETN	D7	*	RST 10H
CB 16	RL	(HL)	DF	*	RST 18H

Hex	Mnemonic		Hex	Mnemonic	
E7	*	RST 20H	CB D5	SET	2,L
EF	*	RST 28H	CB DE	SET	3,(HL)
F7	*	RST 30H	DD CBddDE	SET	3,(IX+dd)
FF	*	RST 38H	FD CBddDE	SET	3,(IY+dd)
9E	*	SBC A,(HL)	CB DF	SET	3,A
DD 9Edd		SBC A,(IX+dd)	CB D8	SET	3,B
FD 9Edd		SBC A,(IY+dd)	CB D9	SET	3,C
9F	*	SBC A,A	CB DA	SET	3,D
98	*	SBC A,B	CB DB	SET	3,E
99	*	SBC A,C	CB DC	SET	3,H
9A	*	SBC A,D	CB DD	SET	3,L
9B	*	SBC A,E	CB E6	SET	4,(HL)
9C	*	SBC A,H	DD CBddE6	SET	4,(IX+dd)
9D	*	SBC A,L	FD CBddE6	SET	4,(IY+dd)
DE nn	*	SBC A, nn	CB E7	SET	4,A
ED 42		SBC HL,BC	CB E0	SET	4,B
ED 52		SBC HL,DE	CB E1	SET	4,C
ED 62		SBC HL,HL	CB E2	SET	4,D
ED 72		SBC HL,SP	CB E3	SET	4,E
37	*	SCF	CB E4	SET	4,H
CB C6	SET	0,(HL)	CB E5	SET	4,L
DD CBddC6	SET	0,(IX+dd)	CB EE	SET	5,(HL)
FD CBddC6	SET	0,(IY+dd)	DD CBddEE	SET	5,(IX+dd)
CB C7	SET	0,A	FD CBddEE	SET	5,(IY+dd)
CB C0	SET	0,B	CB EF	SET	5,A
CB C1	SET	0,C	CB E8	SET	5,B
CB C2	SET	0,D	CB E9	SET	5,C
CB C3	SET	0,E	CB EA	SET	5,D
CB C4	SET	0,H	CB EB	SET	5,E
CB C5	SET	0,L	CB EC	SET	5,H
CB CE	SET	1,(HL)	CB ED	SET	5,L
DD CBddCE	SET	1,(IX+dd)	CB F6	SET	6,(HL)
FD CBddCE	SET	1,(IY+dd)	DD CBddF6	SET	6,(IX+dd)
CB CF	SET	1,A	FD CBddF6	SET	6,(IY+dd)
CB C8	SET	1,B	CB F7	SET	6,A
CB C9	SET	1,C	CB F0	SET	6,B
CB CA	SET	1,D	CB F1	SET	6,C
CB CB	SET	1,E	CB F2	SET	6,D
CB CC	SET	1,H	CB F3	SET	6,E
CB CD	SET	1,L	CB F4	SET	6,H
CB D6	SET	2,(HL)	CB F5	SET	6,L
DD CBddD6	SET	2,(IX+dd)	CB FE	SET	7,(HL)
FD CBddD6	SET	2,(IY+dd)	DD CBddFE	SET	7,(IX+dd)
CB D7	SET	2,A	FD CBddFE	SET	7,(IY+dd)
CB D0	SET	2,B	CB FF	SET	7,A
CB D1	SET	2,C	CB F8	SET	7,B
CB D2	SET	2,D	CB F9	SET	7,C
CB D3	SET	2,E	CB FA	SET	7,D
CB D4	SET	2,H	CB FB	SET	7,E

Hex	Mnemonic		Hex	Mnemonic	
CB FC	SET	7,H	CB 39	SRL	C
CB FD	SET	7,L	CB 3A	SRL	D
CB 26	SLA	(HL)	CB 3B	SRL	E
DD CBdd26	SLA	(IX+dd)	CB 3C	SRL	H
FD CBdd26	SLA	(IY+dd)	CB 3D	SRL	L
CB 27	SLA	A	96	* SUB	(HL)
CB 20	SLA	B	DD 96dd	SUB	(IX+dd)
CB 21	SLA	C	FD 96dd	SUB	(IY+dd)
CB 22	SLA	D	97	* SUB	A
CB 23	SLA	E	90	* SUB	B
CB 24	SLA	H	91	* SUB	C
CB 25	SLA	L	92	* SUB	D
CB 2E	SRA	(HL)	93	* SUB	E
DD CBdd2E	SRA	(IX+dd)	94	* SUB	H
FD CBdd2E	SRA	(IY+dd)	95	* SUB	L
CB 2F	SRA	A	D6 nn	* SUB	nn
CB 28	SRA	B	AE	* XOR	(HL)
CB 29	SRA	C	DD AEdd	XOR	(IX+dd)
CB 2A	SRA	D	FD AEdd	XOR	(IY+dd)
CB 2B	SRA	E	AF	* XOR	A
CB 2C	SRA	H	A8	* XOR	B
CB 2D	SRA	L	A9	* XOR	C
CB 3E	SRL	(HL)	AA	* XOR	D
DD CBdd3E	SRL	(IX+dd)	AB	* XOR	E
FD CBdd3E	SRL	(IY+dd)	AC	* XOR	H
CB 3F	SRL	A	AD	* XOR	L
CB 38	SRL	B	EE nn	* XOR	nn

APPENDIX F

The Z-80 Instruction Set (Numeric)

The Zilog Z-80 instruction set is listed numerically with the corresponding hexadecimal values. The following representations apply.

nn 8-bit argument
nnnn 16-bit argument
dd 8-bit signed displacement
* instructions common to the 8080

Hex	Mnemonic		Hex	Mnemonic	
00	*	NOP	1C	*	INC E
01 nnnn	*	LD BC, nnnn	1D	*	DEC E
02	*	LD (BC),A	1E nn	*	LD E, nn
03	*	INC BC	1F	*	RRA
04	*	INC B	20 dd		JR NZ, dd
05	*	DEC B	21 nnnn	*	LD HL, nnnn
06 nn	*	LD B, nn	22 nnnn	*	LD (nnnn),HL
07	*	RLCA	23	*	INC HL
08		EX AF,AF'	24	*	INC H
09	*	ADD HL,BC	25	*	DEC H
0A	*	LD A,(BC)	26 nn	*	LD H, nn
0B	*	DEC BC	27	*	DAA
0C	*	INC C	28 dd		JR Z, dd
0D	*	DEC C	29	*	ADD HL,HL
0E nn	*	LD C, nn	2A nnnn	*	LD HL, (nnnn)
0F	*	RRCA	2B	*	DEC HL
10 dd		DJNZ dd	2C	*	INC L
11 nnnn	*	LD DE, nnnn	2D	*	DEC L
12	*	LD (DE),A	2E nn	*	LD L, nn
13	*	INC DE	2F	*	CPL
14	*	INC D	30 dd		JR NC, dd
15	*	DEC D	31 nnnn	*	LD SP, nnnn
16 nn	*	LD D, nn	32 nnnn	*	LD (nnnn),A
17	*	RLA	33	*	INC SP
18 dd		JR dd	34	*	INC (HL)
19	*	ADD HL,DE	35	*	DEC (HL)
1A	*	LD A,(DE)	36 nn	*	LD (HL), nn
1B	*	DEC DE	37	*	SCF

Hex	Mnemonic		Hex	Mnemonic	
38	dd	JR C, dd	69	* LD	L,C
39		* ADD HL,SP	6A	* LD	L,D
3A	nnnn	* LD A, (nnnn)	6B	* LD	L,E
3B		* DEC SP	6C	* LD	L,H
3C		* INC A	6D	* LD	L,L
3D		* DEC A	6E	* LD	L,(HL)
3E	nn	* LD A, nn	6F	* LD	L,A
3F		* CCF	70	* LD	(HL),B
40		* LD B,B	71	* LD	(HL),C
41		* LD B,C	72	* LD	(HL),D
42		* LD B,D	73	* LD	(HL),E
43		* LD B,E	74	* LD	(HL),H
44		* LD B,H	75	* LD	(HL),L
45		* LD B,L	76	* HALT	
46		* LD B,(HL)	77	* LD	(HL),A
47		* LD B,A	78	* LD	A,B
48		* LD C,B	79	* LD	A,C
49		* LD C,C	7A	* LD	A,D
4A		* LD C,D	7B	* LD	A,E
4B		* LD C,E	7C	* LD	A,H
4C		* LD C,H	7D	* LD	A,L
4D		* LD C,L	7E	* LD	A,(HL)
4E		* LD C,(HL)	7F	* LD	A,A
4F		* LD C,A	80	* ADD	A,B
50		* LD D,B	81	* ADD	A,C
51		* LD D,C	82	* ADD	A,D
52		* LD D,D	83	* ADD	A,E
53		* LD D,E	84	* ADD	A,H
54		* LD D,H	85	* ADD	A,L
55		* LD D,L	86	* ADD	A,(HL)
56		* LD D,(HL)	87	* ADD	A,A
57		* LD D,A	88	* ADC	A,B
58		* LD E,B	89	* ADC	A,C
59		* LD E,C	8A	* ADC	A,D
5A		* LD E,D	8B	* ADC	A,E
5B		* LD E,E	8C	* ADC	A,H
5C		* LD E,H	8D	* ADC	A,L
5D		* LD E,L	8E	* ADC	A,(HL)
5E		* LD E,(HL)	8F	* ADC	A,A
5F		* LD E,A	90	* SUB	B
60		* LD H,B	91	* SUB	C
61		* LD H,C	92	* SUB	D
62		* LD H,D	93	* SUB	E
63		* LD H,E	94	* SUB	H
64		* LD H,H	95	* SUB	L
65		* LD H,L	96	* SUB	(HL)
66		* LD H,(HL)	97	* SUB	A
67		* LD H,A	98	* SBC	A,B
68		* LD L,B	99	* SBC	A,C

Hex	Mnemonic		Hex	Mnemonic	
9A	*	SBC A,D	CB 00		RLC B
9B	*	SBC A,E	CB 01		RLC C
9C	*	SBC A,H	CB 02		RLC D
9D	*	SBC A,L	CB 03		RLC E
9E	*	SBC A,(HL)	CB 04		RLC H
9F	*	SBC A,A	CB 05		RLC L
A0	*	AND B	CB 06		RLC (HL)
A1	*	AND C	CB 07		RLC A
A2	*	AND D	CB 08		RRC B
A3	*	AND E	CB 09		RRC C
A4	*	AND H	CB 0A		RRC D
A5	*	AND L	CB 0B		RRC E
A6	*	AND (HL)	CB 0C		RRC H
A7	*	AND A	CB 0D		RRC L
A8	*	XOR B	CB 0E		RRC (HL)
A9	*	XOR C	CB 0F		RRC A
AA	*	XOR D	CB 10		RL B
AB	*	XOR E	CB 11		RL C
AC	*	XOR H	CB 12		RL D
AD	*	XOR L	CB 13		RL E
AE	*	XOR (HL)	CB 14		RL H
AF	*	XOR A	CB 15		RL L
B0	*	OR B	CB 16		RL (HL)
B1	*	OR C	CB 17		RL A
B2	*	OR D	CB 18		RR B
B3	*	OR E	CB 19		RR C
B4	*	OR H	CB 1A		RR D
B5	*	OR L	CB 1B		RR E
B6	*	OR (HL)	CB 1C		RR H
B7	*	OR A	CB 1D		RR L
B8	*	CP B	CB 1E		RR (HL)
B9	*	CP C	CB 1F		RR A
BA	*	CP D	CB 20		SLA B
BB	*	CP E	CB 21		SLA C
BC	*	CP H	CB 22		SLA D
BD	*	CP L	CB 23		SLA E
BE	*	CP (HL)	CB 24		SLA H
BF	*	CP A	CB 25		SLA L
C0	*	RET NZ	CB 26		SLA (HL)
C1	*	POP BC	CB 27		SLA A
C2 nnnn	*	JP NZ, nnnn	CB 28		SRA B
C3 nnnn	*	JP nnnn	CB 29		SRA C
C4 nnnn	*	CALL NZ, nnnn	CB 2A		SRA D
C5	*	PUSH BC	CB 2B		SRA E
C6 nn	*	ADD A, nn	CB 2C		SRA H
C7	*	RST 0	CB 2D		SRA L
C8	*	RET Z	CB 2E		SRA (HL)
C9	*	RET	CB 2F		SRA A
CA nnnn	*	JP Z, nnnn	CB 38		SRL B

Hex	Mnemonic		Hex	Mnemonic	
CB 39	SRL	C	CB 6A	BIT	5,D
CB 3A	SRL	D	CB 6B	BIT	5,E
CB 3B	SRL	E	CB 6C	BIT	5,H
CB 3C	SRL	H	CB 6D	BIT	5,L
CB 3D	SRL	L	CB 6E	BIT	5,(HL)
CB 3E	SRL	(HL)	CB 6F	BIT	5,A
CB 3F	SRL	A	CB 70	BIT	6,B
CB 40	BIT	0,B	CB 71	BIT	6,C
CB 41	BIT	0,C	CB 72	BIT	6,D
CB 42	BIT	0,D	CB 73	BIT	6,E
CB 43	BIT	0,E	CB 74	BIT	6,H
CB 44	BIT	0,H	CB 75	BIT	6,L
CB 45	BIT	0L	CB 76	BIT	6,(HL)
CB 46	BIT	0,(HL)	CB 77	BIT	6,A
CB 47	BIT	0,A	CB 78	BIT	7,B
CB 48	BIT	1,B	CB 79	BIT	7,C
CB 49	BIT	1,C	CB 7A	BIT	7,D
CB 4A	BIT	1,D	CB 7B	BIT	7,E
CB 4B	BIT	1,E	CB 7C	BIT	7,H
CB 4C	BIT	1,H	CB 7D	BIT	7,L
CB 4D	BIT	1,L	CB 7E	BIT	7,(HL)
CB 4E	BIT	1,(HL)	CB 7F	BIT	7,A
CB 4F	BIT	1,A	CB 80	RES	0,B
CB 50	BIT	2,B	CB 81	RES	0,C
CB 51	BIT	2,C	CB 82	RES	0,D
CB 52	BIT	2,D	CB 83	RES	0,E
CB 53	BIT	2,E	CB 84	RES	0,H
CB 54	BIT	2,H	CB 85	RES	0,L
CB 55	BIT	2,L	CB 86	RES	0,(HL)
CB 56	BIT	2,(HL)	CB 87	RES	0,A
CB 57	BIT	2,A	CB 88	RES	1,B
CB 58	BIT	3,B	CB 89	RES	1,C
CB 59	BIT	3,C	CB 8A	RES	1,D
CB 5A	BIT	3,D	CB 8B	RES	1,E
CB 5B	BIT	3,E	CB 8C	RES	1,H
CB 5C	BIT	3,H	CB 8D	RES	1,L
CB 5D	BIT	3,L	CB 8E	RES	1,(HL)
CB 5E	BIT	3,(HL)	CB 8F	RES	1,A
CB 5F	BIT	3,A	CB 90	RES	2,B
CB 60	BIT	4,B	CB 91	RES	2,C
CB 61	BIT	4,C	CB 92	RES	2,D
CB 62	BIT	4,D	CB 93	RES	2,E
CB 63	BIT	4,E	CB 94	RES	2,H
CB 64	BIT	4,H	CB 95	RES	2,L
CB 65	BIT	4,L	CB 96	RES	2,(HL)
CB 66	BIT	4,(HL)	CB 97	RES	2,A
CB 67	BIT	4,A	CB 98	RES	3,B
CB 68	BIT	5,B	CB 99	RES	3,C
CB 69	BIT	5,C	CB 9A	RES	3,D

Hex	Mnemonic	Hex	Mnemonic
CB 9B	RES 3,E	CB CC	SET 1,H
CB 9C	RES 3,H	CB CD	SET 1,L
CB 9D	RES 3,L	CB CE	SET 1,(HL)
CB 9E	RES 3,(HL)	CB CF	SET 1,A
CB 9F	RES 3,A	CB D0	SET 2,B
CB A0	RES 4,B	CB D1	SET 2,C
CB A1	RES 4,C	CB D2	SET 2,D
CB A2	RES 4,D	CB D3	SET 2,E
CB A3	RES 4,E	CB D4	SET 2,H
CB A4	RES 4,H	CB D5	SET 2,L
CB A5	RES 4,L	CB D6	SET 2,(HL)
CB A6	RES 4,(HL)	CB D7	SET 2,A
CB A7	RES 4,A	CB D8	SET 3,B
CB A8	RES 5,B	CB D9	SET 3,C
CB A9	RES 5,C	CB DA	SET 3,D
CB AA	RES 5,D	CB DB	SET 3,E
CB AB	RES 5,E	CB DC	SET 3,H
CB AC	RES 5,H	CB DD	SET 3,L
CB AD	RES 5,L	CB DE	SET 3,(HL)
CB AE	RES 5,(HL)	CB DF	SET 3,A
CB AF	RES 5,A	CB E0	SET 4,B
CB B0	RES 6,B	CB E1	SET 4,C
CB B1	RES 6,C	CB E2	SET 4,D
CB B2	RES 6,D	CB E3	SET 4,E
CB B3	RES 6,E	CB E4	SET 4,H
CB B4	RES 6,H	CB E5	SET 4,L
CB B5	RES 6,L	CB E6	SET 4,(HL)
CB B6	RES 6,(HL)	CB E7	SET 4,A
CB B7	RES 6,A	CB E8	SET 5,B
CB B8	RES 7,B	CB E9	SET 5,C
CB B9	RES 7,C	CB EA	SET 5,D
CB BA	RES 7,D	CB EB	SET 5,E
CB BB	RES 7,E	CB EC	SET 5,H
CB BC	RES 7,H	CB ED	SET 5,L
CB BD	RES 7,L	CB EE	SET 5,(HL)
CB BE	RES 7,(HL)	CB EF	SET 5,A
CB BF	RES 7,A	CB F0	SET 6,B
CB C0	SET 0,B	CB F1	SET 6,C
CB C1	SET 0,C	CB F2	SET 6,D
CB C2	SET 0,D	CB F3	SET 6,E
CB C3	SET 0,E	CB F4	SET 6,H
CB C4	SET 0,H	CB F5	SET 6,L
CB C5	SET 0,L	CB F6	SET 6,(HL)
CB C6	SET 0,(HL)	CB F7	SET 6,A
CB C7	SET 0,A	CB F8	SET 7,B
CB C8	SET 1,B	CB F9	SET 7,C
CB C9	SET 1,C	CB FA	SET 7,D
CB CA	SET 1,D	CB FB	SET 7,E
CB CB	SET 1,E	CB FC	SET 7,H

Hex	Mnemonic	Hex	Mnemonic
CB FD	SET 7,L	DD 9Edd	SBC A,(IX+dd)
CB FE	SET 7,(HL)	DD A6dd	AND (IX+dd)
CB FF	SET 7,A	DD AEdd	XOR (IX+dd)
CC nnnn	* CALL Z, nnnn	DD B6dd	OR (IX+dd)
CD nnnn	* CALL nnnn	DD BEdd	CP (IX+dd)
CE nn	* ADC A, nn	DD CBdd06	RLC (IX+dd)
CF	* RST 8	DD CBdd0E	RRC (IX+dd)
D0	* RET NC	DD CBdd16	RL (IX+dd)
D1	* POP DE	DD CBdd1E	RR (IX+dd)
D2 nnnn	* JP NC, nnnn	DD CBdd26	SLA (IX+dd)
D3 nn	* OUT (nn),A	DD CBdd2E	SRA (IX+dd)
D4 nnnn	* CALL NC, nnnn	DD CBdd3E	SRL (IX+dd)
D5	* PUSH DE	DD CBdd46	BIT 0,(IX+dd)
D6 nn	* SUB nn	DD CBdd4E	BIT 1,(IX+dd)
D7	* RST 10H	DD CBdd56	BIT 2,(IX+dd)
D8	* RET C	DD CBdd5E	BIT 3,(IX+dd)
D9	EXX	DD CBdd66	BIT 4,(IX+dd)
DA nnnn	* JP C, nnnn	DD CBdd6E	BIT 5,(IX+dd)
DB nn	* IN A, (nn)	DD CBdd76	BIT 6,(IX+dd)
DC nnnn	* CALL C, nnnn	DD CBdd7E	BIT 7,(IX+dd)
DD 09	ADD IX,BC	DD CBdd86	RES 0,(IX+dd)
DD 19	ADD IX,DE	DD CBdd8E	RES 1,(IX+dd)
DD 21nnnn	LD IX, nnnn	DD CBdd96	RES 2,(IX+dd)
DD 22nnnn	LD (nnnn),IX	DD CBdd9E	RES 3,(IX+dd)
DD 23	INC IX	DD CBddA6	RES 4,(IX+dd)
DD 29	ADD IX,IX	DD CBddAE	RES 5,(IX+dd)
DD 2Annnn	LD IX, (nnnn)	DD CBddB6	RES 6,(IX+dd)
DD 2B	DEC IX	DD CBddBE	RES 7,(IX+dd)
DD 34dd	INC (IX+dd)	DD CBddC6	SET 0,(IX+dd)
DD 35dd	DEC (IX+dd)	DD CBddCE	SET 1,(IX+dd)
DD 36ddnn	LD (IX+dd), nn	DD CBddD6	SET 2,(IX+dd)
DD 39	ADD IX,SP	DD CBddDE	SET 3,(IX+dd)
DD 46dd	LD B,(IX+dd)	DD CBddE6	SET 4,(IX+dd)
DD 4Edd	LD C,(IX+dd)	DD CBddEE	SET 5,(IX+dd)
DD 56dd	LD D,(IX+dd)	DD CBddF6	SET 6,(IX+dd)
DD 5Edd	LD E,(IX+dd)	DD CBddFE	SET 7,(IX+dd)
DD 66dd	LD H,(IX+dd)	DD E1	POP IX
DD 6Edd	LD L,(IX+dd)	DD E3	EX (SP),IX
DD 70dd	LD (IX+dd),B	DD E5	PUSH IX
DD 71dd	LD (IX+dd),C	DD E9	JP (IX)
DD 72dd	LD (IX+dd),D	DD F9	LD SP,IX
DD 73dd	LD (IX+dd),E	DE nn	* SBC A, nn
DD 74dd	LD (IX+dd),H	DF	* RST 18H
DD 75dd	LD (IX+dd),L	E0	* RET PO
DD 77dd	LD (IX+dd),A	E1	* POP HL
DD 7Edd	LD A,(IX+dd)	E2 nnnn	* JP PO, nnnn
DD 86dd	ADD A,(IX+dd)	E3	* EX (SP),HL
DD 8Edd	ADC A,(IX+dd)	E4 nnnn	* CALL PO, nnnn
DD 96dd	SUB (IX+dd)	E5	* PUSH HL

Hex	Mnemonic		Hex	Mnemonic	
E6 nn	*	AND nn	ED A2		INI
E7	*	RST 20H	ED A3		OUTI
E8	*	RET PE	ED A8		LDD
E9	*	JP (HL)	ED A9		CPD
EA nnnn	*	JP PE, nnnn	ED AA		IND
EB	*	EX DE,HL	ED AB		OUTD
EC nnnn	*	CALL PE, nnnn	ED B0		LDIR
ED 40		IN B,(C)	ED B1		CPIR
ED 41		OUT (C),B	ED B2		INIR
ED 42		SBC HL,BC	ED B3		OTIR
ED 43nnnn		LD (nnnn),BC	ED B8		LDDR
ED 44		NEG	ED B9		CPDR
ED 45		RETN	ED BA		INDR
ED 46		IM 0	ED BB		OTDR
ED 47		LD I,A	EE nn	*	XOR N
ED 48		IN C,(C)	EF	*	RST 28H
ED 49		OUT (C),C	F0	*	RET P
ED 4A		ADC HL,BC	F1	*	POP AF
ED 4Bnnnn		LD BC, (nnnn)	F2 nnnn	*	JP P, nnnn
ED 4D		RETI	F3	*	DI
ED 4F		LD R,A	F4 nnnn	*	CALL P, nnnn
ED 50		IN D,(C)	F5	*	PUSH AF
ED 51		OUT (C),D	F6 nn	*	OR nn
ED 52		SBC HL,DE	F7	*	RST 30H
ED 53nnnn		LD (nnnn),DE	F8	*	RET M
ED 56		IM 1	F9	*	LD SP,HL
ED 57		LD A,I	FA nnnn	*	JP M, nnnn
ED 58		IN E,(C)	FB	*	EI
ED 59		OUT (C),E	FC nnnn	*	CALL M, nnnn
ED 5A		ADC HL,DE	FD 09		ADD IY,BC
ED 5Bnnnn		LD DE, (nnnn)	FD 19		ADD IY,DE
ED 5E		IM 2	FD 21nnnn		LD IY, nnnn
ED 5F		LD A,R	FD 22nnnn		LD (nnnn),IY
ED 60		IN H,(C)	FD 23		INC IY
ED 61		OUT (C),H	FD 29		ADD IY,IY
ED 62		SBC HL,HL	FD 2Annnn		LD IY, (nnnn)
ED 67		RRD	FD 2B		DEC IY
ED 68		IN L,(C)	FD 34dd		INC (IY+dd)
ED 69		OUT (C),L	FD 35dd		DEC (IY+dd)
ED 6A		ADC HL,HL	FD 36ddnn		LD (IY+dd), nn
ED 6F		RLD	FD 39		ADD IY,SP
ED 72		SBC HL,SP	FD 46dd		LD B,(IY+dd)
ED 73nnnn		LD (nnnn),SP	FD 4Edd		LD C,(IY+dd)
ED 78		IN A,(C)	FD 56dd		LD D,(IY+dd)
ED 79		OUT (C),A	FD 5Edd		LD E,(IY+dd)
ED 7A		ADC HL,SP	FD 66dd		LD H,(IY+dd)
ED 7Bnnnn		LD SP, (nnnn)	FD 6Edd		LD L,(IY+dd)
ED A0		LDI	FD 70dd		LD (IY+dd),B
ED A1		CPI	FD 71dd		LD (IY+dd),C

Hex	Mnemonic		Hex	Mnemonic	
FD 72dd	LD	(IY+dd),D	FD CBdd6E	BIT	5,(IY+dd)
FD 73dd	LD	(IY+dd),E	FD CBdd7E	BIT	6,(IY+dd)
FD 74dd	LD	(IY+dd),H	FD CBdd8E	RES	0,(IY+dd)
FD 75dd	LD	(IY+dd),L	FD CBdd9E	RES	1,(IY+dd)
FD 77dd	LD	(IY+dd),A	FD CBddA6	RES	2,(IY+dd)
FD 7Edd	LD	A,(IY+dd)	FD CBddAE	RES	3,(IY+dd)
FD 86dd	ADD	A,(IY+dd)	FD CBddB6	RES	4,(IY+dd)
FD 8Edd	ADC	A,(IY+dd)	FD CBddBE	RES	5,(IY+dd)
FD 96dd	SUB	(IY+dd)	FD CBddC6	SET	0,(IY+dd)
FD 9Edd	SBC	A,(IY+dd)	FD CBddCE	SET	1,(IY+dd)
FD A6dd	AND	(IY+dd)	FD CBddD6	SET	2,(IY+dd)
FD AEdd	XOR	(IY+dd)	FD CBddDE	SET	3,(IY+dd)
FD B6dd	OR	(IY+dd)	FD CBddE6	SET	4,(IY+dd)
FD BEdd	CP	(IY+dd)	FD CBddEE	SET	5,(IY+dd)
FD CBdd06	RLC	(IY+dd)	FD CBddF6	SET	6,(IY+dd)
FD CBdd0E	RRC	(IY+dd)	FD CBddFE	SET	7,(IY+dd)
FD CBdd16	RL	(IY+dd)	FD E1	POP	IY
FD CBdd1E	RR	(IY+dd)	FD E3	EX	(SP),IY
FD CBdd26	SLA	(IY+dd)	FD E5	PUSH	IY
FD CBdd2E	SRA	(IY+dd)	FD E9	JP	(IY)
FD CBdd3E	SRL	(IY+dd)	FD F9	LD	SP,IY
FD CBdd46	BIT	0,(IY+dd)	FE nn	* CP	nn
FD CBdd4E	BIT	1,(IY+dd)	FF	* RST	38H
FD CBdd56	BIT	2,(IY+dd)			
FD CBdd5E	BIT	3,(IY+dd)			
FD CBdd66	BIT	4,(IY+dd)			

APPENDIX G

Cross-Reference of 8080 and Z-80 Instructions

The instructions are listed in alphabetic order according to the 8080 mnemonic. The following representations are used.

N	8-bit constant
NN	16-bit constant
R	single register
RR	double register
—	range of values expressed as one character
--	range of values expressed as two characters

8080 code		HEX code	Z-80 code	
ACI	N	CE	ADC	A,N
ADC	M	8E	ADC	A,(HL)
ADC	R	8—	ADC	A,R
ADD	M	86	ADD	A,(HL)
ADD	R	8—	ADD	A,R
ADI	N	C6	ADD	A,N
ANA	M	A6	AND	(HL)
ANA	R	A—	AND	R
ANI	N	E6	AND	N
CALL	NN	CD	CALL	NN
CC	NN	DC	CALL	C,NN
CM	NN	FC	CALL	M,NN
CMA		2F	CPL	
CMC		3F	CCF	
CMP	M	BE	CP	(HL)
CMP	R	B—	CP	R
CNC	NN	D4	CALL	NC,NN
CNZ	NN	C4	CALL	NZ,NN
CP	NN	F4	CALL	P,NN
CPE	NN	EC	CALL	PE,NN
CPI	N	FE	CP	N
CPO	NN	E4	CALL	PO,NN
CZ	NN	CC	CALL	Z,NN

8080 code		HEX code	Z-80 code	
DAA		27	DAA	
DAD	B	09	ADD	HL,BC
DAD	D	19	ADD	HL,DE
DAD	H	29	ADD	HL,HL
DAD	SP	39	ADD	HL,SP
DCR	M	35	DEC	(HL)
DCR	R	—	DEC	R
DCX	B	0B	DEC	BC
DCX	D	1B	DEC	DE
DCX	H	2B	DEC	HL
DCX	SP	3B	DEC	SP
DI		F3	DI	
EI		FB	EI	
HLT		76	HALT	
IN	N	DB	IN	A,(N)
INR	M	34	INC	(HL)
INR	R	—	INC	R
INX	B	03	INC	BC
INX	D	13	INC	DE
INX	H	23	INC	HL
INX	SP	33	INC	SP
JC	NN	DA	JP	C,NN
JM	NN	FA	JP	M,NN
JMP	NN	C3	JP	NN
JNC	NN	D2	JP	NC,NN
JNZ	NN	C2	JP	NZ,NN
JP	NN	F2	JP	P,NN
JPE	NN	EA	JP	PE,NN
JPO	NN	E2	JP	PO,NN
JZ	NN	CA	JP	Z,NN
LDA	NN	3A	LD	A,(NN)
LDAX	B	0A	LD	A,(BC)
LDAX	D	26	LD	A,(DE)
LHLD	NN	2A	LD	HL,(NN)
LXI	B,NN	01	LD	BC,NN
LXI	D,NN	11	LD	DE,NN
LXI	H,NN	21	LD	HL,NN
LXI	SP,NN	31	LD	SP,NN
MOV	M,R	—	LD	(HL),R
MOV	R,M	—	LD	R,(HL)
MOV	R,R2	—	LD	R,R2
MVI	M,N	36	LD	(HL),N
MVI	R,N	—	LD	R,N
NOP		00	NOP	
ORA	M	B6	OR	(HL)
ORA	R	B—	OR	R
ORI	N	F6	OR	N
OUT	N	D3	OUT	(N),A

8080 code	HEX code	Z-80 code
PCHL	E9	JP (HL)
POP B	C1	POP BC
POP D	D1	POP DE
POP H	E1	POP HL
POP PSW	F1	POP AF
PUSH B	C5	PUSH BC
PUSH D	D5	PUSH DE
PUSH H	E5	PUSH HL
PUSH PSW	F5	PUSH AF
RAL	17	RLA
RAR	1F	RRA
RC	D8	RET C
RET	C9	RET
RLC	07	RLCA
RM	F8	RET M
RNC	D0	RET NC
RNZ	C0	RET NZ
RP	F0	RET P
RPE	E8	RET PE
RPO	E0	RET PO
RRC	15	RRCA
RST 0	C7	RST 0
RST 1	CF	RST 8
RST 2	D7	RST 10H
RST 3	DF	RST 18H
RST 4	E7	RST 20H
RST 5	EF	RST 28H
RST 6	F7	RST 30H
RST 7	FF	RST 38H
RZ	C8	RET Z
SBB M	9E	SBC A,(HL)
SBB R	9—	SBC A,R
SBI N	DE	SBC A,N
SHLD NN	22	LD (NN),HL
SPHL	F9	LD SP,HL
STA NN	32	LD (NN),A
STAX B	02	LD (BC),A
STAX D	12	LD (DE),A
STC	37	SCF
SUB M	96	SUB (HL)
SUB R	9—	SUB R
SUI N	D6	SUB N
XCHG	EB	EX DE,HL
XRA M	AE	XOR (HL)
XRA R	A—	XOR R
XRI N	EE	XOR N
XTHL	E3	EX (SP),HL

APPENDIX H

Details of the Z-80 and 8080 Instruction Set

A summary of the Z-80 and 8080 instruction set is given in this appendix.* The instructions are listed alphabetically by the official Zilog mnemonic. If there is a corresponding 8080 instruction, the Intel mnemonic is shown in angle brackets; if not, "no 8080" is shown in the angle brackets. The Z-80 mnemonics are listed in numeric order in Appendix F. The Z-80 equivalent of an 8080 mnemonic can be found from the cross-reference given in Appendix G.

The letters A, B, C, D, E, H, I, L, IX, IY, R, and SP are used for the standard Z-80 register names. In addition, the symbols BC, DE, and HL are used for the register pairs. The following symbols are used for general arguments.

r, r2	8-bit CPU register
dd	8-bit signed displacement
nn	general 8-bit constant
nnnn	16-bit constant

The flag bits are represented by:

C	carry
H	half carry
N	add/subtract
P/O	parity/overflow
S	sign
Z	zero

Pointers to memory or input or output addresses are enclosed in parentheses.

*More details can be obtained from the Zilog programmer's manual, *Z-80 Assembly Language Programming Manual*, Zilog, Inc., 1977.

ADC	A,(HL)	<ADC	M>
-----	--------	------	----

Add the memory byte pointed to by the HL register pair to the accumulator and the carry flag. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z

Flag reset: N

ADC	A,(IX+dd)	<no 8080>
ADC	A,(IY+dd)	<no 8080>

Add the memory byte referenced by the sum of the specified index register and the displacement to the accumulator and the carry flag. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z

Flag reset: N

ADC	A,r	<ADC	r>
-----	-----	------	----

Add the value in register r to the accumulator and the carry flag. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z,

Flags reset: N

ADC	A,nn	<ACI	nn>
-----	------	------	-----

Add the constant given in the second operand to the accumulator and the carry flag. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z

Flag reset: N

ADC	HL,BC	<no 8080>
ADC	HL,DE	<no 8080>
ADC	HL,HL	<no 8080>
ADC	HL,SP	<no 8080>

Add the indicated double register to the HL register and the carry flag. The result is placed in HL.

Flags affected: C, H, O, S, Z,

Flag reset: N

ADD	A,(HL)	<ADD	M>
-----	--------	------	----

Add the memory byte pointed to by the HL pair to the accumulator. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z

Flag reset: N

```

ADD    A,(IX+dd)  <no 8080>
ADD    A,(IY+dd)  <no 8080>

```

Add the memory byte pointed to by the sum of the specified index register and the displacement to the accumulator. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z
Flag reset: N

```

ADD    A,r        <ADD    r>

```

Add the value in register r to the accumulator. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z
Flag reset: N

```

ADD    A,nn        <ADI    nn>

```

Add the immediate byte (the second operand) to the accumulator. The result is placed in A.

Flags affected: C, H, O, S, Z
Flag reset: N

```

ADD    HL,BC       <DAD    B>
ADD    HL,DE       <DAD    D>
ADD    HL,HL       <DAD    H>
ADD    HL,SP       <DAD    SP>

```

Add the specified double register to the HL pair. The result is placed in HL. This is a double-precision addition. The carry flag is set if an overflow occurs. The instruction ADD HL,HL performs a 16-bit arithmetic shift left, effectively doubling the value in HL. The ADD HL,SP instruction can be used with the 8080 CPU to save an incoming stack pointer:

```

LXI    H,0
DAD    SP
SHLD   nnnn

```

Flags affected: C, H, O, S, Z
Flag reset: N

```

ADD    IX,BC        <no 8080>
ADD    IX,DE        <no 8080>
ADD    IX,IX        <no 8080>
ADD    IX,SP        <no 8080>
ADD    IY,BC        <no 8080>
ADD    IY,DE        <no 8080>
ADD    IY,IY        <no 8080>
ADD    IY,SP        <no 8080>

```

Add the indicated double register to the specified index register. The result is placed in the index register. The HL register pair does not participate in this group of instructions. Notice that there is no equivalent series of ADC instructions.

Flags affected: C, O, S, Z
Flag reset: N

AND (HL) <ANA M>

Perform a logical AND with the accumulator and the memory location pointed to by the HL register pair. The result is placed in the accumulator.

Flags affected: P, S, Z
Flags reset: C, N
Flag set: H

AND (IX+dd) <no 8080>
AND (IY+dd) <no 8080>

Perform a logical AND with the accumulator and the memory byte referenced by the sum of the index register and displacement. The result is placed in the accumulator.

Flags affected: P, S, Z
Flags reset: C, N
Flag set: H

AND r <ANA r>

Perform a logical AND with the accumulator and register r. The result is placed in the accumulator. An instruction AND A is an effective way to test the parity, sign, and zero flags.

Flags affected: P, S, Z
Flags reset: C, N
Flag set: H

AND nn <ANI nn>

Perform a logical AND with the accumulator and the constant given in the argument. The result is placed in the accumulator. This instruction can be used to selectively reset bits of the accumulator. For example, the instruction AND 7FH will reset bit 7.

Flags affected: P, S, Z
Flags reset: C, N
Flag set: H

BIT	b,(HL)	<no 8080>
BIT	b,(IX+dd)	<no 8080>
BIT	b,(IY+dd)	<no 8080>

Test bit b of the memory byte referenced by the second operand. Bit b can range from zero through 7. The zero flag is set if the referenced bit is a logical 1; otherwise, it is reset. Thus, the zero flag becomes the complement of the selected bit.

Flag affected: Z
 Flag set: H
 Flag reset: N

BIT	b,r	<no 8080>
-----	-----	-----------

Test bit b of register r, where b can range from zero through 7. The zero flag is set if the referenced bit is a logical 1. It is reset otherwise.

Flag affected: Z
 Flag set: H
 Flag reset: N

CALL	nnnn	<CALL nnnn>
------	------	-------------

Unconditional subroutine call to address nnnn. The address of the following instruction is pushed onto the stack.

Flags affected: none

CALL	C,nnnn	<CC	nnnn>
CALL	M,nnnn	<CM	nnnn>
CALL	NC,nnnn	<CNC	nnnn>
CALL	NZ,nnnn	<CNZ	nnnn>
CALL	P,nnnn	<CP	nnnn>
CALL	PE,nnnn	<CPE	nnnn>
CALL	PO,nnnn	<CPO	nnnn>
CALL	Z,nnnn	<CZ	nnnn>

Conditional subroutine call to address nnnn. The address of the following instruction is pushed onto the stack. The conditions are:

C	carry flag set	(carry)
M	sign flag set	(minus)
NC	carry flag reset	(not carry)
NZ	zero flag reset	(not zero)
P	sign flag reset	(plus)
PE	parity flag set	(parity even)
PO	parity flag reset	(parity odd)
Z	zero flag set	(zero)

CCF < CMC >

Complement the carry flag. This instruction can be given after a SCF command to reset the carry flag.

Flag affected: C

Flag reset: N

CP (HL) <CMP M>

Compare the byte in memory pointed to by the HL pair to the accumulator (an implied operand). The zero flag is set if the accumulator is equal to the operand. The carry flag is set if the accumulator is smaller than the operand.

Flags affected: C, H, O, S, Z

Flag set: N

CP (IX+dd) <no 8080>
CP (IY+dd) <no 8080>

Compare the memory location referenced by the sum of the index register and displacement to the accumulator which is an implied operand. The zero flag is set if the accumulator is equal to the operand. The carry flag is set if the accumulator is smaller than the operand.

Flags affected: C, H, O, S, Z

Flag set: N

CP r <CMP r>

Compare register r to the accumulator, which is an implied operand. The zero flag is set if the accumulator is equal to the operand. The carry flag is set if the accumulator is smaller than the operand.

Flags affected: C, H, O, S, Z

Flag set: N

CP nn <CPI nn>

Compare the constant given in the operand to the accumulator, which is an implied operand. The zero flag is set if the accumulator is equal to the operand. The carry flag is set if the accumulator is smaller than the operand.

Flags affected: C, H, O, S, Z

Flag set: N

CPD <no 8080>
CPDR <no 8080>
CPI <no 8080>
CPIR <no 8080>

Compare the memory byte pointed to by HL to the accumulator. Decrement HL (if D) or increment HL (if I). Decrement the byte count in the BC register. Repeat the operation for CPDR and CPIR until a match is found or until the BC register pair has been decremented to zero. The zero flag is set if a match is found. The parity flag is set if BC is decremented to zero.

Flags affected: H, S

Flags set: N, Z if A = (HL), P if BC = 0

CPL < CMA >

Complement the accumulator. This instruction performs a one's complement on the accumulator. (Compare to the instruction NEG.)

Flags set: H, N

DAA < DAA >

Decimal adjust the accumulator. This instruction is used after each addition with BCD numbers. The Z-80 performs this operation properly for both addition and subtraction. The 8080, however, gives an incorrect result for subtraction.

Flags affected: O, S, Z, C, H

DEC (HL) <DCR M>

Decrement the memory byte pointed to by the HL register pair.

Flags affected: H, O, S, Z

Flag set: N

Flag not affected: C

DEC	(IX+dd)	<no 8080>
DEC	(IY+dd)	<no 8080>

Decrement the memory byte pointed to by the sum of the index register and the displacement.

Flags affected: H, O, S, Z

Flag set: N

Flag not affected: C

DEC r <DCR r>

Decrement the register r. Don't try to decrement a register past zero while executing a JP NC loop. The carry flag is not affected by this operation.

Flags affected: H, O, S, Z

Flag set: N

Flag not affected: C

DEC	BC	<DCX	B>
DEC	DE	<DCX	D>
DEC	HL	<DCX	H>
DEC	SP	<DCX	SP>

Decrement the indicated double register. Don't try to decrement a double register to zero in a JP NZ loop. It won't work since this operation does not affect any of the PSW flags. Instead, move one byte of the double register into the accumulator and perform a logical OR with the other byte.

```
LD  A,C
OR  B
JR  NZ,nnnn
```

Flags affected: none!!!!

DEC	IX	<no 8080>
DEC	IY	<no 8080>

Decrement the index register.

Flags affected: none

```
DI    < DI >
```

Disable maskable interrupt request.

```
DJNZ  dd    <no 8080>
```

Decrement register B and jump relative to displacement dd if B register is not zero.

Flags affected: none

```
EI    < EI >
```

Enable maskable interrupt request.

```
EX      (SP),HL      < XTHL >
```

Exchange the byte at the stack pointer with register L. Exchange the byte at the stack pointer + 1 with register H.

Flags affected: none

EX	(SP),IX	<no 8080>
EX	(SP),IY	<no 8080>

Exchange the 16 bits referenced by the stack pointer with the specified index register.

Flags affected: none

EX AF,AF' <no 8080>

Exchange the accumulator and flag register with the alternate set.

Flags affected: all

EX DE,HL < XCHG >

Exchange the double registers DE and HL.

Flags affected: none

EXX <no 8080>

Exchange BC, DE, and HL with the alternate set.

Flags affected: none

HALT < HLT >

Suspend operation of the CPU until a reset or interrupt occurs. Dynamic memory refresh continues during a halt.

IM	0	<no 8080>
IM	1	<no 8080>
IM	2	<no 8080>

Sets interrupt mode 0, 1, or 2. Interrupt mode 0 is automatically selected when a Z-80 reset occurs. The result is the same as the 8080 interrupt response. Interrupt mode 1 performs an RST 38H instruction. Interrupt mode 2 provides for many interrupt locations.

IN r,(C) <no 8080>

⁹ Input a byte from the port address in register C to register r.

Flags affected: P, S, Z

Flags reset: H, N

IN A,(nn) <IN nn>

Input a byte from the port address nn to the accumulator.

Flags affected: none

INC (HL) <INR M>

Increment the memory byte pointed to by the HL pair.

Flags affected: H, O, S, Z

Flag set: N

Flag not affected. C!!!!

INC	(IX+dd)	<no 8080>
INC	(IY+dd)	<no 8080>

Increment the memory byte pointed to by the sum of the index register and the displacement.

Flags affected: H, O, S, Z

Flag set: N

Flag not affected: C!!!

INC	r	<INR	r>
-----	---	------	----

Increment the 8-bit register r. Don't try to increment a register past zero while executing a JP NC loop. It won't work because the carry flag is unaffected by this instruction.

Flags affected: H, O, S, Z

Flag set: N

Flag not affected: C!!!

INC	BC	<INX	B>
INC	DE	<INX	D>
INC	HL	<INX	H>
INC	SP	<INX	SP>

Increment the specified double register.

Flags affected: none!!!!

INC	IX	<no 8080>
INC	IY	<no 8080>

Increment the specified index register.

Flags affected: none

IND	<no 8080>
INDR	<no 8080>
INI	<no 8080>
INIR	<no 8080>

Input a byte from the port address in register C to the memory byte pointed to by HL. Decrement register B. The HL register is incremented (if I) or decremented (if D). For INDR and INIR the process is repeated until the 8-bit register B becomes zero.

Flag affected: Z (if B = 0)

Flag set: N

JP (HL) < PCHL >

Copy the HL register pair into the program counter; then retrieve the next instruction from the address referenced by HL. This instruction causes a jump to the address referenced by HL.

Flags affected: none

JP (IX) <no 8080>
JP (IY) <no 8080>

Copy the contents of the specified index register into the program counter; then retrieve the next instruction from the address referenced by IX or IY.

Flags affected: none

JP nnnn <JMP nnnn>

Unconditional jump to address nnnn.

Flags affected: none

JP	C,nnnn	<JC	nnnn>
JP	M,nnnn	<JM	nnnn>
JP	NC,nnnn	<JNC	nnnn>
JP	NZ,nnnn	<JNZ	nnnn>
JP	P,nnnn	<JP	nnnn>
JP	PE,nnnn	<JPE	nnnn>
JP	PO,nnnn	<JPO	nnnn>
JP	Z,nnnn	<JZ	nnnn>

Conditional jump to address nnnn where:

C	means carry flag set	(carry)
M	means sign flag set	(minus)
NC	means carry flag reset	(not carry)
NZ	means zero flag reset	(not zero)
P	means sign flag reset	(plus)
PE	means parity flag set	(parity even)
PO	means parity flag reset	(parity odd)
Z	means zero flag set	(zero)

JR dd <no 8080>

Unconditional relative jump with a signed displacement nn. The jump is limited to 129 bytes forward and 126 bytes backward in memory.

Flags affected: none

JR	C,dd	<no 8080>
JR	NC,dd	<no 8080>
JR	NZ,dd	<no 8080>
JR	Z,dd	<no 8080>

Conditional relative jump to address nn where:

C	means carry flag set	(carry)
NC	means carry flag reset	(not carry)
NZ	means zero flag reset	(not zero)
Z	means zero flag set	(zero)

LD	(BC),A	<STAX B>
LD	(DE),A	<STAX D>

Move the byte in the accumulator to the memory byte referenced by the specified register pair.

LD	(HL),r	<MOV M,r>
----	--------	-----------

Move the byte in register r to the memory byte pointed to by the HL pair.

LD	(HL),nn	<MVI M,nn>
----	---------	------------

Move the immediate byte nn into the memory byte referenced by the HL pair.

LD	(IX+dd),r	<no 8080>
LD	(IX+dd),nn	<no 8080>
LD	(IY+dd),r	<no 8080>
LD	(IY+dd),nn	

Move the byte in register r or the immediate byte nn into the memory byte referenced by the sum of the index register plus the displacement. These instructions can be used to load relocatable binary code.

LD	(nnnn),A	<STA nnnn>
----	----------	------------

Store the accumulator in the memory location referenced by nnnn.

LD	(nnnn),BC	<no 8080>
LD	(nnnn),DE	<no 8080>

Store the low-order byte (C or E) of the specified double register at the memory location nnnn. Store the high-order byte (B or D) at nnnn + 1.

LD	(nnnn),HL	<SHLD nnnn>
----	-----------	-------------

Store register L at the memory address nnnn. Store register H at the address nnnn + 1.

LD	(nnnn), IX	<no 8080>
LD	(nnnn), IY	<no 8080>
LD	(nnnn), SP	<no 8080>

Store the low-order byte of the specified register IX, IY, or SP at the location nnnn. Store the high-order byte at nnnn + 1. The instruction LD (nnnn),SP can be used to temporarily save an incoming stack pointer. It can later be restored by a LD SP,(nnnn) operation.

LD	A, (BC)	<LDAX	B>
LD	A, (DE)	<LDAX	D>

Move the memory byte referenced by the specified register pair BC or DE into the accumulator.

LD	A, I	<no 8080>
----	------	-----------

Load the accumulator from the interrupt-vector register. The parity flag reflects the state of the interrupt-enable flip-flop.

Flags affected: S, Z, P
Flags reset: H, N

LD	A, R	<no 8080>
----	------	-----------

Load the accumulator from the memory-refresh register. The parity flag reflects the state of the interrupt-enable flip-flop. This is an easy way to obtain a fairly decent random number.

Flags affected: S, Z, P
Flags reset: H, N

LD	I, A	<no 8080>
----	------	-----------

Copy the accumulator into the interrupt-vector register.

Flags affected: none

LD	R, A	<no 8080>
----	------	-----------

Copy the accumulator into memory-refresh register.

Flags affected: none

LD	r, (HL)	<MOV	r, M>
----	---------	------	-------

Move the byte in the memory location pointed to by the HL register pair into register r.

LD	r,(IX+dd)	<no 8080>
LD	r,(IY+dd)	<no 8080>

Move the byte at the memory location referenced by the sum of the index register and the displacement into register r.

LD	r,r2	<MOV	r,r2>
----	------	------	-------

Move the byte from register r2 to r.

LD	r,nn	<MVI	r,nn>
----	------	------	-------

Load register r with the 8-bit data byte nn.

LD	A,(nnnn)	<LDA	nnnn>
----	----------	------	-------

Load the accumulator from the memory byte referenced by the 16-bit pointer nnnn.

LD	BC,(nnnn)	<no 8080>
LD	DE,(nnnn)	<no 8080>

Load the low-order byte (C or E) from the location referenced by the 16-bit pointer nnnn. Load the high-order byte (B or D) from nnnn + 1.

LD	HL,(nnnn)	<LHLD	nnnn>
----	-----------	-------	-------

Load register L from the address referenced by the 16-bit value nnnn. Load register H from the address nnnn + 1.

LD	BC,nnnn	<LXI	B,nnnn>
LD	DE,nnnn	<LXI	D,nnnn>
LD	HL,nnnn	<LXI	H,nnnn>
LD	SP,nnnn	<LXI	SP,nnnn>
LD	IX,nnnn	<no 8080>	
LD	IY,nnnn	<no 8080>	

Load the specified double register with the 16-bit constant nnnn. Be careful not to confuse LD HL,(nnnn) with LD HL,nnnn.

LD	IX,(nnnn)	<no 8080>
LD	IY,(nnnn)	<no 8080>
LD	SP,(nnnn)	<no 8080>

Load the low byte of IX, IY, or SP from the memory location nnnn. Load the high byte from nnnn + 1. The LD SP,(nnnn) instruction can be used to retrieve a previously saved stack pointer.

LD	SP, HL	< SPHL >
LD	SP, IX	<no 8080>
LD	SP, IY	<no 8080>

Load the stack pointer from the specified 16-bit register. The SPHL instruction can be used to retrieve a previously saved stack pointer when the 8080 CPU is used.

LHLD	nnnn
SPHL	

LDD	<no 8080>
LDDR	<no 8080>
LDI	<no 8080>
LDIR	<no 8080>

Move the byte referenced by the HL pair into the location pointed to by the DE register pair. Decrement the 16-bit byte counter in BC. Increment (if I) or decrement (if D) both HL and DE. Repeat the operation for LDDR and LDIR until the BC register has been decremented to zero.

NEG	<no 8080>
-----	-----------

This instruction performs a two's complement on the accumulator. It effectively subtracts the accumulator from zero. To perform this task on an 8080, use a CMA command followed by an INR A command.

Flags affected: all

NOP	< NOP >
-----	---------

No operation is performed by the CPU.

Flags affected: none

OR	(HL)	<ORA	M>
----	------	------	----

Perform a logical OR with the accumulator and the byte referenced by HL. The result is placed in the accumulator.

Flags affected: P, S, Z

Flags reset: C, H, N

OR	(IX+dd)	<no 8080>
OR	(IY+dd)	<no 8080>

Perform a logical OR with the accumulator and the byte referenced by the specified index register plus the displacement. The result is placed in the accumulator.

Flags affected: P, S, Z

Flags reset: C, H, N

OR r <ORA r>

Perform a logical OR with the accumulator and the register r. The result is placed in the accumulator. An instruction of OR A is an efficient way to test the parity, sign, and zero flags.

Flags affected: P, S, Z

Flags reset: C, H, N

OR nn <ORI nn>

Perform a logical OR with the accumulator and the byte nn. The result is placed in the accumulator. This instruction can be used to set individual bits of the accumulator. For example, OR 20H will set bit 5 to a logical 1.

Flags affected: P, S, Z

Flags reset: C, H, N

OTDR <no 8080>
OTIR <no 8080>

Output a byte from the memory location pointed to by the HL pair. The port address is contained in register C. Register B is decremented. The HL register pair is incremented (if I) or decremented (if D). The process is repeated until register B has become zero.

Flags set: N, Z

OUT (C),r <no 8080>

Output the byte in register r to the port address contained in register C.

Flags affected: none

OUT (nn),A <OUT nn>

Output the byte in the accumulator to the port address nn.

Flags affected: none

OUTD <no 8080>
OUTI <no 8080>

Output a byte from the memory location pointed to by the HL pair. The port address is contained in register C. Register B is decremented. The HL register pair is incremented (if I) or decremented (if D).

Flag affected: Z

Flag set: N

POP	AF	<POP	PSW>
-----	----	------	------

Move the byte at the memory location referenced by the stack pointer into the flag register (PSW), and increment the stack pointer. Then move the byte at the location referenced by the new stack-pointer value into the accumulator and increment the stack pointer a second time.

Flags affected: all

POP	BC	<POP	B>
POP	DE	<POP	D>
POP	HL	<POP	H>

Copy two bytes of memory into the appropriate double register as follows. The memory byte referenced by the stack pointer is moved into the low-order byte (C, E, or L), then the stack pointer is incremented. The memory byte referenced by the new stack pointer is then moved into the high-order byte (B, D, or H). The stack pointer is incremented a second time.

Flags affected: none

POP	IX	<no 8080>
POP	IY	<no 8080>

Copy the top of the stack into the specified index register. Increment the stack pointer twice.

Flags affected: none

PUSH	AF	<PUSH	PSW>
------	----	-------	------

Store the accumulator and flag register in memory as follows. The stack pointer is decremented, then the value in the accumulator is moved to the memory byte referenced by the stack pointer. The stack pointer is decremented a second time. The flag register is copied to the byte at the memory address referenced by the current stack-pointer position.

Flags affected: none

PUSH	BC	<PUSH	B>
PUSH	DE	<PUSH	D>
PUSH	HL	<PUSH	H>

Store the referenced double register in memory as follows. The stack pointer is decremented, then the byte in the specified high-order register B, D, or H is copied to the memory location referenced by the stack pointer. The stack pointer is decremented a second time. The byte in the low-order position C, E, or L is moved to the byte referenced by the current value of the stack pointer.

Flags affected: none

PUSH	IX	<no 8080>
PUSH	IY	<no 8080>

The indicated index register is copied to the top of the stack. The stack pointer is decremented twice.

Flags affected: none

RES	b,(HL)	<no 8080>
RES	b,(IX+dd)	<no 8080>
RES	b,(IY+dd)	<no 8080>

Reset bit b of the memory byte referenced by the second operand. Bit b can range from zero through 7.

Flag reset: N

Other flags affected: none

RES	b,r	<no 8080>
-----	-----	-----------

Reset bit b of register r to a value of zero. Bit b can range from zero through 7.

Flag reset: N

Other flags affected: none

RET	< RET >
-----	---------

Return from a subroutine. The top of the stack is moved into the program counter. The stack pointer is incremented twice.

RET	C	< RC >
RET	M	< RM >
RET	NC	< RNC >
RET	NZ	< RNZ >
RET	P	< RP >
RET	PE	< RPE >
RET	PO	< RPO >
RET	Z	< RZ >

Conditional return from a subroutine. If the condition is met, the top of the stack is moved into the program counter. The stack pointer is incremented twice.

C	means carry flag set	(carry)
M	means sign flag set	(minus)
NC	means carry flag reset	(not carry)
NZ	means zero flag reset	(not zero)
P	means sign flag reset	(plus)
PE	means parity flag set	(parity even)
PO	means parity flag reset	(parity odd)
Z	means zero flag set	(zero)

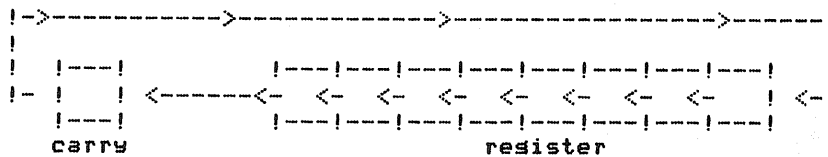
RETI <no 8080>

Return from maskable interrupt.

RETN <no 8080>

Return from nonmaskable interrupt.

The following RL and RLA instructions rotate bits to the left through carry.



RL (HL) <no 8080>

The memory byte referenced by the HL pair is rotated left through carry. The carry flag moves into bit zero. Bit 7 moves to the carry flag.

Flags affected: C, P, S, Z

Flags reset: H, N

RL (IX+dd) <no 8080>
RL (IY+dd) <no 8080>

The memory byte referenced by the sum of the index register and the displacement is rotated left through carry. The carry flag moves into bit zero. Bit 7 moves to the carry flag.

Flags affected: C, P, S, Z

Flags reset: H, N

RL r <no 8080>

The byte in register r is rotated left through carry. The carry flag moves into bit zero. Bit 7 moves to the carry flag. Note: the instruction RL A performs the same task that the separate instruction RLA does, but the former takes twice as long as the latter.

Flags affected: C, P, S, Z

Flags reset: H, N

RLA < RAL >

The byte in the accumulator is rotated left through carry. The carry flag moves to bit zero. Bit 7 of the accumulator moves to the carry flag.

Flag affected: C
Flags reset: H, N

The following RLC and RLCA instructions rotate bits to the left.



RLC (HL) <no 8080>

The byte referenced by the HL pair is rotated left circularly. Bit 7 moves to both the zero bit and to the carry flag.

Flags affected: C, P, S, Z
Flags reset: H, N

RLC (IX+dd) <no 8080>
RLC (IY+dd) <no 8080>

The byte referenced by the specified index register plus the displacement is rotated left circularly. Bit 7 moves to both bit zero and the carry flag.

Flags affected: C, P, S, Z
Flags reset: H, N

RLC r <no 8080>

The byte in register r is rotated left circularly. Bit 7 moves to both bit zero and the carry flag. Note: RLC A performs the same task that another instruction RLCA does, but the former instruction takes twice as long as the latter.

Flags affected: C, P, S, Z
Flags reset: H, N

RLCA < RLC >

The accumulator is rotated left circularly. Bit 7 moves to both bit zero and the carry flag.

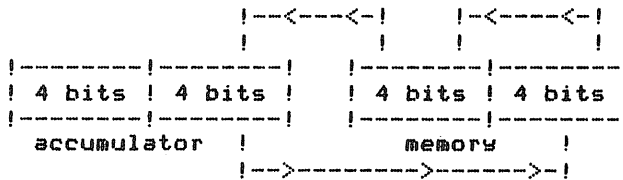
Flag affected: C
Flags reset: H, N

RLD <no 8080>

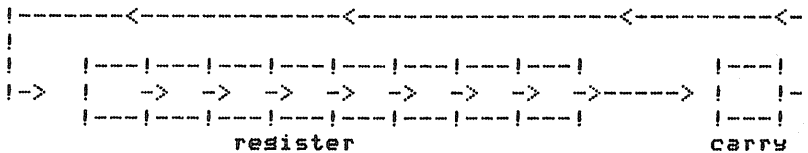
A 4-bit rotation over 12 bits. The low 4 bits of A move to the low 4 bits of the memory location referenced by the HL pair. The original low 4 bits of

memory move to the high 4 bits. The original high 4 bits move to the low 4 bits of A. This instruction is used for BCD operations.

Flags affected: P, S, Z
Flags reset: H, N



The following RR and RRA instructions rotate bits to the right through carry.



RR (HL) <no 8080>

The memory byte pointed to by the HL pair is rotated right through carry. Carry moves to bit 7. Bit zero moves to the carry flag.

Flags affected: C, P, S, Z
Flags reset: H, N

RR (IX+dd) <no 8080>
RR (IY+dd) <no 8080>

The memory byte pointed to by the specified index register plus the offset is rotated right through carry. The carry flag moves to bit 7. Bit zero moves to the carry flag.

Flags affected: C, P, S, Z
Flags reset: H, N

RR r <no 8080>

The byte in register r is rotated right through carry. Carry moves to bit 7. Bit zero moves to the carry flag. Note: RR A performs the same task that another instruction RRA does, but the former instruction takes twice as long as the latter.

Flags affected: C, P, S, Z
Flags reset: H, N

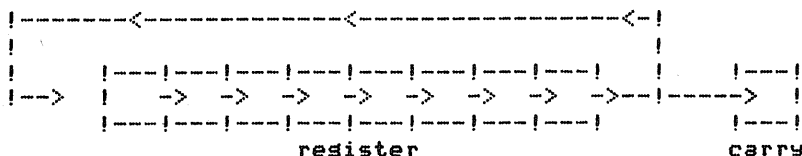
RRA < RAR >

The accumulator is rotated right through carry. The carry flag moves to bit 7. Bit zero moves to the carry flag.

Flag affected: C

Flags reset: H, N

The following RRC and RRCA instructions rotate bits to the right.

**RRC** (HL) <no 8080>

The memory byte pointed to by the HL pair is rotated right circularly. Bit zero moves to both the carry flag and bit 7.

Flags affected: C, P, S, Z

Flags reset: H, N

RRC (IX+dd) <no 8080>
RRC (IY+dd) <no 8080>

The memory byte pointed to by the index register plus the offset is rotated right circularly. Bit zero moves to both the carry flag and bit 7.

Flags affected: C, P, S, Z

Flags reset: H, N

RRC r <no 8080>

The byte in register r is rotated right circularly. Bit zero moves to both the carry flag and bit 7. Note: RRC A performs the same task that another instruction RRCA does, but the former instruction takes twice as long as the latter.

Flags affected: C, P, S, Z

Flags reset: H, N

RRCA < RRC >

The accumulator is rotated right circularly. Bit zero moves to both the carry flag and bit 7.

Flag affected: C

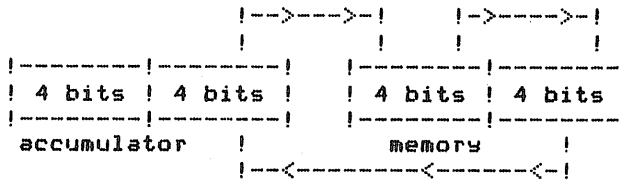
Flags reset: H, N

RRD <no 8080>

A 4-bit rotation over 12 bits. The low 4 bits of A move to the high 4 bits of the memory location referenced by the HL pair. The original high 4 bits of memory move to the low 4 bits. The original low 4 bits move to the low 4 bits of A. This instruction is used for BCD operations.

Flags affected: P, S, Z

Flags reset: H, N



RST 00H	<RST 0>
RST 08H	<RST 1>
RST 10H	<RST 2>
RST 18H	<RST 3>
RST 20H	<RST 4>
RST 28H	<RST 5>
RST 30H	<RST 6>
RST 38H	<RST 7>

These restart instructions generate one-byte subroutine calls to address given in the Z-80 operand.

SBC A, (HL) <SBB M>

Subtract the carry flag and the memory byte pointed to by the HL pair from the accumulator. The result is placed in the accumulator. Some Z-80 assemblers allow the 8080 mnemonic of SBB to be used as an alternate Z-80 mnemonic for this instruction.

Flags affected: C, H, O, S, Z

Flag set: N

SBC	A, (IX+dd)	<no 8080>
SBC	A, (IY+dd)	<no 8080>

Subtract the carry flag and the memory byte pointed to by the sum of the index register and displacement from the accumulator. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z

Flag set: N

SBC A,r <SBB r>

Subtract the carry flag and the specified CPU register from the accumulator. The result is placed in the accumulator. Some Z-80 assemblers allow the 8080 mnemonic of SBB to be used as an alternate Z-80 mnemonic for this instruction.

Flags affected: C, H, O, S, Z

Flag set: N

SBC A,nn <SBI nn>

Subtract the immediate byte (the second operand) and the carry flag from the accumulator. The result is placed in the accumulator. Some Z-80 assemblers allow the 8080 mnemonic of SBB to be used as an alternate Z-80 mnemonic for this instruction.

Flags affected: C, H, O, S, Z

Flag set: N

SBC HL,BC <no 8080>

SBC HL,DE <no 8080>

SBC HL,HL <no 8080>

SBC HL,SP <no 8080>

Subtract the specified CPU double register and the carry flag from the HL register pair. The result is placed in HL. You may need to reset the carry flag with an OR A operation before using these instructions.

Flags affected: C, H, O, S, Z

Flag set: N

SCF < STC >

Set the carry flag. There is no equivalent reset command. However, the carry flag can be reset with the XOR A instruction, or with the pair of instructions SCF and CCF.

Bit set: C

Bits reset: H, N

SET b,(HL) <no 8080>

SET b,(IX+dd) <no 8080>

SET b,(IY+dd) <no 8080>

Set bit b of the memory byte referenced by the second operand. Bit b can range from zero through 7.

Flag reset: N

Other flags affected: none

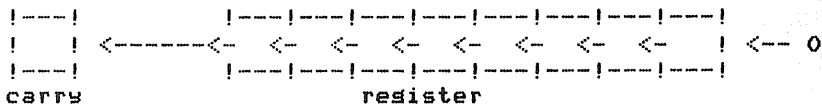
```
SET      b,r      <no 8080>
```

Set bit b of register r. Bit b can range from zero through 7.

Flag reset: N

Other flags affected: none

The following SLA instructions shift bits to the left.



SLA (HL) <no 8080>

Perform an arithmetic shift left on the memory byte pointed to by the HL pair. Bit 7 is moved to the carry flag. A zero is moved into bit zero. This operation doubles the original value.

Bits affected: C, P, S, Z

Bits reset: H, N

```
SLA      (IX+dd)      <no 8080>
SLA      (IY+dd)      <no 8080>
```

Perform an arithmetic shift left on the memory byte pointed to by the index register plus the displacement. Bit 7 is moved to the carry flag. A zero is moved into bit zero. This operation doubles the original value.

Bits affected: C, P, S, Z

Bits reset: H, N

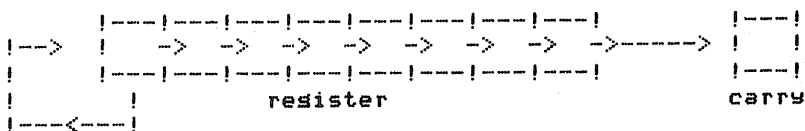
SLA r <no 8080>

Perform an arithmetic shift left on register r. Bit 7 is moved to the carry flag. A zero is moved into bit zero. This operation doubles the original value. Note: SLA A performs the same task that another instruction ADD A,A does, but the former instruction takes twice as long as the latter.

Bits affected: C, P, S, Z

Bits reset: H, N

The following SRA instructions shift bits to the right.



Bits affected: C, P, Z

Bits reset: H, N, S

SRL r <no 8080>

Perform a logical shift right on register r. A zero bit is moved into bit 7. Bit zero moves to the carry flag.

Bits affected: C, P, S, Z

Bits reset: H, N

SUB (HL) <SUB M>

Subtract the memory byte referenced by the HL pair from the accumulator. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z

Flag set: N

SUB	(IX+dd)	<no 8080>
SUB	(IY+dd)	<no 8080>

Subtract the memory byte referenced by the index register plus the displacement from the value in the accumulator. The result is placed in A.

Flags affected: C, H, O, S, Z

Flag set: N

SUB r <SUB r>

Subtract the specified CPU register from the accumulator. The result is placed in the accumulator. Notice that Z-80 SUB mnemonic has only one operand, whereas there are two operands in the corresponding 8-bit ADC, ADD, and SBC mnemonics. The destination operand for all four of these instructions is always the accumulator. Consequently, the first operand is optional with some assemblers.

Flags affected: C, H, O, S, Z

Flag set: N

SUB nn <SUI nn>

Subtract the immediate byte nn from the accumulator. The result is placed in the accumulator.

Flags affected: C, H, O, S, Z

Flag set: N

XOR	(HL)	<XRA	M>
-----	------	------	----

Perform a logical exclusive OR with the accumulator and the byte referenced by the HL pair. The result is placed in the accumulator.

Flags affected: P, S, Z

Flags reset: C, H, N

XOR	(IX+dd)	<no 8080>
XOR	(IY+dd)	<no 8080>

Perform a logical exclusive OR with the accumulator and the byte referenced by the sum of specified index register and the displacement. The result is placed in the accumulator.

Flags affected: P, S, Z

Flags reset: C, H, N

XOR	r	<XRA	r>
-----	---	------	----

Perform a logical exclusive OR with the accumulator and register r. The result is placed in the accumulator. The XOR A instruction is an efficient way to zero the accumulator, although all the flags are then reset. XOR A is also used to reset the carry flag.

Flags affected: P, S, Z

Flags reset: C, H, N

XOR	nn	<XRI	nn>
-----	----	------	-----

Perform a logical exclusive OR with the accumulator and the byte nn. The result is placed in the accumulator.

Flags affected: P, S, Z

Flags reset: C, H, N

APPENDIX I

Abbreviations and Acronyms

A/D	Analogue to Digital
APL	A Programming Language
ASCII	American Standard Code for Information Interchange
BCD	Binary-Coded Decimal
BDOS	Basic Disk-Operating System (CP/M)
BIOS	Basic Input/Output System (CP/M)
Bit	BIrary digiT
BJT	Bipolar Junction Transistor
CBIOS	Customized Bios (CP/M)
CCD	Charge-Coupled Device
CCP	Console Command Processor (CP/M)
CMOS	Complementary Metal-Oxide Semiconductor
COBOL	COmmon BUiness-ORiented Language
CP/M	Control Program for Microcomputers
CPU	Central Processing Unit
CRC	Cyclical-Redundancy Check
CRT	Cathode Ray Tube
CTS	Clear To Send
D/A	Digital to Analogue
DCD	Data-Carrier Detect
DDT	Dynamic Debugging Tool (CP/M)
DMA	Direct Memory Access
DOS	Disk-Operating System
ECL	Emitter-Coupled Logic
EOF	End Of File
EPROM	Erasable PROM
FCB	File Control Block (CP/M)
FDOS	Full DOS (CP/M)
FET	Field-Effect Transistor
FIFO	First-In, First-Out
FORTRAN	FORmula TRANslation
Hz	Hertz (cycles per second)
IC	Integrated Circuit
IGFET	Insulated-Gate FET

IIL	Integrated Injection Logic
I/O	Input/Output
JFET	Junction FET
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
LIFO	Last-In, First-Out
LSB	Least-Significant Bit (or Byte)
LSI	Large-Scale Integration
MHz	Megahertz (million Hz)
MODEM	MODulator/DEModulator
MOS	Metal-Oxide Semiconductor
MOSFET	MOS FET
MSB	Most Significant Bit (or Byte)
NAND	Not AND
NOR	Not OR
OP AMP	OPerational AMPlifier
PIP	Peripheral Interchange Program (CP/M)
PPL	Phase-Locked Loop
PROM	Programmable ROM
PSW	Program-Status Word
R/W	Read/Write
RAM	Random-Access Memory
ROM	Read-Only Memory
RTS	Request To Send
SCR	Silicon-Controlled Rectifier
SID	Symbolic Instruction Debugger (CP/M)
TPA	Transient Program Area (CP/M)
TTL	Transistor-Transistor Logic
TTY	Teletype
UART	Universal Asynchronous Receiver/Transmitter
UJT	UniJunction Transistor
XOR	Exclusive OR

APPENDIX J

Undocumented Z-80 Instructions

The Z-80 CPU contains two 16-bit index registers called IX and IY. All of the official Zilog instructions which refer to IX and IY are 16-bit operations. For example, the IX register can be assigned the constant value 1234 with the LD instruction

```
LD      IX,1234H
```

And the contents of the IY register can be saved on the stack with a PUSH operation.

```
PUSH    IY
```

A perusal of the numerically ordered Z-80 instructions, given in Appendix F, reveals that sequences beginning with the byte DD hex refer to operations involving the IX register. Similarly, the byte FD hex signifies an IY operation.

In addition to the 16-bit operations, there are many 8-bit operations that can be performed with the Z-80 index registers. These instructions are not shown in Appendix F because they have not been officially documented by Zilog. All of these 8-bit IX and IY instructions follow the same pattern. The first byte of the IX operation codes is DD hex and the first byte of the IY operation codes is FD hex. The remaining byte of the instruction is a regular Z-80 operation which refers to the H or L register. But, in this case, H now refers to the high 8 bits of the index register and L refers to the low 8 bits.

As an example, consider the Z-80 instruction:

```
LD      H,B
```

which moves the byte in register B into the H register. If this operation code is preceded by a DD hex byte, then the B register is moved into the high 8 bits of the IX register. An assembler that incorporated these undocumented instructions might generate the following source code.

60	LD	H,B	;MOVE B TO H
DD60	LD	XH,B	;MOVE B TO HIGH IX
DD6B	LD	XL,E	;MOVE E TO LOW IX
FD67	LD	YH,A	;MOVE A TO HIGH IY
FD69	LD	YL,C	;MOVE C TO LOW IY

But, except for Allen Ashley's PDS assembler, these XH, XL, YH, and YL symbols have not actually been incorporated into Z-80 assemblers. The undocumented instructions encompass all of the 8-bit LD op codes involving the H and L registers. These include the register-to-register moves

```
LD      H,r
LD      L,r
LD      r,H
LD      r,L
```

where r is one of the general-purpose registers A, B, C, D, and E. The instructions

```
LD      L,H  and
LD      H,L
```

are also included. In this case the H and L refer respectively to the high 8 bits and the low 8 bits of the same index register. Thus, the instruction

```
LD      L,H
```

preceded by a DD byte will move the high 8 bits of the IX register into the low 8 bits. The regular H and L registers cannot be operands for these moves. Move-immediate instructions are not included in the new instructions. Furthermore, 8-bit transfers cannot be made from one index register to the other.

Many of the other 8-bit register operations can be utilized in this way. In addition to the above LD instructions, these include the following.

ADC	A,H	ADC	A,L
ADD	A,H	ADD	A,L
AND	H	AND	L
CP	H	CP	L
DEC	H	DEC	L
INC	H	INC	L
OR	H	OR	L
SBC	A,H	SBC	A,L
SUB	H	SUB	L
XOR	H	XOR	L

The rotations and shifts, the bit manipulations that set, reset and test, and the input and output operations are not included.

All of these undocumented operations can be produced with a regular Z-80 assembler. One method is to generate the initial DD or FD hex with the DEFB directive. Then, the corresponding regular Z-80 instruction follows. For example, the following two lines will generate the instruction needed to move the accumulator into the high half of IX.

```
DEFB    ODDH      ;SET FOR IX
LD       H,A       ;MOVE A TO XH
```

Alternately, a macro can be used. The definition could be

```
LDX      MACRO    REG1,REG2
          DEFB     ODDH
          LD        REG1,REG2
          ENDM
```

Then the macro call

```
LDX      H,A
```

will generate the desired code.

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