

# DEBUG

## Advanced 8080 Debugger

### User's Manual

Describes DEBUG 1.1

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Corporation**

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## TABLE OF CONTENTS

SECTION		PAGE
1	INTRODUCTION .....	1-1
	1.1 GENERAL INFORMATION .....	1-1
	1.2 LOADING AND INITIALIZATION OF THE DEBUGGER .....	1-1
	1.3 BREAKPOINTS AND RESTARTS .....	1-2
2	COMMANDS .....	2-1
	2.1 CONVENTIONS .....	2-1
	2.2 DEBUGGER COMMAND LIST .....	2-2
	2.3 DESCRIPTION OF COMMANDS .....	2-4
	2.4 A WALK THROUGH THE DEBUGGER .....	2-14



## SECTION 1

### INTRODUCTION

#### 1.1 GENERAL INFORMATION

This program is an aid for debugging a machine language program developed and assembled on a Sol Terminal Computer or other 8080 computer system using CUTER software and CUTS format cassette tape. With DEBUG, you are permitted to set as many as fifteen "breakpoints" in a program you want to debug or examine. When that program is executed under the control of DEBUG, it will stop at each of these addresses so that CPU registers, flags, and specified memory locations may be examined and modified. It is possible to resume execution at a breakpoint (or at another specified memory location) after you have made modifications. At the conclusion of debugging, you can save the modified version of your program with the SOLOS/CUTER SAVE command.

There are five versions of the DEBUG program on the cassette tape. Each version is designed for use on a system with a particular amount of memory:

DBG8 is for a system with 8K of memory, and occupies memory between 0E00H and 1FFFH.  
DBG16 is for a system with 16K of memory, and occupies memory between 2E00H and 3FFFH.  
DBG32 is for a system with 32K of memory, and occupies memory between 6E00H and 7FFFH.  
DBG48 is for a system with 48K of memory, and occupies memory between AE00H and BFFFH.  
DBG64 is for a system with 64K of memory, and occupies memory between EE00H and FFFFH.

The versions are identical, except that they run at different memory locations. Each version occupies 4 1/2 K of memory and may be restarted at the address at which it is loaded. Hereafter DEBUG or "the debugger" will be used to designate any version of the program.

The DEBUG program contains its own VDM output driver. When execution begins, however, all output is sent to the current SOLOS/CUTER pseudo-port; a command is provided (the V command, described in Subsection 2.3) to direct output to the internal VDM driver, instead of to the current pseudo-port.

#### 1.2 LOADING AND INITIALIZATION OF THE DEBUGGER

1) Connect a cassette recorder to the computer. (Your Sol manual has instructions for setting up a recorder.)

2) Insert the cassette tape on which you have recorded the program you want to debug. Use the SOLOS/CUTER CATALOG command to rewind the tape and position it before the part of the tape on which the program is recorded. Use the MODE SELECT or CTRL and @ keys to return to SOLOS/CUTER command mode. (Omit this step if the program you want to examine is already in memory.)

3) Use the GET command to load your program into memory. Do not use XEQ, because you do not want to execute the program until you can do so under control of DEBUG.

4) When you have loaded your own program, remove the cassette from the recorder and insert the DEBUG program tape. Position the tape as in step 1, and use the SOLOS/CUTER XEQ command to load and execute DEBUG.

When DEBUG begins to run, it will display the question

RST?

on the output device (probably the video display). Your response, a number between 0 and 7, inclusive, will determine which 8080 "restart" location will be used by the debugger to implement breakpoints. (Subsection 1.3 discusses breakpoints and restarts.)

When the > prompt appears, the debugger is ready to accept a command from the keyboard.

### 1.3 BREAKPOINTS AND RESTARTS

A BREAKPOINT is a location at which the operation of a program stops to permit some kind of external intervention; in the case of DEBUG, the user program (or the program being examined) stops to permit the user to examine and modify registers and memory. A breakpoint can be set at any address; when the debugger is in operation and a breakpoint has been implemented, it is possible to proceed from that breakpoint, or even to determine that execution will no longer stop there.

When a breakpoint is encountered by the debugger, the value of each register is immediately displayed as a hexadecimal number following the letter symbol for the register and an equals sign (=). For example, B=3E means that the number 3E is in register B. The symbols for the registers are:

- A for the Accumulator
- B for register B
- C for register C
- D for register D
- E for register E
- F for CPU Flags
- H for register H
- L for register L
- M for the content of the memory location to which H and L point
- P for Program Counter
- S for Stack Pointer

The flags that were set at the time of the breakpoint are indicated by letter symbols following the letter "F" and an equals sign. The symbols for the flags are:

S for the Sign flag  
Z for the Zero flag  
A for the Auxiliary Carry flag  
P for the Parity flag  
C for the Carry flag  
N for no flag

Thus, f=ZAP means that the Zero, Auxiliary Carry, and Parity flags were set. (Obviously, the letter N will only appear if no other symbol follows the equals sign.)

The X command (discussed in Subsection 2.3, below) may be used to modify any of the values existing in the registers or flags at the time of the breakpoint. There are also commands that make it possible to examine and modify the contents of memory at any named location.

The 8080 microcomputer allows for eight possible RESTART locations, numbered 0 through 7 and corresponding to memory addresses 0, 8, 16, 24, 32, 40, 48, and 56 Decimal. It is quite common to give a much-used subroutine an origin at one of the restart locations, because a call to such a location requires only the one-byte RST instruction, rather than the three-byte CALL instruction. In the debugger a subroutine for dealing with breakpoints has its origin at whatever restart location is specified in answer to the RST? question. The program provides for a choice of restart locations, in order to allow the other restart addresses to remain available for access by the user. (For example, the program being debugged may use restart addresses as origins for some of its subroutines.) If all eight of the restart locations are available for use by the debugger, then the answer to RST? can be any number between 0 and 7.



## SECTION 2

### COMMANDS

#### 2.1 CONVENTIONS

On the next page is a list of the commands accepted by the DEBUG program. In this list and for the remainder of the manual, the following conventions are used:

The symbol <cr> denotes the RETURN key.

Upper case letters are literal: the \$Bexpr<cr> command actually contains the upper case letter B. (Note that it also ends with a carriage return.)

Lower case letters are not literal: the \$Bexpr<cr> command contains a four character hexadecimal address or an expression that evaluates to a four character hexadecimal address. (The rules governing expressions are given below.) If a number occupying more than four hexadecimal places is entered as an address, only the rightmost four characters are significant. Similarly, if an expression evaluates to a number occupying more than four hexadecimal places, only the rightmost four places are significant.

Brackets {} indicate that a parameter is optional. The command \$P{n}<cr> contains an optional parameter represented by the letter n.

Other punctuation is literal, except that the dollar sign (\$) signifies the ESCape key, rather than the shift-4. (The ESCape key is actually echoed on the screen as a dollar sign.)

#### EXPRESSIONS

The letters expr denote an expression that points to an address in memory, i.e., an expression that evaluates to a number between 0 and 65535, inclusive. The characteristics of an expression are as follows:

1) An expression may involve any of the operators + (add), - (subtract), \* (multiply), and % (divide). Expressions are evaluated from left to right, with no operator precedence. Parentheses are not allowed.

2) An operand is assumed to be a hexadecimal number, unless it is preceded by an exclamation point (!), in which case it is assumed to be a decimal number.

100 is 100 Hexadecimal, or 256 Decimal.

!100 is 106 Decimal, or 64 Hexadecimal.

3) Multiplication and division operate on two 16-bit unsigned numbers. The result of division is truncated to its integer part, and the remainder is lost.

3D%7 evaluates to 0008.

4) There is no check for overflow or for division by zero.

It may be useful to imagine the acceptable range of numerical values (corresponding exactly to the range of addressable memory) on a circular number "clock," with 0 at the twelve o'clock position and values increasing in a clockwise direction. Thus the largest number in the system (65535) is next to the smallest (0), just counter-clockwise of twelve o'clock. If we follow the rule, "Move clockwise to increment a value, counter-clockwise to decrement a value," it becomes clear that in this system 3-5 will be 65534, and 65534+5 will be 3. Although it is possible to utilize this arrangement to advantage, it is probably less confusing to use expressions that actually evaluate to a number neither less than zero, nor greater than 65535.

Division by zero will always give the result 65535 Decimal.

5) A period (.) in an expression represents the address of the last memory location examined. Thus, a memory location offset by 100 Hexadecimal from the last location examined could be represented as 100+. or as .+100. If no memory location has yet been examined, the value of . is 0000.

6) BLANKS ARE NOT ACCEPTABLE WITHIN EXPRESSIONS.

## 2.2 DEBUGGER COMMAND LIST

All of these commands will be described in the next subsection. A command may be entered at any time that the > prompt appears on the video display.

SYNTAX	FUNCTION
\$A<cr>	Set breakpoint mode to Static.
\$Bexpr<cr>	Set breakpoint at address expr. Up to fifteen breakpoints may be set.
\$C<cr>	Set output mode to Character.
\$Daddr<cr>	Delete the breakpoint at address expr.
\$E<cr>	Exit DEBUG; return to PTDOS.
expr/	Display the content of the location designated by expr. Allow modification of the value at that location.
expr=	Print the value of expr in Hexadecimal.

expr#	Print the value of expr in Decimal.
\$Fexpr1,expr2,bb<cr>	Fill memory from address expr1 to address expr2 with byte bb.
\$H<cr>	Set output mode to Hexadecimal.
\$I<cr>	Set output mode to Instruction.
\$K<cr>	Delete all currently set breakpoints.
\$P{n}<cr>	Proceed from a breakpoint; continue execution, skipping this breakpoint until it is met again for the nth time. Default for n is 1.
\$Rexpr<cr>	Begin execution (of the program being debugged or examined) at address expr.
\$Sexpr1,expr2,bb,mm<cr>	Search memory from address expr1 to address expr2 for byte bb using mask mm.
\$T<cr>	Display a list of current breakpoint addresses.
\$V<cr>	Change output driver (SOUT to VDM, or vice-versa).
\$Wexpr1{,expr2}<cr>	Dump contents of memory from address expr1 to address expr2.
\$Xr<cr>	Display the content of CPU register r. Allow modification of that value.
\$Z<cr>	Set breakpoint mode to Remove.

## 2.3 DESCRIPTION OF COMMANDS

This subsection describes all of the commands in the debugger and provides short examples of their use. (There are no examples in cases in which the operation of a command is not evident on the display, i.e., in which the DEBUG program simply issues a carriage return and a prompt after the command is executed.) For the purpose of this discussion, it is convenient to group the commands as follows:

### GROUP 1 DEBUGGER CONTROL

These are commands not directly related to the process of debugging a program. They determine where output will be sent from the debugger (V), and whether the contents of memory will be represented as hexadecimal numbers (H), characters (C), or 8080 instructions (I). Also included in this group is the command that terminates execution of the debugger (E).

### GROUP 2 CONTROLLING EXECUTION OF THE USER PROGRAM

These commands set and delete breakpoints (B,D,T,K), start and restart the program being debugged (R,P).

### GROUP 3 EXAMINING AND MODIFYING MEMORY

These commands are related to the examination and modification of particular memory locations (expr/,W,F,S), CPU registers and flags (X). These commands are generally used after a breakpoint has been encountered, although it is possible to examine memory without setting any breakpoints.

Subsection 2.4, below, illustrates a typical sequence of steps followed while debugging a program.

GROUP 1: V sets the output port.  
H sets output mode to Hexadecimal.  
I sets output mode to Instruction.  
C sets output mode to Character.  
E exits the program.

CHANGE OUTPUT DRIVER \$V<cr>

DEBUG can send output either to the internal VDM driver or to the current SOLOS/CUTER pseudo-port; the V command changes the output driver from the current pseudo-port to VDM, or vice-versa. When the program is first executed, output is sent to the current pseudo-port. (Normally, this is also the video display.)

The internal VDM driver has a variable speed option: while output is being displayed, it is possible to alter the speed of the display by striking a key representing one of the digits (0 is fastest, 9 is slowest). Output can be suspended temporarily by the space bar and reactivated by any other key. The default display speed is 2.

SET OUTPUT MODE TO HEXADECIMAL \$H<cr>

This command determines that when the content of a memory location is examined (expr/ command), it will be displayed as a hexadecimal number. (The commands to examine memory are in Group 3.) The default mode for output is Hexadecimal; it is therefore unnecessary to specify this mode unless another mode is in force.

SET OUTPUT MODE TO INSTRUCTION FORMAT \$I<cr>

This command determines that when the content of a memory location is examined (expr/ command) or dumped (W command), it will be decoded into the corresponding 8080 instruction mnemonic. (The twelve undefined operation codes are output in Hexadecimal.) In Instruction mode, DEBUG will assume that the location given by the expression in the expr/ command is the first byte of an instruction. If the location specified in the command is, in fact, the second or third byte of a multiple-byte instruction, DEBUG will still decode the byte as an assembly language instruction mnemonic, and the result will not reflect what is actually happening in the object code.

There are two exceptions to the rule that every byte displayed in Instruction mode will be displayed as an 8080 instruction mnemonic. If the W command is entered while Instruction mode is set, or if expr/ specifies the first byte of a multiple-byte instruction and the linefeed key is used to examine the next location(s), the DEBUG program will display the second and third bytes of instructions in Hexadecimal format.

SET OUTPUT MODE TO CHARACTER \$C<cr>

This command determines that when the contents of memory are examined (expr/ command), any value that corresponds to the code for a printable ASCII character will be displayed as that ASCII character. Any value that does not correspond to a printable ASCII character will be printed as a hexadecimal number.

EXIT TO SOLOS/CUTER \$E<cr>

This command terminates execution of the debugger and returns to SOLOS/CUTER. At this point the altered program may be saved from memory, or its source may be altered in EDIT. If the program is going to be saved from memory, all current breakpoints must be removed before the E command is entered.

GROUP 2: B sets a breakpoint; D deletes a breakpoint.  
T displays all breakpoints; K deletes all breakpoints.  
A and Z set breakpoint mode.  
R and P begin and restart program execution.

SET BREAKPOINT \$Bexpr<cr>

This command sets a breakpoint at the location specified by the expression expr. A breakpoint causes program execution to stop immediately BEFORE the execution of the instruction at the specified address; for this reason it is not permissible to set a breakpoint on the second or third byte of a multiple-byte instruction.

There may be as many as fifteen breakpoints set at any given time.

DELETE BREAKPOINT \$Dexpr<cr>

This command deletes the breakpoint currently set at the location specified by the expression expr. If there is no breakpoint at the specified address, a question mark will be printed.

DISPLAY ALL CURRENT BREAKPOINTS \$T<cr>

This command causes the addresses of all current breakpoints to be displayed; thus it becomes evident how many breakpoints have been set and whether there are any that can be deleted.

EXAMPLE:

```
>$T<cr>      (command to type out current breakpoints)
4075         (addresses at which breakpoints have been
4089         set with the B command)
4102
```

KILL ALL CURRENT BREAKPOINTS \$K<cr>

This command deletes all of the breakpoints that have been set. Once a program has been debugged, it can be executed normally from within the debugger if all breakpoints have been removed. If the altered version of a program is going to be saved following a return to PTDOS, it is necessary to delete all breakpoints before entering the E command.

SET BREAKPOINT MODE TO STATIC \$A<cr>

This command determines that breakpoints will NOT be deleted after they are encountered, that is, that execution will stop again every time a breakpoint address is reached. Static mode is set when the debugger is entered.

SET BREAKPOINT MODE TO REMOVE \$Z<cr>

This command determines that breakpoints WILL be deleted after they are encountered. Execution will stop only the FIRST time that the breakpoint address is reached.

PROCEED FROM A BREAKPOINT    \$P{n}<cr>

This command causes program execution to resume after a breakpoint has been encountered and related examination or modification of the code has been completed. Execution will continue, beginning at the instruction that caused the break, and will proceed until the next breakpoint is encountered. All registers will be loaded with values that reflect the modifications that have been made; a register or flag whose value has not been modified will retain the value that it contained when the breakpoint was encountered.

If a number is given after the letter P, the command is taken to mean: proceed with execution and do not stop again for this breakpoint until it is encountered for the nth time. For example, the command \$P5<cr> will cause the breakpoint just implemented to be bypassed four times; all other breakpoints will be implemented normally. The default for n is 1; that is, normally execution will proceed, and any breakpoint that has not been deleted or removed will be implemented normally.

BEGIN EXECUTION    \$Rexpr<cr>

This command will start execution of a program at the location specified by expression expr. The R command is used to execute a program at its starting address; it should not be used to proceed from a breakpoint, because the values of registers and flags will not be restored! (The P command, by contrast, restores the values of registers and flags.)

GROUP 3:    X displays CPU registers and flags.  
          W dumps a series of memory locations.  
          F fills a series of locations with a given value.  
          S searches a series of locations for a given value.  
          expr/ displays the contents of location expr.  
          expr= displays the value of expr in Hexadecimal.  
          expr# displays the value of expr in Decimal.

DISPLAY CPU REGISTERS AND FLAGS    \$Xr<cr>

This command is used to examine and modify the values of CPU registers and flags after a breakpoint has been encountered. The r in the command format represents a symbol for the register that is to be examined or modified. If no value is specified for r, the values of ALL registers and flags are displayed. The carriage return is NOT required if a value is specified for r.

SYMBOLS DESIGNATING REGISTERS AND FLAGS

Here is a list of the symbols for registers and memory. Any of these symbols may be used as the r element in the X command.

A for the Accumulator  
 B for register B  
 C for register C  
 D for register D  
 E for register E  
 F for CPU Flags  
 H for register H  
 L for register L  
 M for the content of the memory location  
 to which H and L point  
 P for Program Counter  
 S for Stack Pointer

These are the symbols for the flags. The X command will not display the value of an individual flag; rather, the flags are displayed as a group when F is specified in the X command.

S for the Sign flag  
 Z for the Zero flag  
 A for the Auxiliary Carry flag  
 P for the Parity flag  
 C for the Carry flag  
 N for no flag

#### MODIFYING A REGISTER OR FLAG

In order to modify a register or flag, enter the X command, following the letter "X" with the symbol that designates the register. To modify one of the flags, type \$XF<cr>, NOT the symbol that stands for the particular flag! If the letter "X" is followed simply by a carriage return, the values of all registers and flags will be displayed again.

When the X command is entered, the value of the named register will be displayed.

#### EXAMPLE:

```
>$XB          (command to display register B)
B=52          (hexadecimal value of register B)
```

If you do not want to modify the register, after all, type a carriage return to re-enter command mode. If you DO want to modify the register, enter a new value at the cursor position, without inserting additional punctuation or spaces. The value that you enter will replace the value currently in the register. Follow the entry with a space or a carriage return; a space dictates that the next register be displayed (on the current line), while a carriage return effects a return to command mode. To modify the value of a flag, enter the symbols of all flags that are to be set, whether or not they are set already.

```
>$XF<cr>      (examine flags)
F=SZC SZP<cr> (Sign, Zero, and Carry flags already set; user
               sets Parity, alters carry so no longer set)
>             (back in command mode)
```

DUMP MEMORY      \$Wexpr1{,expr2}<cr>

This command causes the contents of a specified section of memory to be displayed in the current output mode (see Group 1). If the mode is not Instruction format, memory will be dumped with fourteen bytes represented on each line: first all bytes are displayed in Hexadecimal, and then all are displayed as characters. (A period will be printed if the value of the byte does not correspond to a printable ASCII character.) In Instruction format, memory will be dumped in decoded format, with one instruction per line and the second and third bytes of multiple-byte instructions represented in Hexadecimal.

Memory will be dumped starting at the location specified by expr1 and continuing to that specified by expr2. If no value is specified for expr2, the value expr1 will be used; the dump will continue as though memory were circular, starting at expr1 and continuing past 65535 to 0, finally stopping when the byte before expr1 is reached. To terminate a dump before it reaches expr2, type MODE SELECT or CTRL-@.

```
>$W100,110<cr>
```

```
0100 01 07 00 21 50 00 11 65 00 78 B1 C8 0B 7E      ...!P...e.x...~
010E 12 24 14                                            .$.
```

FILL MEMORY WITH A GIVEN BYTE      \$Fexpr1,expr2,bb<cr>

This command fills memory from expr1 to expr2 with byte bb. If expr1 and expr2 are quite far apart in memory, a few moments may pass before the prompt (>) reappears on the screen.

SEARCH MEMORY FOR A GIVEN BYTE      \$Sexpr1,expr2,bb,{mm}<cr>

This command searches memory from the location specified by expr1 to that specified by expr2 for byte bb, using mm as a mask.

As each byte is examined, it is ANDed with mask mm and then checked for equality to byte bb. If the quantities are equal, then the memory address and the byte at the address are printed. If the mask is not specified, it will be assumed to have the value OFF Hexadecimal, i.e., all bits will be compared.

EXAMPLE:

```
>$S2340,2375,4C<cr>                    (search for 4CH, using default mask)
2357 4C                                 (4C is found at location 2357)
>$S5261,5269,0,1<cr>                   (search for even numbers)
5261 C2                                 (even numbers found at five locations)
5263 52
5264 3E
5265 0E
5266 90
```

EVALUATE EXPRESSION OR EXAMINE MEMORY    `expr=, expr#, expr/`

If an expression is entered and followed immediately by an equals sign (`=`), the expression is evaluated and the result is displayed as a Hexadecimal number.

```
>5*6=001E        (result displayed in Hexadecimal)
```

If an expression is entered and followed immediately by a pound sign (`#`), the expression is evaluated and the result is displayed as a Decimal number.

```
>5*6#00030       (result displayed in Decimal)
```

If an expression is entered and followed by a slash (`/`), the expression is evaluated and the content of the memory location denoted by the expression is displayed in the current output mode (see Group 1).

```
>$H<cr>            (output mode set at Hexadecimal)
>!34%2/ 40        (value of location 17 Decimal is displayed in
Hexadecimal output mode)
```

Note that none of these commands requires a carriage return. In the rules for expressions (see Subsection 2.1), an expression was defined as POINTING to an address in memory. Actually, in the case of an expression followed by an equals sign or a pound sign, the expression need not denote a location that is to be examined; any arithmetic problem whose result will lie between 0 and 65535, inclusive, can be entered, even if the computer being used does not have any memory at the designated location. If the `expr/` command is entered and there is no memory at the specified location, the result will be FF in Hexadecimal mode, RST 07 in Instruction mode.

Once `expr/` has been entered and the location has been displayed, several different entries are possible.

A CARRIAGE RETURN effects a return to command mode.

A SINGLE QUOTE MARK (`'`) causes the value of the location to be displayed in Character mode (without changing the current mode setting for the debugger).

```
>$H<cr>            (set output mode to Hexadecimal)
>5002/ 50 ' P<cr>   (value displayed in Hex, then as
>                    Character; return to command mode)
```

A SEMI-COLON (`;`) causes the byte to be displayed in Instruction format; the location is assumed to be the first byte of an 8080 instruction. The current mode setting for the debugger is not altered.

```
>$H<cr>            (set output mode to Hexadecimal)
>1234/ 39 ; DAD SP<cr> (value displayed in Hex, then as
>                    Instruction; return to command mode)
```

An EQUALS SIGN (=) causes the contents of the present memory location to be displayed in Hexadecimal, without changing the current mode setting for the debugger.

```
>$I<cr>          (set output mode to Instruction)
>025F/XCHG =EB<cr> (value displayed as Instruction, then
>                in Hex; return to command mode)
```

A DOUBLE QUOTE MARK (") followed by a character specifies that character as a replacement for the current value of the location. Replacement input must be terminated by a carriage return, linefeed, or up arrow; each of these delimiters will also perform the function ascribed to it elsewhere in this list, e.g., a linefeed will delimit replacement input and then cause the next location to be displayed. If an attempt is made to enter more than one character following a double quote mark, DEBUG will respond with a question mark and will not accept either character entered.

```
>$C<cr>          (set output mode to Character)
>47D8/ @ " B<cr> (value displayed as Character, replaced
>./ B<cr>        with letter B; new value displayed)
>                (return to command mode)
```

(In this example, the period is used to designate the last location displayed; see the rules for expressions in subsection 2.1, above.)

A COLON indicates that subsequent input is an instruction. It is possible to enter a multiple byte instruction in place of a single byte instruction; input will be placed in successive memory locations and the previous contents of those locations will be overwritten. Such a disturbance of the previous contents of memory will seldom be desirable.

To enter a replacement in Instruction format, type the mnemonic for the instruction, rather than the corresponding machine code. The standard Intel instruction mnemonics have been implemented. (See the appendix of 880 Operation Codes.) Most of the standard symbolic names for registers may be used in the operand field; the two exceptions are that "P" should be used to denote the Program Status Word (PSW) and "S" should be used to denote the Stack Pointer (SP). The instruction must be entered immediately after the colon. Use a single blank to separate operands from the operation code, and a comma to separate two operands. Terminate the input with a carriage return, linefeed, or up arrow; any of these delimiters will first delimit the input and then perform the function ascribed to it elsewhere in this list, e.g., a carriage return will delimit the input and then cause a return to command mode.

```
>$H<cr>          (set output mode to Hexadecimal)
>2113/ 1C ;INR E : INR C<cr> (value displayed in Hex, then as
>                Instruction; Instruction input and
>                return to command mode)
```

A LINEFEED causes the contents of the next location to be displayed. If the current output mode is Instruction mode and the last location

examined was interpreted as the first byte of a multiple-byte instruction, the next one or two locations, if examined by means of the linefeed, will be displayed in Hexadecimal.

```
>$I<cr>          (set output mode to Instruction)
>5002/MOV D,B <linefeed> (value displayed; display next
5003 LXI SP, <linefeed> location, and next...)
5004 3E <linefeed>      (second and third bytes of multi-byte
5005 F5 <cr>           instruction are displayed in Hex)
>                    (return to command mode)
```

An UP ARROW C) causes the content of the previous location to be examined. If the current mode is Instruction mode, the location will be assumed to be the first byte of an instruction (whether or not this is actually the case) and will be decoded into an 8080 instruction mnemonic. (Consider that whereas it is possible to determine from an operation code how many subsequent bytes are part of the instruction, it is not always possible to tell whether or not PRECEDING bytes are operation codes.)

```
>$C<cr>          (set output mode to Character)
>2300/ G ^       (value displayed as Character)
2299 U<cr>       (value of previous location displayed)
>                (return to command mode)
```

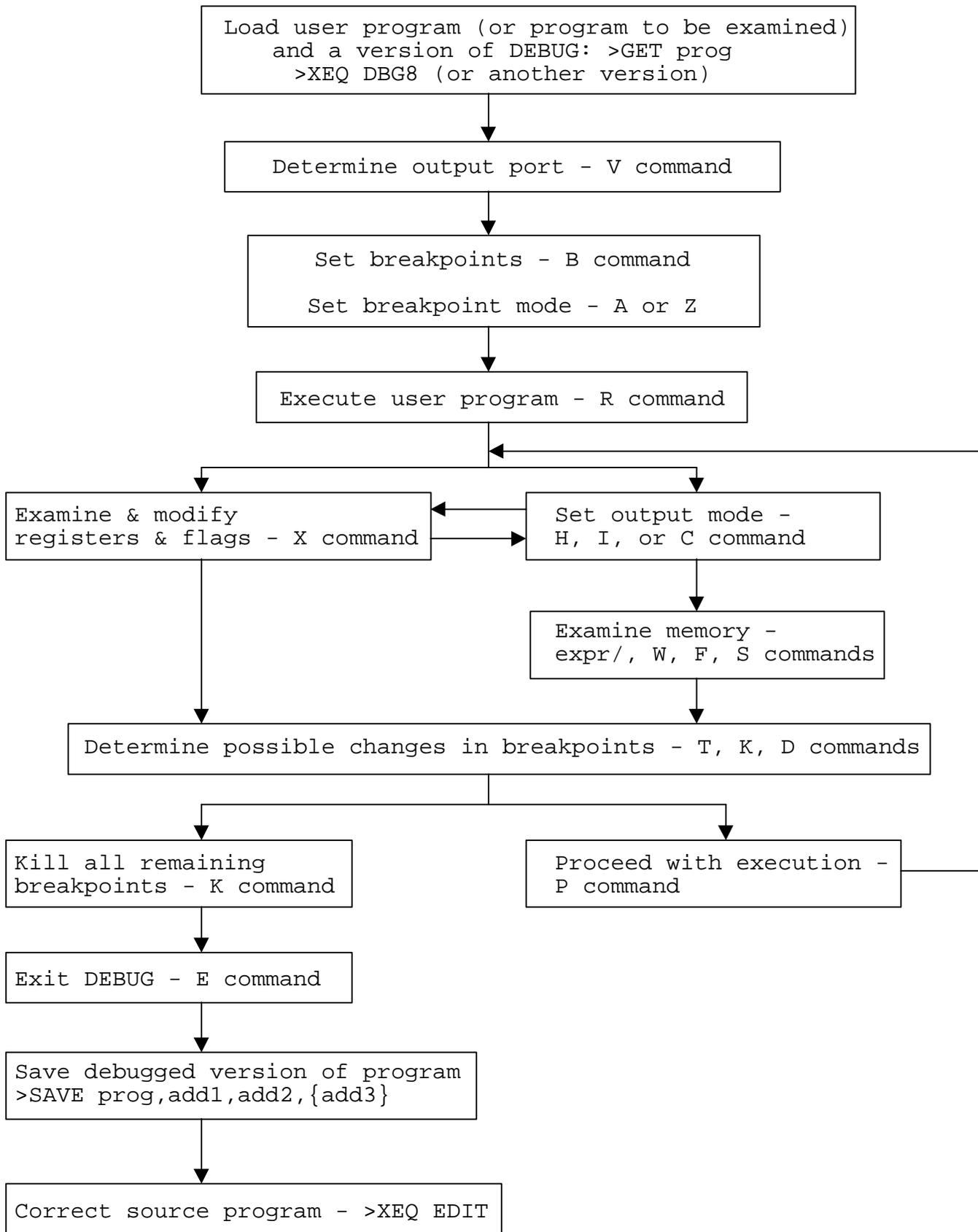


Fig. 2-1 Typical Procedure for Using DEBUG to Debug A Program

## 2.4 A WALK THROUGH THE DEBUGGER

The example below illustrates the use of DEBUG to locate and correct the errors in an assembly language program. The next few pages consist entirely of tutorial material; they do not contain any additional information about the features of the debugger. The figure on the facing page is a generalized diagram of the process of using DEBUG to debug a program. This figure and the command summary in subsection 2.2 are intended to serve as your quick reference materials after you have read the detailed descriptions in the rest of the manual.

### SAMPLE PROBLEM

Below is the assembler listing of a routine just added to a large program called TEST. The purpose of this routine is to move BC bytes of information from one area of memory to another. When the routine is first called, the H and L registers point to the first of BC consecutive locations occupied by the information to be moved; the D and E registers point to the first of BC consecutive locations to be occupied by the same information when control returns to the calling routine. The calling routine prints out the BC bytes beginning at the location to which the first byte was moved.

```
0100 78          BMOVE  MOV    A,B
0101 B1          ORA    C
0102 C8          RZ     .
0103 0B          DCX   B
0104 7E          MOV   A,M
0105 12          STAX  D
0106 24          INR   H
0107 14          INR   D
0108 C3 00 01   JMP   BMOVE
```

Let us assume that we have run TEST in SOLOS/CUTER, and that where we would expect 7 bytes, the characters F, I, D, D, L, E, and S, to be printed out as the ASCII string FIDDLES, we see a good first character 'F' followed by a great deal of suspicious screen activity. (Write and execute a program that calls BMOVE and then prints out about 100 bytes, beginning at the location indexed by D and E at the time of the call.) Let us also assume that we do not immediately recognize the bugs in the program, and that we decide to use the debugger to take a closer look at the BMOVE routine during its execution.

Remember that the symbol > is the prompt character and should not be typed. Also, \$ signifies the ESCape key, not the dollar sign.

1) LOAD TEST and DEBUG from SOLOS/CUTER

```
>CA<cr>
>GET TEST<cr>      (SOLOS/CUTER will print load address and
                    byte count on the same line as the command.)
>CA<cr>
>XEQ DBG8<cr>     (or whatever version you want to use.)
```

TEST is loaded but not executed. DEBUG is loaded and executed.

RST? 3

DEBUG asks user to assign restart location. User enters 3.

2) DETERMINE OUTPUT PORT V command

>\$V<cr>

Output will be sent to the internal VDM driver, instead of to the current SOLOS/CUTER pseudo-port. (If the current pseudo-port setting is the VDM, it really does not matter which output driver you use.)

3) SET BREAKPOINTS) with B command

>\$B0102<cr>

Because only the first byte of information appears to have been moved properly (see description above), it is worth checking whether the BMOVE loop is executed only once, that is, whether the zero flag is set and causes a return the second time the RZ instruction is reached. By setting a breakpoint at 0102H, we can examine the condition of the flags at the time of the RZ instruction. (More breakpoints could, of course, be set; to simplify this example, we set only one at a time.)

4) SET BREAKPOINT MODE with A or Z command

>\$A<cr>

Breakpoints will not be deleted automatically after they have been encountered once. The distinction between the modes is relevant here, because the breakpoint at 0102H will give useful information only the second time it is encountered. (It is actually unnecessary to use the A command, unless the Z command has been used previously; Static breakpoint mode is set when the DEBUG program begins to run.)

5) EXECUTE USER PROGRAM (or program to be examined) with R command

>\$R1200<cr>

The address specified in this command is the starting address of the program called TEST. Execution will proceed until it reaches the breakpoint address; then that address and the contents of all registers and flags will be displayed.

\*0102

A=07 B=00 C=07 D=00 E=65 F=N H=00 L=50 M=46 S=625C P=0102

Assuming that we intended to move 7 bytes of information beginning at address 50 to consecutive addresses beginning at 65, all is well so far. The STAX operation will put the value 46 (or ASCII 'F') in location 0065H. (M represents the value of the location addressed by H and L.)

SET OUTPUT MODE With H, I, or C commands  
EXAMINE MEMORY with expr, W, F, or S command

For good measure, we can EXAMINE MEMORY to make sure that the characters F, I, D, D, L, E, and S are actually stored at consecutive locations beginning at 50. The W command can be used to display the locations; output mode does not need to be set to Character, because in the default Hexadecimal mode the dump will appear both in Hexadecimal and in Characters.

```
>$W50,56<cr>
```

```
0050 46 49 50 44 4C 45 53 FIPDLES
```

The dump shows that the third character is incorrect. To insert the correct character at address 52, we can enter

```
>$C<cr>
```

to set the output mode to Character, and then

```
>52/
```

to display the contents of location 52. The contents of the location will be displayed right after the slash. To enter the correct character, we type a double quote ("), the character, and a carriage return. Now the line looks like this:

```
>52/ P " D<cr>
```

Of course, the fact that there was a P instead of a D at location 52 does not account for the fact that the program does not run properly.

#### 6) DETERMINE POSSIBLE CHANGES IN BREAKPOINTS with T,K,D,B

In this instance, we have no real reason to type out or delete our one breakpoint, but we might want to add a breakpoint at address 0108H. By looking at the registers at that point, we can see whether the locations addressed by HL and DE are what we would expect them to be, i.e., whether the value of each of these register pairs has been incremented by 1.

```
>$B0108<cr>
```

#### 7) PROCEED FROM BREAKPOINT with P command

```
>$P<cr>
```

Execution will continue until the next breakpoint is encountered.

```
*0108
```

```
A=46 B=00 C=06 D=01 E=65 F=N H=01 L=50 M=2E S=625C P=0108
```

From this display of the values of registers and flags, it becomes clear that the register pairs that address memory locations have

actually been incremented not by 1, but by 100H (256 Decimal). In order to verify that data is actually being stored at every hundredth (or 256th) address, we can proceed with execution until the next time 0108H is reached. Then we can use other commands to examine memory locations in the areas from which and to which we want to move our data. To proceed with execution, we enter the command

```
>$P<cr>
```

(We will not delete the breakpoint at 0102, because we might want to look at it again; the next time that breakpoint is encountered, however, we can ignore it and Proceed with execution.)

When we reach 0108, the values of registers and flags are:

```
*0108  
A=2E B=00 C=05 D=02 E=65 F=N H=02 L=50 M=06 S=625C P=0108
```

8) EXAMINE MEMORY with the `expr/` command

If we enter the command to examine locations 150 and 165, we can indeed see that the second byte to be moved was taken from location 150 and moved to 165, instead of being taken from location 51 and moved to 66.

```
>150/ @<cr>  
>165/ @<cr>
```

If we look at location 66, we find whatever value was at that location when the debugger began its operation:

```
>66/ .<cr>
```

If our sample routine were not so short, we might want to use the MEMORY SEARCH (S) command to locate the part of the program containing the INX instructions. The table of 8080 Operation Mnemonics in the ASSM subsystem manual indicates that INX H, which should be one of our instructions, corresponds to the Hexadecimal value of 23. To search a section of memory above our most recent breakpoint, we can enter

```
>$S100,108,23<cr>
```

only to find that the BMOVE routine does not contain an INX H instruction at all!

Using the `expr` command to EXAMINE MEMORY, we can look at the code in the same area that we just searched for INX. First we shall change the output mode to Instruction, so that we will see the contents of memory as a series of assembly language instructions, rather than as Hexadecimal numbers.

```

>$I<cr>
>0100/ MOV A,B<linefeed>    (you enter the linefeeds)
0101/  ORA C<linefeed>
0102/  RZ .<linefeed>
      etc.
0106/  INR H<linefeed>
0107/  INR D<cr>

```

Now the cause of our troubles is clear: instead of adding 1 to each of the register pairs HL and DE, we have added 1 to each of the single registers H and L. By examining locations 0106 and 0107 again, we can change the two INR instructions to IT4X instructions and solve our problem. The colon indicates instruction input.

```

>0106/ INR H :INX H<linefeed>
0107   INR D :INX D<cr>

```

#### 9) EXAMINE AND MODIFY REGISTERS AND FLAGS with X command

We have found the bug in BMOVE and want to continue running TEST, rather than reinitiate execution of that calling program. We can use the X command to modify several registers, and so backtrack in our execution of the program to a point before BMOVE first put an incorrect byte in an incorrect location.

Remember, we are still at a breakpoint. The X command without a register specification will cause the contents of all registers and flags to be displayed:

```

>$X<cr>
A=2E B=00 C=85 D=02 E=65 F=P H=02 L=50 P9=B6 S=625C P=0108

```

The bug in BMOVE caused all bytes but the first to be moved to incorrect locations in memory. To backtrack to the point from which we want to reinitiate execution, we must alter the following registers:

C, so that BC indicates that the last 6 of the 7 bytes that compose the (English) word FIDDLE must still be moved:

```

>$XC
C=05 06

```

D and E, so that they point to the next location to which information should be moved:

```

>$XD
D=02 00
>$XE
E=65 66

```

and

H and L, so that they point to the next location from which information should be taken.

```
>$XH
H=02 00
>$XL
L=50 51
```

10) KILL ALL BREAKPOINTS using K command

Before either proceeding with execution or exiting to PTDOS to save the file, we kill all current breakpoints. In order to have used almost all possible commands in this example, we may as well type out the breakpoints first with the T command.

```
>$T<cr>
0102
0108
>$K<cr>
```

11) EXIT DEBUG with the E command

```
>$E<cr>
```

This is the command to return to SOLOS/CUTER. Once in SOLOS/CUTER, we can use the SAVE command to save the object file, and EDIT to alter the source code file.

