DIGITAL RESEARCH™

CP/M-86®

Operating System

Programmer's Guide

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Foreword

This manual assists the 8086 assembly language programmer working in a CP/M-86® environment. It assumes you are familiar with the CP/M-86 implementation of CP/M and have read the following Digital Research publications:

- *CP/M 2 Documentation*
- *CP/M-86 Operating System User's Guide*

The reader should also be familiar with the 8086 assembly language instruction set, which is defined in Intel®'s *8086 Family User's Manual.*

The first section of this manual discusses ASM-86™ operation and the various assembler options which may be enabled when invoking ASM-86. One of these options controls the hexadecimal output format. ASM-86 can generate 8086 machine code in either Intel or Digital Research format. These two hexadecimal formats are described in Appendix A.

The second section discusses the elements of ASM-86 assembly language. It defines ASM-86's character set, constants, variables, identifiers, operators, expressions, and statements.

The third section discusses the ASM-86 directives, which perform housekeeping functions such as requesting conditional assembly, including multiple source files, and controlling the format of the listing printout.

The fourth section is a concise summary of the 8086 instruction mnemonics accepted by ASM-86. The mnemonics used by the Digital Research assembler are the same as those used by the Intel assembler except for four instructions: the intra-segment short jump, and inter-segment jump, return and call instructions. These differences are summarized in Appendix B.

The fifth section of this manual discusses the code-macro facilities of ASM-86. Code-macro definition, specifiers and modifiers as well as nine special code-macro directives are discussed. This information is also summarized in Appendix H.

The sixth section discusses the DDT-86™ program, which allows the user to test and debug programs interactively in the CP/M-86 enviornment. Section 6 includes a DDT-86 sample debugging session.

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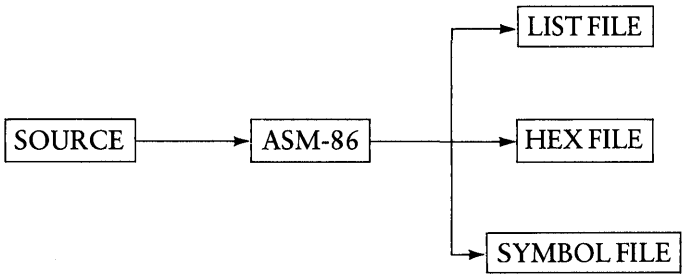
Section 1
Introduction

1.1 Assembler Operation

ASM-86 processes an 8086 assembly language source file in three passes and produces three output files, including an 8086 machine language file in hexadecimal format. This object file may be in either Intel or Digital Research hex format, which are described in Appendix C. ASM-86 is shipped in two forms: an 8086 cross-assembler designed to run under CP/M® on an Intel 8080 or Zilog Z80® based system, and a 8086 assembler designed to run under CP/M-86 on an Intel 8086 or 8088 based system. ASM-86 typically produces three output files from one input file as shown in Figure 1-1, below.



<*file name*>.A86 - contains source
<*file name*>.LST - contains listing
<*file name*>.H86 - contains assembled program in hexadecimal format
<*file name*>.SYM - contains all user-defined symbols

Figure 1-1. ASM-86 Source and Object Files

Figure 1-1 also lists ASM-86 filename extensions. ASM-86 accepts a source file with any three letter extension, but if the extension is omitted from the invoking command, it looks for the specified filename with the extension .A86 in the directory. If the file has an extension other than .A86 or has no extension at all, ASM-86 returns an error message.

The other extensions listed in Figure 1-1 identify ASM-86 output files. The .LST file contains the assembly language listing with any error messages. The .H86 file contains the machine language program in either Digital Research or Intel hexadecimal format. The .SYM file lists any user-defined symbols.

Invoke ASM-86 by entering a command of the following form:

ASM86 <*source filename*> [$ <*optional parameters*>]

Section 1.2 explains the optional parameters. Specify the source file in the following form:

[<*optional drive*>:]<*filename*>[.<*optional extension*>]

where

<*optional drive*>	is a valid drive letter specifying the source file's location. Not needed if source is on current drive.
<*filename*>	is a valid CP/M filename of 1 to 8 characters.
<*optional extension*>	is a valid file extension of 1 to 3 characters, usually .A86.

Some examples of valid ASM-86 commands are:

```
A>ASM86 B:BIOS88

A>ASM86 BIOS88.A86  $FI AA HB PB SB

A>ASM86 D:TEST
```

Once invoked, ASM-86 responds with the message:

CP/M 8086 ASSEMBLER VER x.x

where x.x is the ASM-86 version number. ASM-86 then attempts to open the source file. If the file does not exist on the designated drive, or does not have the correct extension as described above, the assembler displays the message:

```
NO FILE
```

If an invalid parameter is given in the optional parameter list, ASM-86 displays the message:

```
PARAMETER ERROR
```

After opening the source, the assembler creates the output files. Usually these are placed on the current disk drive, but they may be redirected by optional parameters, or by a drive specification in the source file name. In the latter case, ASM-86 directs the output files to the drive specified in the source file name.

During assembly, ASM-86 aborts if an error condition such as disk full or symbol table overflow is detected. When ASM-86 detects an error in the source file, it places an error message line in the listing file in front of the line containing the error. Each error message has a number and gives a brief explanation of the error. Appendix H lists ASM-86 error messages. When the assembly is complete, ASM-86 displays the message:

END OF ASSEMBLY. NUMBER OF ERRORS: n

1.2 Optional Run-time Parameters

The dollar-sign character, $, flags an optional string of run-time parameters. A parameter is a single letter followed by a single letter device name specification. The parameters are shown in Table 1-1, below.

Table 1-1. Run-time Parameters

Parameter	*To Specify*	*Valid Arguments*
A	source file device	A, B, C, ... P
H	hex output file device	A ... P, X, Y, Z
P	list file device	A ... P, X, Y, Z
S	symbol file device	A ... P, X, Y, Z
F	format of hex output file	I, D

All parameters are optional, and can be entered in the command line in any order. Enter the dollar sign only once at the beginning of the parameter string. Spaces may separate parameters, but are not required. No space is permitted, however, between a parameter and its device name.

A device name must follow parameters A, H, P and S. The devices are labeled:

A, B, C, ... P or X, Y, Z

Device names A through P respectively specify disk drives A through P. X specifies the user console (CON:), Y specifies the line printer (LST:), and Z suppresses output (NUL:).

If output is directed to the console, it may be temporarily stopped at any time by typing a control-S. Restart the output by typing a second control-S or any other character.

The F parameter requires either an I or a D argument. When I is specified, ASM-86 produces an object file in Intel hex format. A D argument requests Digital Research hex format. Appendix C discusses these formats in detail. If the F parameter is not entered in the command line, ASM-86 produces Digital Research hex format.

Table 1-2. Run-time Parameter Examples

Command Line	*Result*
ASM86 IO	Assemble file IO.A86, produce IO.HEX, IO.LST and IO.SYM, all on the default drive.
ASM86 IO.ASM $ AD SZ	Assemble file IO.ASM on device D, produce IO.LST and IO.HEX, no symbol file.
ASM86 IO $ PY SX	Assemble file IO.A86, produce IO.HEX, route listing directly to printer, output symbols on console.
ASM86 IO $ FD	Produce Digital Research hex format.
ASM86 IO $ FI	Produce Intel hex format.

1.3 Aborting ASM-86

You may abort ASM-86 execution at any time by hitting any key on the console keyboard. When a key is pressed, ASM-86 responds with the question:

```
USER BREAK. OK(Y/N)?
```

A Y response aborts the assembly and returns to the operating system. An N response continues the assembly.

End of Section 1

Section 2
Elements of ASM-86 Assembly Language

2.1 ASM-86 Character Set

ASM-86 recognizes a subset of the ASCII character set. The valid characters are the alphanumerics, special characters, and non-printing characters shown below:

```
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
0 1 2 3 4 5 6 7 8 9

+ - * / = ( ) [ ] ; ' . ! , _ : @ $

space, tab, carriage-return, and line-feed
```

Lower-case letters are treated as upper-case except within strings. Only alphanumerics, special characters, and spaces may appear within a string.

2.2 Tokens and Separators

A token is the smallest meaningful unit of an ASM-86 source program, much as a word is the smallest meaningful unit of an English composition. Adjacent tokens are commonly separated by a blank character or space. Any sequence of spaces may appear wherever a single space is allowed. ASM-86 recognizes horizontal tabs as separators and interprets them as spaces. Tabs are expanded to spaces in the list file. The tab stops are at each eighth column.

2.3 Delimiters

Delimiters mark the end of a token and add special meaning to the instruction, as opposed to separators, which merely mark the end of a token. When a delimiter is present, separators need not be used. However, separators after delimiters can make your program easier to read.

Table 2-1 describes ASM-86 separators and delimiters. Some delimiters are also operators and are explained in greater detail in Section 2.6.

Table 2-1. Separators and Delimiters

Character	*Name*	*Use*
20H	space	separator
09H	tab	legal in source files, expanded in list files
CR	carriage return	terminate source lines
LF	line feed	legal after CR; if within source lines, it is interpreted as a space
;	semicolon	start comment field
:	colon	identifies a label, used in segment override specification
.	period	forms variables from numbers
$	dollar sign	notation for 'present value of location pointer'
+	plus	arithmetic operator for addition
–	minus	arithmetic operator for subtraction
*	asterisk	arithmetic operator for multiplication
/	slash	arithmetic operator for division
@	at-sign	legal in identifiers
_	underscore	legal in identifiers
!	exclamation point	logically terminates a statement, thus allowing multiple statements on a single source line
'	apostrophe	delimits string constants

2.4 Constants

A constant is a value known at assembly time that does not change while the assembled program is executed. A constant may be either an integer or a character string.

2.4.1 Numeric Constants

A numeric constant is a 16-bit value in one of several bases. The base, called the radix of the constant, is denoted by a trailing radix indicator. The radix indicators are shown in Table 2-2, below.

Table 2-2. Radix Indicators for Constants

Indicator	*Constant Type*	*Base*
B	binary	2
O	octal	8
Q	octal	8
D	decimal	10
H	hexadecimal	16

ASM-86 assumes that any numeric constant not terminated with a radix indicator is a decimal constant. Radix indicators may be upper or lower case.

A constant is thus a sequence of digits followed by an optional radix indicator, where the digits are in the range for the radix. Binary constants must be composed of 0's and 1's. Octal digits range from 0 to 7; decimal digits range from 0 to 9. Hexadecimal constants contain decimal digits as well as the hexadecimal digits A (10D), B (11D), C (12D), D (13D), E (14D), and F (15D). Note that the leading character of a hexadecimal constant must be either a decimal digit so that ASM-86 cannot confuse a hex constant with an identifier, or leading 0 to prevent this problem. The following are valid numeric constants:

```
1234     1234D    1100B    1111000011110000B
1234H    0FFEH    33770    13772Q
33770    0FE3H    1234d    0fffh
```

2.4.2 Character Strings

ASM-86 treats an ASCII character string delimited by apostrophes as a string constant. All instructions accept only one- or two-character constants as valid arguments. Instructions treat a one-character string as an 8-bit number. A two-character string is treated as a 16-bit number with the value of the second character in the low-order byte, and the value of the first character in the high-order byte.

The numeric value of a character is its ASCII code. ASM-86 does not translate case within character strings, so both upper- and lower-case letters can be used. Note that only alphanumerics, special characters, and spaces are allowed within strings.

A DB assembler directive is the only ASM-86 statement that may contain strings longer than two characters. The string may not exceed 255 bytes. Include any apostrophe to be printed within the string by entering it twice. ASM-86 interprets the two keystrokes '' as a single apostrophe. Table 2-3 shows valid strings and how they appear after processing:

Table 2-3. String Constant Examples

```
              'a' -> a
         'Ab''Cd' -> Ab,'Cd
    'I like CP/M' -> I like CP/M
              '''' -> '
'ONLY UPPER CASE' -> ONLY UPPER CASE
'only lower case' -> only lower case
```

2.5 Identifiers

Identifiers are character sequences which have a special, symbolic meaning to the assembler. All identifiers in ASM-86 must obey the following rules:

1. The first character must be alphabetic (A,...Z, a,...z).
2. Any subsequent characters can be either alphabetical or a numeral (0,1,.....9). ASM-86 ignores the special characters @ and _, but they are still legal. For example, a_b becomes ab.
3. Identifiers may be of any length up to the limit of the physical line.

Identifiers are of two types. The first are keywords, which have predefined meanings to the assembler. The second are symbols, which are defined by the user. The following are all valid identifiers:

```
NOLIST
WORD
AH
Third_street
How_are_you_today
variable@number@1234567890
```

2.5.1 Keywords

A keyword is an identifier that has a predefined meaning to the assembler. Keywords are reserved; the user cannot define an identifier identical to a keyword. For a complete list of keywords, see Appendix D.

ASM-86 recognizes five types of keywords: instructions, directives, operators, registers and predefined numbers. 8086 instruction mnemonic keywords and the actions they initiate are defined in Section 4. Directives are discussed in Section 3. Section 2.6 defines operators. Table 2-4 lists the ASM-86 keywords that identify 8086 registers.

Three keywords are predefined numbers: BYTE, WORD, and DWORD. The values of these numbers are 1, 2 and 4, respectively. In addition, a Type attribute is associated with each of these numbers. The keyword's Type attribute is equal to the keyword's numeric value. See Section 2.5.2 for a complete discussion of Type attributes.

Table 2-4. Register Keywords

Register Symbol	*Size*	*Numeric Value*	*Meaning*
AH	1 byte	100 B	Accumulator-High-Byte
BH	1 '	111 B	Base-Register-High-Byte
CH	1 '	101 B	Count-Register-High-Byte
DH	1 '	110 B	Data-Register-High-Byte
AL	1 '	000 B	Accumulator-Low-Byte
BL	1 '	011 B	Base-Register-Low-Byte
CL	1 '	001 B	Count-Register-Low-Byte
DL	1 '	010 B	Data-Register-Low-Byte
AX	2 bytes	000 B	Accumulator (full word)
BX	2 '	011 B	Base-Register '
CX	2 '	001 B	Count-Register '
DX	2 '	010 B	Data-Register '
BP	2 '	101 B	Base Pointer
SP	2 '	100 B	Stack Pointer
SI	2 '	110 B	Source Index
DI	2 '	111 B	Destination Index
CS	2 '	01 B	Code-Segment-Register
DS	2 '	11 B	Data-Segment-Register
SS	2 '	10 B	Stack-Segment-Register
ES	2 '	00 B	Extra-Segment-Register

2.5.2 Symbols and Their Attributes

A symbol is a user-defined identifier that has attributes which specify what kind of information the symbol represents. Symbols fall into three categories:

- variables
- labels
- numbers

Variables identify data stored at a particular location in memory. All variables have the following three attributes:

- Segment—tells which segment was being assembled when the variable was defined.
- Offset—tells how many bytes there are between the beginning of the segment and the location of this variable.
- Type—tells how many bytes of data are manipulated when this variable is referenced.

A Segment may be a code-segment, a data-segment, a stack-segment or an extra-segment depending on its contents and the register that contains its starting address (see Section 3.2). A segment may start at any address divisible by 16. ASM-86 uses this boundary value as the Segment portion of the variable's definition.

The Offset of a variable may be any number between 0 and 0FFFFH or 65535D. A variable must have one of the following Type attributes:

- BYTE
- WORD
- DWORD

BYTE specifies a one-byte variable, WORD a two-byte variable and DWORD a four-byte variable. The DB, DW, and DD directives respectively define variables as these three types (see Section 3). For example, a variable is defined when it appears as the name for a storage directive:

```
VARIABLE  DB 0
```

A variable may also be defined as the name for an EQU directive referencing another label, as shown below:

```
VARIABLE   EQU   ANOTHER_VARIABLE
```

Labels identify locations in memory that contain instruction statements. They are referenced with jumps or calls. All labels have two attributes:

- Segment
- Offset

Label segment and offset attributes are essentially the same as variable segment and offset attributes. Generally, a label is defined when it precedes an instruction. A colon, :, separates the label from instruction; for example:

```
LABEL:    ADD   AX,BX
```

A label may also appear as the name for an EQU directive referencing another label; for example:

```
LABEL    EQU    ANOTHER_LABEL
```

Numbers may also be defined as symbols. A number symbol is treated as if you had explicitly coded the number it represents. For example:

```
Number_five     EQU    5
MOV    AL,Number_five
```

is equivalent to:

```
MOV    AL,5
```

Section 2.6 describes operators and their effects on numbers and number symbols.

2.6 Operators

ASM-86 operators fall into the following categories: arithmetic, logical, and relational operators, segment override, variable manipulators and creators. Table 2-5 defines ASM-86 operators. In this table, a and b represent two elements of the expression. The validity column defines the type of operands the operator can manipulate, using the or bar character, |, to separate alternatives.

Table 2-5. ASM-86 Operators

Syntax	*Result*	*Validity*
	Logical Operators	
a XOR b	bit-by-bit logical EXCLUSIVE OR of a and b.	a, b = number
a OR b	bit-by-bit logical OR of a and b.	a, b = number
a AND b	bit-by-bit logical AND of a and b.	a, b = number
NOT a	logical inverse of a: all 0's become 1's, 1's become 0's.	a = 16-bit number
	Relational Operators	
a EQ b	returns 0FFFFH if a = b, otherwise 0.	a, b = unsigned number
a LT b	returns 0FFFFH if a < b, otherwise 0.	a, b = unsigned number
a LE b	returns 0FFFFH if a <= b, otherwise 0.	a, b = unsigned number
a GT b	returns 0FFFFH if a > b, otherwise 0.	a, b = unsigned number
a GE b	returns 0FFFFH if a >= b, otherwise 0.	a, b = unsigned number
a NE b	returns 0FFFFH if a < > b, otherwise 0.	a, b = unsigned number
	Arithmetic Operators	
a + b	arithmetic sum of a and b.	a = variable, label or number b = number
a − b	arithmetic difference of a and b.	a = variable, label or number b = number

Table 2-5. (continued)

Syntax	*Result*	*Validity*
a * b	does unsigned multiplication of a and b.	a, b = number
a / b	does unsigned division of a and b.	a, b = number
a MOD b	returns remainder of a / b.	a, b = number
a SHL b	returns the value which results from shifting a to left by an amount b.	a, b = number
a SHR b	returns the value which results from shifting a to the right by an amount b.	a, b = number
+ a	gives a.	a = number
− a	gives 0 − a.	a = number
Segment Override		
<seg reg>: *<addr exp>*	overrides assembler's choice of segment register.	*<seg reg>* = CS, DS, SS or ES
Variable Manipulators, Creators		
SEG a	creates a number whose value is the segment value of the variable or label a.	a = label | variable
OFFSET a	creates a number whose value is the offset value of the variable or label a.	a = label | variable

Table 2-5. (continued)

Syntax	*Result*	*Validity*
TYPE a	creates a number. If the variable a is of type BYTE, WORD or DWORD, the value of the number will be 1, 2 or 4, respectively.	a = label | variable
LENGTH a	creates a number whose value is the LENGTH attribute of the variable a. The length attribute is the number of bytes associated with the variable.	a = label | variable
LAST a	if LENGTH a > 0, then LAST a = LENGTH a − 1; if LENGTH a = 0, then LAST a = 0.	a = label | variable
a PTR b	creates virtual variable or label with type of a and attributes of b.	a = BYTE | WORD, | DWORD b = <*addr exp*>
.a	creates variable with an offset attribute of a. Segment attribute is current segment.	a = number
$	creates label with offset equal to current value of location counter; segment attribute is current segment.	no argument

2.6.1 Operator Examples

Logical operators accept only numbers as operands. They perform the boolean logic operations AND, OR, XOR, and NOT. For example:

```
  00FC              MASK    EQU     0FCH
  0080              SIGNBIT EQU     80H
0000 B180                   MOV     CL,MASK AND SIGNBIT
0002 B003                   MOV     AL,NOT MASK
```

Relational operators treat all operands as unsigned numbers. The relational operators are EQ (equal), LT (less than), LE (less than or equal), GT (greater than), GE (greater than or equal), and NE (not equal). Each operator compares two operands and returns all ones (0FFFFH) if the specified relation is true and all zeros if it is not. For example:

```
  000A              LIMIT1  EQU     10
  0019              LIMIT2  EQU     25
                            .
                            .
                            .
0004 B8FFFF                 MOV     AX,LIMIT1 LT LIMIT2
0007 B80000                 MOV     AX,LIMIT1 GT LIMIT2
```

Addition and subtraction operators compute the arithmetic sum and difference of two operands. The first operand may be a variable, label, or number, but the second operand must be a number. When a number is added to a variable or label, the result is a variable or label whose offset is the numeric value of the second operand plus the offset of the first operand. Subtraction from a variable or label returns a variable or label whose offset is that of first operand decremented by the number specified in the second operand. For example:

```
  0002              COUNT   EQU     2
  0005              DISP1   EQU     5
000A FF             FLAG    DB      0FFH
                            .
                            .
                            .
000B 2EA00B00               MOV     AL,FLAG+1
000F 2E8A0E0F00             MOV     CL,FLAG+DISP1
0014 B303                   MOV     BL,DISP1-COUNT
```

The multiplication and division operators *, /, MOD, SHL, and SHR accept only numbers as operands. * and / treat all operators as unsigned numbers. For example:

```
0016 BE5500                    MOV     SI,256/3
0019 B310                      MOV      BL,64/4
  0050                BUFFERSIZE       EQU      80
001B B8A000                    MOV      AX,BUFFERSIZE * 2
```

Unary operators accept both signed and unsigned operators as shown below:

```
001E B123                      MOV      CL,+35
0020 B007                      MOV      AL,2--5
0022 B2F4                      MOV      DL,-12
```

When manipulating variables, the assembler decides which segment register to use. You may override the assembler's choice by specifying a different register with the segment override operator. The syntax for the override operator is *<segment register> : <address expression>* where the *<segment register>* is CS, DS, SS, or ES. For example:

```
0024 368B472D                  MOV      AX,SS:WORDBUFFER[BX]
0028 268B0E5B00                MOV      CX,ES:ARRAY
```

A variable manipulator creates a number equal to one attribute of its variable operand. SEG extracts the variable's segment value, OFFSET its offset value, TYPE its type value (1, 2, or 4), and LENGTH the number of bytes associated with the variable. LAST compares the variable's LENGTH with 0 and if greater, then decrements LENGTH by one. If LENGTH equals 0, LAST leaves it unchanged. Variable manipulators accept only variables as operators. For example:

```
002D 000000000000 WORDBUFFER     DW       0,0,0
0033 0102030405   BUFFER         DB       1,2,3,4,5
                                 .
                                 .
                                 .
0038 B80500                    MOV      AX,LENGTH BUFFER
003B B80400                    MOV      AX,LAST BUFFER
003E B80100                    MOV      AX,TYPE BUFFER
0041 B80200                    MOV      AX,TYPE WORDBUFFER
```

The PTR operator creates a virtual variable or label, one valid only during the execution of the instruction. It makes no changes to either of its operands. The temporary symbol has the same Type attribute as the left operator, and all other attributes of the right operator as shown below.

```
0044 C60705                    MOV     BYTE PTR [BX], 5
0047 8A07                      MOV     AL,BYTE PTR [BX]
0049 FF04                      INC     WORD PTR [SI]
```

The Period operator, ., creates a variable in the current data segment. The new variable has a segment attribute equal to the current data segment and an offset attribute equal to its operand. Its operand must be a number. For example:

```
004B A10000                    MOV     AX, .0
004E 268B1E0040                MOV     BX, ES: .4000H
```

The Dollar-sign operator, $, creates a label with an offset attribute equal to the current value of the location counter. The label's segment value is the same as the current code segment. This operator takes no operand. For example:

```
0053 E9FDFF                    JMP     $
0056 EBFE                      JMPS    $
0058 E9FD2F                    JMP     $+3000H
```

2.6.2 Operator Precedence

Expressions combine variables, labels or numbers with operators. ASM-86 allows several kinds of expressions which are discussed in Section 2.7. This section defines the order in which operations are executed should more than one operator appear in an expression.

In general, ASM-86 evaluates expressions left to right, but operators with higher precedence are evaluated before operators with lower precedence. When two operators have equal precedence, the left-most is evaluated first. Table 2-6 presents ASM-86 operators in order of increasing precedence.

Parentheses can override normal rules of precedence. The part of an expression enclosed in parentheses is evaluated first. If parentheses are nested, the innermost expressions are evaluated first. Only five levels of nested parentheses are legal. For example:

```
15/3 + 18/9 = 5 + 2 = 7
15/(3 + 18/9) = 15/(3 + 2) = 15/5 = 3
```

Table 2-6. Precedence of Operations in ASM-86

Order	*Operator Type*	*Operators*
1	Logical	XOR, OR
2	Logical	AND
3	Logical	NOT
4	Relational	EQ, LT, LE, GT, GE, NE
5	Addition/subtraction	+, −
6	Multiplication/division	*, /, MOD, SHL, SHR
7	Unary	+, −
8	Segment override	*<segment override>*:
9	Variable manipulators, creators	SEG, OFFSET, PTR, TYPE, LENGTH, LAST
10	Parentheses/brackets	( ), [ ]
11	Period and Dollar	., $

2.7 Expressions

ASM-86 allows address, numeric, and bracketed expressions. An address expression evaluates to a memory address and has three components:

- A segment value
- An offset value
- A type

Both variables and labels are address expressions. An address expression is not a number, but its components are. Numbers may be combined with operators such as PTR to make an address expression.

A numeric expression evaluates to a number. It does not contain any variables or labels, only numbers and operands.

Bracketed expressions specify base- and index- addressing modes. The base registers are BX and BP, and the index registers are DI and SI. A bracketed expression may consist of a base register, an index register, or a base register and an index register.

Use the + operator between a base register and an index register to specify both base- and index-register addressing. For example:

```
MOV   variable[bx],0
MOV   AX,[BX+DI]
MOV   AX,[SI]
```

2.8 Statements

Just as 'tokens' in this assembly language correspond to words in English, so are statements analogous to sentences. A statement tells ASM-86 what action to perform. Statements are of two types: instructions and directives. Instructions are translated by the assembler into 8086 machine language instructions. Directives are not translated into machine code but instead direct the assembler to perform certain clerical functions.

Terminate each assembly language statement with a carriage return (CR) and line feed (LF), or with an exclamation point, !, which ASM-86 treats as an end-of-line. Multiple assembly language statements can be written on the same physical line if separated by exclamation points.

The ASM-86 instruction set is defined in Section 4. The syntax for an instruction statement is:

[label:] [prefix] mnemonic [operand(s)] [;comment]

where the fields are defined as:

label:	A symbol followed by ':' defines a label at the current value of the location counter in the current segment. This field is optional.
prefix	Certain machine instructions such as LOCK and REP may prefix other instructions. This field is optional.
mnemonic	A symbol defined as a machine instruction, either by the assembler or by an EQU directive. This field is optional unless preceded by a prefix instruction. If it is omitted, no operands may be present, although the other fields may appear. ASM-86 mnemonics are defined in Section 4.
operand(s)	An instruction mnemonic may require other symbols to represent operands to the instruction. Instructions may have zero, one or two operands.
comment	Any semicolon (;) appearing outside a character string begins a comment, which is ended by a carriage return. Comments improve the readability of programs. This field is optional.

ASM-86 directives are described in Section 3. The syntax for a directive statement is:

[name] directive operand(s) [;comment]

where the fields are defined as:

name	Unlike the label field of an instruction, the name field of a directive is never terminated with a colon. Directive names are legal for only DB, DW, DD, RS and EQU. For DB, DW, DD and RS the name is optional; for EQU it is required.
directive	One of the directive keywords defined in Section 3.
operand(s)	Analogous to the operands to the instruction mnemonics. Some directives, such as DB, DW, and DD, allow any operand while others have special requirements.
comment	Exactly as defined for instruction statements.

End of Section 2

Section 3
Assembler Directives

3.1 Introduction

Directive statements cause ASM-86 to perform housekeeping functions such as assigning portions of code to logical segments, requesting conditional assembly, defining data items, and specifying listing file format. General syntax for directive statements appears in Section 2.8.

In the sections that follow, the specific syntax for each directive statement is given under the heading and before the explanation. These syntax lines use special symbols to represent possible arguments and other alternatives. Square brackets, [ ], enclose optional arguments. Angle brackets, <>, enclose descriptions of user-supplied arguments. Do not include these symbols when coding a directive.

3.2 Segment Start Directives

At run-time, every 8086 memory reference must have a 16-bit segment base value and a 16-bit offset value. These are combined to produce the 20-bit effective address needed by the CPU to physically address the location. The 16-bit segment base value or boundary is contained in one of the segment registers CS, DS, SS, or ES. The offset value gives the offset of the memory reference from the segment boundary. A 16-byte physical segment is the smallest relocatable unit of memory.

ASM-86 predefines four logical segments: the Code Segment, Data Segment, Stack Segment, and Extra Segment, which are respectively addressed by the CS, DS, SS, and ES registers. Future versions of ASM-86 will support additional segments such as multiple data or code segments. All ASM-86 statements must be assigned to one of the four currently supported segments so that they can be referenced by the CPU. A segment directive statement, CSEG, DSEG, SSEG, or ESEG, specifies that the statements following it belong to a specific segment. The statements are then addressed by the corresponding segment register. ASM-86 assigns statements to the specified segment until it encounters another segment directive.

Instruction statements must be assigned to the Code Segment. Directive statements may be assigned to any segment. ASM-86 uses these assignments to change from one segment register to another. For example, when an instruction accesses a memory variable, ASM-86 must know which segment contains the variable so it can generate a segment override prefix byte if necessary.

3.2.1 The CSEG Directive

CSEG *<numeric expression>*
CSEG
CSEG $

This directive tells the assembler that the following statements belong in the Code Segment. All instruction statements must be assigned to the Code Segment. All directive statements are legal within the Code Segment.

Use the first form when the location of the segment is known at assembly time; the code generated is not relocatable. Use the second form when the segment location is not known at assembly time; the code generated is relocatable. Use the third form to continue the Code Segment after it has been interrupted by a DSEG, SSEG, or ESEG directive. The continuing Code Segment starts with the same attributes, such as location and instruction pointer, as the previous Code Segment.

3.2.2 The DSEG Directive

DSEG *<numeric expression>*
DSEG
DSEG $

This directive specifies that the following statements belong to the Data Segment. The Data Segment primarily contains the data allocation directives DB, DW, DD and RS, but all other directive statements are also legal. Instruction statements are illegal in the Data Segment.

Use the first form when the location of the segment is known at assembly time; the code generated is not relocatable. Use the second form when the segment location is not known at assembly time; the code generated is relocatable. Use the third form to continue the Data Segment after it has been interrupted by a CSEG, SSEG, or ESEG directive. The continuing Data Segment starts with the same attributes as the previous Data Segment.

3.2.3 The SSEG Directive

SSEG <*numeric expression*>
SSEG
SSEG $

The SSEG directive indicates the beginning of source lines for the Stack Segment. Use the Stack Segment for all stack operations. All directive statements are legal in the Stack Segment, but instruction statements are illegal.

Use the first form when the location of the segment is known at assembly time; the code generated is not relocatable. Use the second form when the segment location is not known at assembly time; the code generated is relocatable. Use the third form to continue the Stack Segment after it has been interrupted by a CSEG, DSEG, or ESEG directive. The continuing Stack Segment starts with the same attributes as the previous Stack Segment.

3.2.4 The ESEG Directive

ESEG <*numeric expression*>
ESEG
ESEG $

This directive initiates the Extra Segment. Instruction statements are not legal in this segment, but all directive statements are.

Use the first form when the location of the segment is known at assembly time; the code generated is not relocatable. Use the second form when the segment location is not known at assembly time; the code generated is relocatable. Use the third form to continue the Extra Segment after it has been interrupted by a DSEG, SSEG, or CSEG directive. The continuing Extra Segment starts with the same attributes as the previous Extra Segment.

3.3 The ORG Directive

ORG <*numeric expression*>

The ORG directive sets the offset of the location counter in the current segment to the value specified in the numeric expression. Define all elements of the expression before the ORG directive because forward references may be ambiguous.

In most segments, an ORG directive is unnecessary. If no ORG is included before the first instruction or data byte in a segment, assembly begins at location zero relative to the beginning of the segment. A segment can have any number of ORG directives.

3.4 The IF and ENDIF Directives

```
IF <numeric expression>
   <source line 1 >
   <source line 2 >
        .
        .
        .
   <source line n >
   ENDIF
```

The IF and ENDIF directives allow a group of source lines to be included or excluded from the assembly. Use conditional directives to assemble several different versions of a single source program.

When the assembler finds an IF directive, it evaluates the numeric expression following the IF keyword. If the expression evaluates to a non-zero value, then <*source line 1*> through <*source line n*> are assembled. If the expression evaluates to zero, then all lines are listed but not assembled. All elements in the numeric expression must be defined before they appear in the IF directive. Nested IF directives are not legal.

3.5 The INCLUDE Directive

INCLUDE <*file name*>

This directive includes another ASM-86 file in the source text. For example:

```
INCLUDE  EQUALS.A86
```

Use INCLUDE when the source program resides in several different files. INCLUDE directives may not be nested; a source file called by an INCLUDE directive may not contain another INCLUDE statement. If <*file name*> does not contain a file type, the file type is assumed to be .A86. If no drive name is specified with <*file name*>, ASM-86 assumes the drive containing the source file.

3.6 The END Directive

END

An END directive marks the end of a source file. Any subsequent lines are ignored by the assembler. END is optional. If not present, ASM-86 processes the source until it finds an End-Of-File character (1AH).

3.7 The EQU Directive

symbol EQU <*numeric expression*>
symbol EQU <*address expression*>
symbol EQU <*register*>
symbol EQU <*instruction mnemonic*>

The EQU (equate) directive assigns values and attributes to user-defined symbols. The required symbol name may not be terminated with a colon. The symbol cannot be redefined by a subsequent EQU or another directive. Any elements used in numeric or address expressions must be defined before the EQU directive appears.

The first form assigns a numeric value to the symbol, the second a memory address. The third form assigns a new name to an 8086 register. The fourth form defines a new instruction (sub)set. The following are examples of these four forms:

```
0005                FIVE     EQU     2*2+1
0033                NEXT     EQU     BUFFER
0001                COUNTER  EQU     CX
                    MOVVV    EQU     MOV
                                     .
                                     .
                                     .
005D 8BC3                    MOVVV   AX,BX
```

3.8 The DB Directive

[symbol] DB <*numeric expression*>[,<*numeric expression*>..]
[symbol] DB <*string constant*>[,<*string constant*>...]

The DB directive defines initialized storage areas in byte format. Numeric expressions are evaluated to 8-bit values and sequentially placed in the hex output file. String constants are placed in the output file according to the rules defined in Section 2.4.2. A DB directive is the only ASM-86 statement that accepts a string constant longer than two bytes. There is no translation from lower to upper case within strings. Multiple expressions or constants, separated by commas, may be added to the definition, but may not exceed the physical line length.

Use an optional symbol to reference the defined data area throughout the program. The symbol has four attributes: the Segment and Offset attributes determine the symbol's memory reference, the Type attribute specifies single bytes, and Length tells the number of bytes (allocation units) reserved.

The following statements show DB directives with symbols:

```
005F 43502F4D2073 TEXT     DB      'CP/M system',0
     797374656D00
0068 E1           AA       DB      'a' + 80H
006C 0102030405   X        DB      1,2,3,4,5
                                   .
                                   .
                                   .
0071 B90C00                MOV     CX,LENGTH TEXT
```

3.9 The DW Directive

[symbol] DW <*numeric expression*>[,<*numeric expression*>..]
[symbol] DW <*string constant*>[,<*string constant*>...]

The DW directive initializes two-byte words of storage. String constants longer than two characters are illegal. Otherwise, DW uses the same procedure to initialize storage as DB. The following are examples of DW statements:

```
0074 0000           CNTR    DW      0
0076 63C166C169C1   JMPTAB  DW      SUBR1,SUBR2,SUBR3
007C 010002000300           DW      1,2,3,4,5,6
     040005000600
```

3.10 The DD Directive

[symbol] DD <*numeric expression*>[,<*numeric expression*>..]

The DD directive initializes four bytes of storage. The Offset attribute of the address expression is stored in the two lower bytes, the Segment attribute in the two upper bytes. Otherwise, DD follows the same procedure as DB. For example:

```
  1234
                                        .
                                        .
                                        .
0000 6CC134126FC1 LONG  JMPTAB      DD      ROUT1,ROUT2
     3412
0008 72C1341275C1                   DD      ROUT3,ROUT4
     3412
```

3.11 The RS Directive

[symbol] RS <*numeric expression*>

The RS directive allocates storage in memory but does not initialize it. The numeric expression gives the number of bytes to be reserved. An RS statement does not give a byte attribute to the optional symbol. For example:

```
0010                BUF     RS      80
0060                        RS      4000H
4060                        RS      1
```

3.12 The RB Directive

[symbol] RB <*numeric expression*>

The RB directive allocates byte storage in memory without any initialization. This directive is identical to the RS directive except that it does give the byte attribute.

3.13 The RW Directive

[symbol] RW <*numeric expression*>

The RW directive allocates two-byte word storage in memory but does not initialize it. The numeric expression gives the number of words to be reserved. For example:

```
4061                BUFF    RW      128
4161                        RW      4000H
C161                        RW      1
```

3.14 The TITLE Directive

TITLE <*string constant*>

ASM-86 prints the string constant defined by a TITLE directive statement at the top of each printout page in the listing file. The title character string should not exceed 30 characters. For example:

```
TITLE   'CP/M monitor'
```

3.15 The PAGESIZE Directive

PAGESIZE <*numeric expression*>

The PAGESIZE directive defines the number of lines to be included on each printout page. The default pagesize is 66.

3.16 The PAGEWIDTH Directive

PAGEWIDTH <*numeric expression*>

The PAGEWIDTH directive defines the number of columns printed across the page when the listing file is output. The default pagewidth is 120 unless the listing is routed directly to the terminal; then the default pagewidth is 79.

3.17 The EJECT Directive

EJECT

The EJECT directive performs a page eject during printout. The EJECT directive itself is printed on the first line of the next page.

3.18 The SIMFORM Directive

SIMFORM

The SIMFORM directive replaces a form-feed (FF) character in the print file with the correct number of line-feeds (LF). Use this directive when printing out on a printer unable to interpret the form-feed character.

3.19 The NOLIST and LIST Directives

NOLIST
LIST

The NOLIST directive blocks the printout of the following lines. Restart the listing with a LIST directive.

End of Section 3

Section 4
The ASM-86 Instruction Set

4.1 Introduction

The ASM-86 instruction set includes all 8086 machine instructions. The general syntax for instruction statements is given in Section 2.7. The following sections define the specific syntax and required operand types for each instruction, without reference to labels or comments. The instruction definitions are presented in tables for easy reference. For a more detailed description of each instruction, see Intel's *MCS-86 Assembly Language Reference Manual.* For descriptions of the instruction bit patterns and operations, see Intel's *MCS-86 User's Manual.*

The instruction-definition tables present ASM-86 instruction statements as combinations of mnemonics and operands. A mnemonic is a symbolic representation for an instruction, and its operands are its required parameters. Instructions can take zero, one or two operands. When two operands are specified, the left operand is the instruction's destination operand, and the two operands are separated by a comma.

The instruction-definition tables organize ASM-86 instructions into functional groups. Within each table, the instructions are listed alphabetically. Table 4-1 shows the symbols used in the instruction-definition tables to define operand types.

Table 4-1. Operand Type Symbols

Symbol	*Operand Type*
numb	any NUMERIC expression
numb8	any NUMERIC expression which evaluates to an 8-bit number
acc	accumulator register, AX or AL
reg	any general purpose register, not segment register
reg16	a 16-bit general purpose register, not segment register
segreg	any segment register: CS, DS, SS, or ES
mem	any ADDRESS expression, with or without base- and/or index-addressing modes, such as: variable variable+3 variable[bx] variable[SI] variable[BX+SI] [BX] [BP+DI]
simpmem	any ADDRESS expression WITHOUT base- and index-addressing modes, such as: variable variable+4
mem|reg	any expression symbolized by 'reg' or 'mem'
mem|reg16	any expression symbolized by 'mem|reg', but must be 16 bits
label	any ADDRESS expression which evaluates to a label
lab8	any 'label' which is within ± 128 bytes distance from the instruction

The 8086 CPU has nine single-bit Flag registers which reflect the state of the CPU. The user cannot access these registers directly, but can test them to determine the effects of an executed instruction upon an operand or register. The effects of instructions on Flag registers are also described in the instruction-definition tables, using the symbols shown in Table 4-2 to represent the nine Flag registers.

Table 4-2. Flag Register Symbols

AF	Auxiliary-Carry-Flag
CF	Carry-Flag
DF	Direction-Flag
IF	Interrupt-Enable-Flag
OF	Overflow-Flag
PF	Parity-Flag
SF	Sign-Flag
TF	Trap-Flag
ZF	Zero-Flag

4.2 Data Transfer Instructions

There are four classes of data transfer operations: general purpose, accumulator specific, address-object and flag. Only SAHF and POPF affect flag settings. Note in Table 4-3 that if acc = AL, a byte is transferred, but if acc = AX, a word is transferred.

Table 4-3. Data Transfer Instructions

Syntax		*Result*
IN	acc,numb8|numb16	transfer data from input port given by numb8 or numb16 (0-255) to accumulator
IN	acc,DX	transfer data from input port given by DX register (0-0FFFFH) to accumulator
LAHF		transfer flags to the AH register
LDS	reg16,mem	transfer the segment part of the memory address (DWORD variable) to the DS segment register, transfer the offset part to a general purpose 16-bit register
LEA	reg16,mem	transfer the offset of the memory address to a (16-bit) register
LES	reg16,mem	transfer the segment part of the memory address to the ES segment register, transfer the offset part to a 16-bit general purpose register
MOV	reg,mem|reg	move memory or register to register
MOV	mem|reg,reg	move register to memory or register
MOV	mem|reg,numb	move immediate data to memory or register
MOV	segreg,mem|reg16	move memory or register to segment register
MOV	mem|reg16,segreg	move segment register to memory or register
OUT	numb8|numb16,acc	transfer data from accumulator to output port (0-255) given by numb8 or numb16

Table 4-3. (continued)

Syntax		*Result*
OUT	DX,acc	transfer data from accumulator to output port (0-0FFFFH) given by DX register
POP	mem|reg16	move top stack element to memory or register
POP	segreg	move top stack element to segment register; note that CS segment register not allowed
POPF		transfer top stack element to flags
PUSH	mem|reg16	move memory or register to top stack element
PUSH	segreg	move segment register to top stack element
PUSHF		transfer flags to top stack element
SAHF		transfer the AH register to flags
XCHG	reg,mem|reg	exchange register and memory or register
XCHG	mem|reg,reg	exchange memory or register and register
XLAT	mem|reg	perform table lookup translation, table given by 'mem|reg', which is always BX. Replaces AL with AL offset from BX

4.3 Arithmetic, Logical, and Shift Instructions

The 8086 CPU performs the four basic mathematical operations in several different ways. It supports both 8- and 16-bit operations and also signed and unsigned arithmetic.

Six of the nine flag bits are set or cleared by most arithmetic operations to reflect the result of the operation. Table 4-4 summarizes the effects of arithmetic instructions on flag bits. Table 4-5 defines arithmetic instructions and Table 4-6 logical and shift instructions.

Table 4-4. Effects of Arithmetic Instructions on Flags

CF	is set if the operation resulted in a carry out of (from addition) or a borrow into (from subtraction) the high-order bit of the result; otherwise CF is cleared.
AF	is set if the operation resulted in a carry out of (from addition) or a borrow into (from subtraction) the low-order four bits of the result; otherwise AF is cleared.
ZF	is set if the result of the operation is zero; otherwise ZF is cleared.
SF	is set if the result is negative.
PF	is set if the modulo 2 sum of the low-order eight bits of the result of the operation is 0 (even parity); otherwise PF is cleared (odd parity).
OF	is set if the operation resulted in an overflow; the size of the result exceeded the capacity of its destination.

Table 4-5. Arithmetic Instructions

Syntax		*Result*
AAA		adjust unpacked BCD (ASCII) for addition—adjusts AL
AAD		adjust unpacked BCD (ASCII) for division—adjusts AL
AAM		adjust unpacked BCD (ASCII) for multiplication—adjusts AX
AAS		adjust unpacked BCD (ASCII) for subtraction—adjusts AL
ADC	reg,mem|reg	add (with carry) memory or register to register
ADC	mem|reg,reg	add (with carry) register to memory or register
ADC	mem|reg,numb	add (with carry) immediate data to memory or register
ADD	reg,mem|reg	add memory or register to register
ADD	mem|reg,reg	add register to memory or register
ADD	mem|reg,numb	add immediate data to memory or register
CBW		convert byte in AL to word in AH by sign extension
CWD		convert word in AX to double word in DX/AX by sign extension
CMP	reg,mem|reg	compare register with memory or register
CMP	mem|reg,reg	compare memory or register with register
CMP	mem|reg,numb	compare data constant with memory or register
DAA		decimal adjust for addition, adjusts AL

Table 4-5. (continued)

Syntax		*Result*
DAS		decimal adjust for subtraction, adjusts AL
DEC	mem|reg	subtract 1 from memory or register
INC	mem|reg	add 1 to memory or register
DIV	mem|reg	divide (unsigned) accumulator (AX or AL) by memory or register. If byte results, AL = quotient, AH = remainder. If word results, AX = quotient, DX = remainder
IDIV	mem|reg	divide (signed) accumulator (AX or AL) by memory or register—quotient and remainder stored as in DIV
IMUL	mem|reg	multiply (signed) memory or register by accumulator (AX or AL)—if byte, results in AH, AL. If word, results in DX, AX
MUL	mem|reg	multiply (unsigned) memory or register by accumulator (AX or AL)—results stored as in IMUL
NEG	mem|reg	two's complement memory or register
SBB	reg,mem|reg	subtract (with borrow) memory or register from register
SBB	mem|reg,reg	subtract (with borrow) register from memory or register
SBB	mem|reg,numb	subtract (with borrow) immediate data from memory or register
SUB	reg,mem|reg	subtract memory or register from register
SUB	mem|reg,reg	subtract register from memory or register
SUB	mem|reg,numb	subtract data constant from memory or register

Table 4-6. Logic Shift Instructions

Syntax		*Result*
AND	reg,mem|reg	perform bitwise logical 'and' of a register and memory register
AND	mem|reg,reg	perform bitwise logical 'and' of memory register and register
AND	mem|reg,numb	perform bitwise logical 'and' of memory register and data constant
NOT	mem|reg	form ones complement of memory or register
OR	reg,mem|reg	perform bitwise logical 'or' of a register and memory register
OR	mem|reg,reg	perform bitwise logical 'or' of memory register and register
OR	mem|reg,numb	perform bitwise logical 'or' of memory register and data constant
RCL	mem|reg,1	rotate memory or register 1 bit left through carry flag
RCL	mem|reg,CL	rotate memory or register left through carry flag, number of bits given by CL register
RCR	mem|reg,1	rotate memory or register 1 bit right through carry flag
RCR	mem|reg,CL	rotate memory or register right through carry flag, number of bits given by CL register
ROL	mem|reg,1	rotate memory or register 1 bit left
ROL	mem|reg,CL	rotate memory or register left, number of bits given by CL register
ROR	mem|reg,1	rotate memory or register 1 bit right

Table 4-6. (continued)

Syntax		*Result*
ROR	mem|reg,CL	rotate memory or register right, number of bits given by CL register
SAL	mem|reg,1	shift memory or register 1 bit left, shift in low-order zero bits
SAL	mem|reg,CL	shift memory or register left, number of bits given by CL register, shift in low-order zero bits
SAR	mem|reg,1	shift memory or register 1 bit right, shift in high-order bits equal to the original high-order bit
SAR	mem|reg,CL	shift memory or register right, number of bits given by CL register, shift in high-order bits equal to the original high-order bit
SHL	mem|reg,1	shift memory or register 1 bit left, shift in low-order zero bits—note that SHL is a different mnemonic for SAL
SHL	mem|reg,CL	shift memory or register left, number of bits given by CL register, shift in low-order zero bits—note that SHL is a different mnemonic for SAL
SHR	mem|reg,1	shift memory or register 1 bit right, shift in high-order zero bits
SHR	mem|reg,CL	shift memory or register right, number of bits given by CL register, shift in high-order zero bits
TEST	reg,mem|reg	perform bitwise logical 'and' of a register and memory or register—set condition flags but do not change destination

Table 4-6. (continued)

Syntax		*Result*
TEST	mem|reg,reg	perform bitwise logical 'and' of memory register and register—set condition flags but do not change destination
TEST	mem|reg,numb	perform bitwise logical 'and'—test of memory register and data constant—set condition flags but do not change destination
XOR	reg,mem|reg	perform bitwise logical 'exclusive OR' of a register and memory or register
XOR	mem|reg,reg	perform bitwise logical 'exclusive OR' of memory register and register
XOR	mem|reg,numb	perform bitwise logical 'exclusive OR' of memory register and data constant

4.4 String Instructions

String instructions take one or two operands. The operands specify only the operand type, determining whether operation is on bytes or words. If there are two operands, the source operand is addressed by the SI register and the destination operand is addressed by the DI register. The DI and SI registers are always used for addressing. Note that for string operations, destination operands addressed by DI must always reside in the Extra Segment (ES).

Table 4-7. String Instructions

Syntax		*Result*
CMPS	mem|reg,mem|reg	subtract source from destination, affect flags, but do not return result.
LODS	mem|reg	transfer a byte or word from the source operand to the accumulator.
MOVS	mem|reg,mem|reg	move 1 byte (or word) from source to destination.
SCAS	mem|reg	subtract destination operand from accumulator (AX or AL), affect flags, but do not return result.
STOS	mem|reg	transfer a byte or word from accumulator to the destination operand.

Table 4-8 defines prefixes for string instructions. A prefix repeats its string instruction the number of times contained in the CX register, which is decremented by 1 for each iteration. Prefix mnemonics precede the string instruction mnemonic in the statement line as shown in Section 2.8.

Table 4-8. Prefix Instructions

Syntax	*Result*
REP	repeat until CX register is zero
REPZ	repeat until CX register is zero and zero flag (ZF) is not zero
REPE	equal to 'REPZ'
REPNZ	repeat until CX register is zero and zero flag (ZF) is zero
REPNE	equal to 'REPNZ'

4.5 Control Transfer Instructions

There are four classes of control transfer instructions:

- calls, jumps, and returns
- conditional jumps
- iterational control
- interrupts

All control transfer instructions cause program execution to continue at some new location in memory, possibly in a new code segment. The transfer may be absolute or depend upon a certain condition. Table 4-9 defines control transfer instructions. In the definitions of conditional jumps, 'above' and 'below' refer to the relationship between unsigned values, and 'greater than' and 'less than' refer to the relationship between signed values.

Table 4-9. Control Transfer Instructions

Syntax		*Result*
CALL	label	push the offset address of the next instruction on the stack, jump to the target label
CALL	mem|reg16	push the offset address of the next instruction on the stack, jump to location indicated by contents of specified memory or register
CALLF	label	push CS segment register on the stack, push the offset address of the next instruction on the stack (after CS), jump to the target label
CALLF	mem	push CS register on the stack, push the offset address of the next instruction on the stack, jump to location indicated by contents of specified double word in memory
INT	numb8	push the flag registers (as in PUSHF), clear TF and IF flags, transfer control with an indirect call through any one of the 256 interrupt-vector elements - uses three levels of stack

Table 4-9. (continued)

Syntax		*Result*
INTO		if OF (the overflow flag) is set, push the flag registers (as in PUSHF), clear TF and IF flags, transfer control with an indirect call through interrupt-vector element 4 (location 10H)—if the OF flag is cleared, no operation takes place
IRET		transfer control to the return address saved by a previous interrupt operation, restore saved flag registers, as well as CS and IP—pops three levels of stack
JA	lab8	jump if 'not below or equal' or 'above' ((CF or ZF) = 0)
JAE	lab8	jump if 'not below' or 'above or equal' (CF = 0)
JB	lab8	jump if 'below' or 'not above or equal' (CF = 1)
JBE	lab8	jump if 'below or equal' or 'not above' ((CF or ZF) = 1)
JC	lab8	same as 'JB'
JCXZ	lab8	jump to target label if CX register is zero
JE	lab8	jump if 'equal' or 'zero' (ZF = 1)
JG	lab8	jump if 'not less or equal' or 'greater' (((SF xor OF) or ZF) = 0)
JGE	lab8	jump if 'not less' or 'greater or equal' ((SF xor OF) = 0)
JL	lab8	jump if 'less' or 'not greater or equal' ((SF xor OF) = 1)

Table 4-9. (continued)

Syntax		*Result*
JLE	lab8	jump if 'less or equal' or 'not greater' (((SF xor OF) or ZF) = 1)
JMP	label	jump to the target label
JMP	mem|reg16	jump to location indicated by contents of specified memory or register
JMPF	label	jump to the target label possibly in another code segment
JMPS	lab8	jump to the target label within ± 128 bytes from instruction
JNA	lab8	same as 'JBE'
JNAE	lab8	same as 'JB'
JNB	lab8	same as 'JAE'
JNBE	lab8	same as 'JA'
JNC	lab8	same as 'JNB'
JNE	lab8	jump if 'not equal' or 'not zero' (ZF = 0)
JNG	lab8	same as 'JLE'
JNGE	lab8	same as 'JL'
JNL	lab8	same as 'JGE'
JNLE	lab8	same as 'JG'
JNO	lab8	jump if 'not overflow' (OF = 0)
JNP	lab8	jump if 'not parity' or 'parity odd'

Table 4-9. (continued)

Syntax		*Result*
JNS	lab8	jump if 'not sign'
JNZ	lab8	same as 'JNE'
JO	lab8	jump if 'overflow' (OF=1)
JP	lab8	jump if 'parity' or 'parity even' (PF=1)
JPE	lab8	same as 'JP'
JPO	lab8	same as 'JNP'
JS	lab8	jump if 'sign' (SF=1)
JZ	lab8	same as 'JE'
LOOP	lab8	decrement CX register by one, jump to target label if CX is not zero
LOOPE	lab8	decrement CX register by one, jump to target label if CX is not zero and the ZF flag is set —'loop while zero' or 'loop while equal'
LOOPNE	lab8	decrement CX register by one, jump to target label if CX is not zero and ZF flag is cleared —'loop while not zero' or 'loop while not equal'
LOOPNZ	lab8	same as 'LOOPNE'
LOOPZ	lab8	same as 'LOOPE'
RET		return to the return address pushed by a previous CALL instruction, increment stack pointer by 2
RET	numb	return to the address pushed by a previous CALL, increment stack pointer by 2+numb

Table 4-9. (continued)

Syntax	*Result*
RETF	return to the address pushed by a previous CALLF instruction, increment stack pointer by 4
RETF numb	return to the address pushed by a previous CALLF instruction, increment stack pointer by 4+numb

4.6 Processor Control Instructions

Processor control instructions manipulate the flag registers. Moreover, some of these instructions can synchronize the 8086 CPU with external hardware.

Table 4-10. Processor Control Instructions

Syntax	*Results*
CLC	clear CF flag
CLD	clear DF flag, causing string instructions to auto-increment the operand pointers
CLI	clear IF flag, disabling maskable external interrupts
CMC	complement CF flag
ESC numb8,mem|reg	do no operation other than compute the effective address and place it on the address bus (ESC is used by the 8087 numeric co-processor), 'numb8' must be in the range 0 to 63

Table 4-10. (continued)

Syntax	*Results*
LOCK	PREFIX instruction, cause the 8086 processor to assert the 'bus-lock' signal for the duration of the operation caused by the following instruction—the LOCK prefix instruction may precede any other instruction—buslock prevents co-processors from gaining the bus; this is useful for shared-resource semaphores
HLT	cause 8086 processor to enter halt state until an interrupt is recognized
STC	set CF flag
STD	set DF flag, causing string instructions to auto-decrement the operand pointers
STI	set IF flag, enabling maskable external interrupts
WAIT	cause the 8086 processor to enter a 'wait' state if the signal on its 'TEST' pin is not asserted

End of Section 4

Section 5
Code-Macro Facilities

5.1 Introduction to Code-macros

ASM-86 does not support traditional assembly-language macros, but it does allow the user to define his own instructions by using the code-macro directive. Like traditional macros, code-macros are assembled wherever they appear in assembly language code, but there the similarity ends. Traditional macros contain assembly language instructions, but a code-macro contains only code-macro directives. Macros are usually defined in the user's symbol table; ASM-86 code-macros are defined in the assembler's symbol table. A macro simplifies using the same block of instructions over and over again throughout a program, but a code-macro sends a bit stream to the output file and in effect adds a new instruction to the assembler.

Because ASM-86 treats a code-macro as an instruction, you can invoke code-macros by using them as instructions in your program. The example below shows how MAC, an instruction defined by a code-macro, can be invoked.

```
      .
      .
      .
XCHG  BX,WORD3
MAC   PAR1,PAR2
MUL   AX,WORD4
      .
      .
      .
```

Note that MAC accepts two operands. When MAC was defined, these two operands were also classified as to type, size, and so on by defining MAC's formal parameters. The names of formal parameters are not fixed. They are stand-ins which are replaced by the names or values supplied as operands when the code-macro is invoked. Thus formal parameters 'hold the place' and indicate where and how the operands are to be used.

The definition of a code-macro starts with a line specifying its name and its formal parameters, if any:

CodeMacro <*name*> [<*formal parameter list*>]

where the optional <*formal parameter list*> is defined:

<*formal name*>:<*specifier letter*>[<*modifier letter*>][*range*>]

As stated above, the formal name is not fixed, but a place holder. If formal parameter list is present, the specifier letter is required and the modifier letter is optional. Possible specifiers are A, C, D, E, M, R, S, and X. Possible modifier letters are b, d, w, and sb. The assembler ignores case except within strings, but for clarity, this section shows specifiers in upper-case and modifiers in lower-case. Following sections describe specifiers, modifiers, and the optional range in detail.

The body of the code-macro describes the bit pattern and formal parameters. Only the following directives are legal within code-macros:

```
SEGFIX
NOSEGFIX
MODRM
RELB
RELW
DB
DW
DD
DBIT
```

These directives are unique to code-macros, and those which appear to duplicate ASM-86 directives (DB, DW, and DD) have different meanings in code-macro context. These directives are discussed in detail in later sections. The definition of a code-macro ends with a line:

```
EndM
```

CodeMacro, EndM, and the code-macro directives are all reserved words. Code-macro definition syntax is defined in Backus-Naur-like form in Appendix H. The following examples are typical code-macro definitions.

```
CodeMacro AAA
  DB 37H
EndM

CodeMacro DIV divisor:Eb
  SEGFIX divisor
  DB     0FH
  MODRM  divisor
EndM

CodeMacro ESC opcode:Db(0,63),src:Eb
  SEGFIX src
  DBIT 5(1BH),3(opcode(3))
  MODRM  opcode,src
EndM
```

5.2 Specifiers

Every formal parameter must have a specifier letter that indicates what type of operand is needed to match the formal parameter. Table 5-1 defines the eight possible specifier letters.

Table 5-1. Code-macro Operand Specifiers

Letter	*Operand Type*
A	Accumulator register, AX or AL.
C	Code, a label expression only.
D	Data, a number to be used as an immediate value.
E	Effective address, either an M (memory address) or an R (register).
M	Memory address. This can be either a variable or a bracketed register expression.
R	A general register only.
S	Segment register only.
X	A direct memory reference.

5.3 Modifiers

The optional modifier letter is a further requirement on the operand. The meaning of the modifier letter depends on the type of the operand. For variables, the modifier requires the operand to be of type: 'b' for byte, 'w' for word, 'd' for double-word and 'sb' for signed byte. For numbers, the modifiers require the number to be of a certain size: 'b' for −256 to 255 and 'w' for other numbers. Table 5-2 summarizes code-macro modifiers.

Table 5-2. Code-macro Operand Modifiers

Variables		*Numbers*	
Modifier	*Type*	*Modifier*	*Size*
b	byte	b	−256 to 255
w	word	w	anything else
d	dword		
sb	signed byte		

5.4 Range Specifiers

The optional range is specified within parentheses by either one expression or two expressions separated by a comma. The following are valid formats:

(numberb)
(register)
(numberb,numberb)
(numberb,register)
(register,numberb)
(register,register)

Numberb is 8-bit number, not an address. The following example specifies that the input port must be identified by the DX register:

```
CodeMacro IN dst:Aw,port:Rw(DX)
```

The next example specifies that the CL register is to contain the 'count' of rotation:

```
CodeMacro ROR dst:Ew,count:Rb(CL)
```

The last example specifies that the 'opcode' is to be immediate data, and may range from 0 to 63 inclusive:

```
CodeMacro ESC opcode:Db(0,63),adds:Eb
```

5.5 Code-macro Directives

Code-macro directives define the bit pattern and make further requirements on how the operand is to be treated. Directives are reserved words, and those that appear to duplicate assembly language instructions have different meanings within a code-macro definition. Only the nine directives defined here are legal within code-macro definitions.

5.5.1 SEGFIX

If SEGFIX is present, it instructs the assembler to determine whether a segment-override prefix byte is needed to access a given memory location. If so, it is output as the first byte of the instruction. If not, no action is taken. SEGFIX takes the form:

SEGFIX <*formal name*>

where <*formal name*> is the name of a formal parameter which represents the memory address. Because it represents a memory address, the formal parameter must have one of the specifiers E, M or X.

5.5.2 NOSEGFIX

Use NOSEGFIX for operands in instructions that must use the ES register for that operand. This applies only to the destination operand of these instructions: CMPS, MOVS, SCAS, STOS. The form of NOSEGFIX is:

NOSEGFIX segreg,<*formname*>

where segreg is one of the segment registers ES, CS, SS, or DS and <*formname*> is the name of the memory-address formal parameter, which must have a specifier E, M, or X. No code is generated from this directive, but an error check is performed. The following is an example of NOSEGFIX use:

```
CodeMacro MOVS si_ptr:Ew,di_ptr:Ew
  NOSEGFIX     ES,di_ptr
  SEGFIX       si_ptr
  DB           0A5H
EndM
```

5.5.3 MODRM

This directive intructs the assembler to generate the ModRM byte, which follows the opcode byte in many of the 8086's instructions. The ModRM byte contains either the indexing type or the register number to be used in the instruction. It also specifies which register is to be used, or gives more information to specify an instruction.

The ModRM byte carries the information in three fields. The mod field occupies the two most significant bits of the byte, and combines with the register memory field to form 32 possible values: 8 registers and 24 indexing modes.

The reg field occupies the three next bits following the mod field. It specifies either a register number or three more bits of opcode information. The meaning of the reg field is determined by the opcode byte.

The register memory field occupies the last three bits of the byte. It specifies a register as the location of an operand, or forms a part of the address-mode in combination with the mod field described above.

For further information of the 8086's instructions and their bit patterns, see Intel's 8086 Assembly Language Programing Manual and the Intel 8086 Family User's Manual. The forms of MODRM are:

MODRM <*form name*>,<*form name*>
MODRM NUMBER7,<form name>

where NUMBER7 is a value 0 to 7 inclusive and <*form name*> is the name of a formal parameter. The following examples show MODRM use:

```
CodeMacro RCR dst:Ew,count:Rb(CL)
  SEGFIX      dst
  DB          0D3H
  MODRM       3,dst
EndM

CodeMacro OR dst:Rw,src:Ew
  SEGFIX      src
  DB          0BH
  MODRM       dst,src
EndM
```

5.5.4 RELB and RELW

These directives, used in IP-relative branch instructions, instruct the assembler to generate displacement between the end of the instruction and the label which is supplied as an operand. RELB generates one byte and RELW two bytes of displacement. The directives the following forms:

RELB *<form name>*
RELW *<form name>*

where *<form name>* is the name of a formal parameter with a 'C' (code) specifier. For example:

```
CodeMacro LOOP place:Cb
  DB          0E2H
  RELB        place
EndM
```

5.5.5 DB, DW and DD

These directives differ from those which occur outside of code-macros. The form of the directives are:

DB *<form name>* | NUMBERB
DW *<form name>* | NUMBERW
DD *<form name>*

where NUMBERB is a single-byte number, NUMBERW is a two-byte number, and *<form name>* is a name of a formal parameter. For example:

```
CodeMacro XOR dst:Ew,src:Db
  SEGFIX      dst
  DB          81H
  MODRM       6,dst
  DW          src
EndM
```

5.5.6 DBIT

This directive manipulates bits in combinations of a byte or less. The form is:

DBIT <*field description*>[,<*field description*>]

where a <*field description*>, has two forms:

<*number*><*combination*>
<*number*>(<*form name*>(<*rshift*>))

where <*number*> ranges from 1 to 16, and specifies the number of bits to be set. <*combination*> specifies the desired bit combination. The total of all the <*number*>s listed in the field descriptions must not exceed 16. The second form shown above contains <*form name*>, a formal parameter name that instructs the assembler to put a certain number in the specified position. This number normally refers to the register specified in the first line of the code-macro. The numbers used in this special case for each register are:

```
AL:    0
CL:    1
DL:    2
BL:    3
AH:    4
CH:    5
DH:    6
BH:    7
AX:    0
CX:    1
DX:    2
BX:    3
```

```
SP:     4
BP:     5
SI:     6
DI:     7
ES:     0
CS:     1
SS:     2
DS:     3
```

<rshift>, which is contained in the innermost parentheses, specifies a number of right shifts. For example, '0' specifies no shift, '1' shifts right one bit, '2' shifts right two bits, and so on. The definition below uses this form.

```
CodeMacro DEC dst:Rw
  DBIT 5(9H),3(dst(0))
EndM
```

The first five bits of the byte have the value 9H. If the remaining bits are zero, the hex value of the byte will be 48H. If the instruction:

```
DEC     DX
```

is assembled and DX has a value of 2H, then 48H + 2H = 4AH, which is the final value of the byte for execution. If this sequence had been present in the definition:

```
DBIT 5(9H),3(dst(1))
```

then the register number would have been shifted right once and the result would had been 48H + 1H = 49H, which is erroneous.

End of Section 5

Section 6
DDT-86

6.1 DDT-86 Operation

The DDT-86™ program allows the user to test and debug programs interactively in a CP/M-86 environment. The reader should be familiar with the 8086 processor, ASM-86 and the CP/M-86 operating system as described in the CP/M-86 System Guide.

6.1.1 Invoking DDT-86

Invoke DDT-86 by entering one of the following commands:

```
DDT86
DDT86 filename
```

The first command simply loads and executes DDT-86. After displaying its sign-on message and prompt character, - , DDT-86 is ready to accept operator commands. The second command is similar to the first, except that after DDT-86 is loaded it loads the file specified by filename. If the file type is omitted from filename, .CMD is assumed. Note that DDT-86 cannot load a file of type .H86. The second form of the invoking command is equivalent to the sequence:

```
A>DDT86
DDT86 x.x
-Efilename
```

At this point, the program that was loaded is ready for execution.

6.1.2 DDT-86 Command Conventions

When DDT-86 is ready to accept a command, it prompts the operator with a hyphen, -. In response, the operator can type a command line or a CONTROL-C or ↑C to end the debugging session (see Section 6.1.4). A command line may have up to 64 characters, and must be terminated with a carriage return. While entering the command, use standard CP/M line-editing functions (↑X, ↑H, ↑R, etc.) to correct typing errors. DDT-86 does not process the command line until a carriage return is entered.

The first character of each command line determines the command action. Table 6-1 summarizes DDT-86 commands. DDT-86 commands are defined individually in Section 6.2.

Table 6-1. DDT-86 Command Summary

Command	*Action*
A	enter assembly language statements
D	display memory in hexadecimal and ASCII
E	load program for execution
F	fill memory block with a constant
G	begin execution with optional breakpoints
H	hexadecimal arithmetic
I	set up file control block and command tail
L	list memory using 8086 mnemonics
M	move memory block
R	read disk file into memory
S	set memory to new values
T	trace program execution
U	untraced program monitoring
V	show memory layout of disk file read
W	write contents of memory block to disk
X	examine and modify CPU state

The command character may be followed by one or more arguments, which may be hexadecimal values, file names or other information, depending on the command. Arguments are separated from each other by commas or spaces. No spaces are allowed between the command character and the first argument.

6.1.3 Specifying a 20-Bit Address

Most DDT-86 commands require one or more addresses as operands. Because the 8086 can address up to 1 megabyte of memory, addresses must be 20-bit values. Enter a 20-bit address as follows:

```
ssss:oooo
```

where ssss represents an optional 16-bit segment number and oooo is a 16-bit offset. DDT-86 combines these values to produce a 20-bit effective address as follows:

```
  ssss0
+ oooo
  eeeee
```

The optional value ssss may be a 16-bit hexadecimal value or the name of a segment register. If a segment register name is specified, the value of ssss is the contents of that register in the user's CPU state, as indicated by the X command. If omitted, a default value appropriate to the command being executed, as described in Section 6.4.

6.1.4 Terminating DDT-86

Terminate DDT-86 by typing a ↑C in response to the hyphen prompt. This returns control to the CCP. Note that CP/M-86 does not have the SAVE facility found in CP/M for 8-bit machines. Thus if DDT-86 is used to patch a file, write the file to disk using the W command before exiting DDT-86.

6.1.5 DDT-86 Operation with Interrupts

DDT-86 operates with interrupts enabled or disabled, and preserves the interrupt state of the program being executed under DDT-86. When DDT-86 has control of the CPU, either when it is initially invoked, or when it regains control from the program being tested, the condition of the interrupt flag is the same as it was when DDT-86 was invoked, except for a few critical regions where interrupts are disabled. While the program being tested has control of the CPU, the user's CPU state, which can be displayed with the X command, determines the state of the interrupt flag.

6.2 DDT-86 Commands

This section defines DDT-86 commands and their arguments. DDT-86 commands give the user control of program execution and allow the user to display and modify system memory and the CPU state.

6.2.1 The A (Assemble) Command

The A command assembles 8086 mnemonics directly into memory. The form is:

```
As
```

where s is the 20-bit address where assembly is to start. DDT-86 responds to the A command by displaying the address of the memory location where assembly is to begin. At this point the operator enters assembly language statements as described in Section 4 on Assembly Language Syntax. When a statement is entered, DDT-86 converts it to binary, places the value(s) in memory, and displays the address of the next available memory location. This process continues until the user enters a blank line or a line containing only a period.

DDT-86 responds to invalid statements by displaying a question mark, ? , and redisplaying the current assembly address.

6.2.2 The D (Display) Command

The D command displays the contents of memory as 8-bit or 16-bit hexadecimal values and in ASCII. The forms are:

```
D
Ds
Ds,f
DW
DWs
DWs,f
```

where s is the 20-bit address where the display is to start, and f is the 16-bit offset within the segment specified in s where the display is to finish.

Memory is displayed on one or more display lines. Each display line shows the values of up to 16 memory locations. For the first three forms, the display line appears as follows:

ssss:oooo bb bb . . . bb cc . . . c

where ssss is the segment being displayed and oooo is the offset within segment ssss. The bb's represent the contents of the memory locations in hexadecimal, and the c's represent the contents of memory in ASCII. Any non-graphic ASCII characters are represented by periods.

In response to the first form shown above, DDT-86 displays memory from the current display address for 12 display lines. The response to the second form is similar to the first, except that the display address is first set to the 20-bit address s. The third form displays the memory block between locations s and f. The next three forms are analogous to the first three, except that the contents of memory are displayed as 16-bit values, rather than 8-bit values, as shown below:

ssss:oooo wwww wwww . . . wwww cccc . . . cc

During a long display, the D command may be aborted by typing any character at the console.

6.2.3 The E (Load for Execution) Command

The E command loads a file into memory so that a subsequent G, T or U command can begin program execution. The E command takes the form:

E<*filename*>

where <*filename*> is the name of the file to be loaded. If no file type is specified, .CMD is assumed. The contents of the user segment registers and IP register are altered according to the information in the header of the file loaded.

An E command releases any blocks of memory allocated by any previous E or R commands or by programs executed under DDT-86. Thus only one file at a time may be loaded for execution.

When the load is complete, DDT-86 displays the start and end addresses of each segment in the file loaded. Use the V command to redisplay this information at a later time.

If the file does not exist or cannot be successfully loaded in the available memory, DDT-86 issues an error message.

6.2.4 The F (Fill) Command

The F command fills an area of memory with a byte or word constant. The forms are:

```
Fs,f,b
FWs,f,w
```

where s is a 20-bit starting address of the block to be filled, and f is a 16-bit offset of the final byte of the block within the segment specified in s.

In response to the first form, DDT-86 stores the 8-bit value b in locations s through f. In the second form, the 16-bit value w is stored in locations s through f in standard form, low 8 bits first followed by high 8 bits.

If s is greater than f or the value b is greater than 255, DDT-86 responds with a question mark. DDT-86 issues an error message if the value stored in memory cannot be read back successfully, indicating faulty or non-existent RAM at the location indicated.

6.2.5 The G (Go) Command

The G command transfers control to the program being tested, and optionally sets one or two breakpoints. The forms are:

```
G
G,b1
G,b1,b2
Gs
Gs,b1
Gs,b1,b2
```

where s is a 20-bit address where program execution is to start, and b1 and b2 are 20-bit addresses of breakpoints. If no segment value is supplied for any of these three addresses, the segment value defaults to the contents of the CS register.

In the first three forms, no starting address is specified, so DDT-86 derives the 20-bit address from the user's CS and IP registers. The first form transfers control to the user's program without setting any breakpoints. The next two forms respectively set one and two breakpoints before passing control to the user's program. The next three forms are analogous to the first three, except that the user's CS and IP registers are first set to s.

Once control has been transferred to the program under test, it executes in real time until a breakpoint is encountered. At this point, DDT-86 regains control, clears all breakpoints, and indicates the address at which execution of the program under test was interrupted as follows:

```
*ssss:oooo
```

where ssss corresponds to the CS and oooo corresponds to the IP where the break occurred. When a breakpoint returns control to DDT-86, the instruction at the breakpoint address has not yet been executed.

6.2.6 The H (Hexadecimal Math) Command

The H command computes the sum and difference of two 16-bit values. The form is:

```
Ha,b
```

where a and b are the values whose sum and difference are to be computed. DDT-86 displays the sum (ssss) and the difference (dddd) truncated to 16 bits on the next line as shown below:

```
ssss dddd
```

6.2.7 The I (Input Command Tail) Command

The I command prepares a file control block and command tail buffer in DDT-86's base page, and copies this information into the base page of the last file loaded with the E command. The form is:

I<*command tail*>

where <*command tail*> is a character string which usually contains one or more filenames. The first filename is parsed into the default file control block at 005CH. The optional second filename (if specified) is parsed into the second part of the default file control block beginning at 006CH. The characters in <*command tail*> are also copied into the default command buffer at 0080H. The length of <*command tail*> is stored at 0080H, followed by the character string terminated with a binary zero.

If a file has been loaded with the E command, DDT-86 copies the file control block and command buffer from the base page of DDT-86 to the base page of the program loaded. 46-bit value at location 0:6. The location of the base page of a program loaded with the E command is the value displayed for DS upon completion of the program load.

6.2.8 The L (List) Command

The L command lists the contents of memory in assembly language. The forms are:

```
L
Ls
Ls,f
```

where s is a 20-bit address where the list is to start, and f is a 16-bit offset within the segment specified in s where the list is to finish.

The first form lists twelve lines of disassembled machine code from the current list address. The second form sets the list address to s and then lists twelve lines of code. The last form lists disassembled code from s through f. In all three cases, the list address is set to the next unlisted location in preparation for a subsequent L command. When DDT-86 regains control from a program being tested (see G, T and U commands), the list address is set to the current value of the CS and IP registers.

Long displays may be aborted by typing any key during the list process. Or, enter ↑S to halt the display temporarily.

The syntax of the assembly language statements produced by the L command is described in Section 4.

6.2.9 The M (Move) Command

The M command moves a block of data values from one area of memory to another. The form is:

Ms,f,d

where s is the 20-bit starting address of the block to be moved, f is the offset of the final byte to be moved within the segment described by s, and d is the 20-bit address of the first byte of the area to receive the data. If the segment is not specified in d, the same value is used that was used for s. Note that if d is between s and f, part of the block being moved will be overwritten before it is moved, because data is transferred starting from location s.

6.2.10 The R (Read) Command

The R command reads a file into a contiguous block of memory. The form is:

R<*filename*>

where <*filename*> is the name and type of the file to be read.

DDT-86 reads the file into memory and displays the start and end addresses of the block of memory occupied by the file. A V command can redisplay this information at a later time. The default display pointer (for subsequent D commands) is set to the start of the block occupied by the file.

The R command does not free any memory previously allocated by another R or E command. Thus a number of files may be read into memory without overlapping. The number of files which may be loaded is limited to seven, which is the number of memory allocations allowed by the BDOS, minus one for DDT-86 itself.

If the file does not exist or there is not enough memory to load the file, DDT-86 issues an error message.

6.2.11 The S (Set) Command

The S command can change the contents of bytes or words of memory. The forms are:

Ss
SWs

where s is the 20-bit address where the change is to occur.

DDT-86 displays the memory address and its current contents on the following line. In response to the first form, the display is:

```
ssss:oooo bb
```

and in response to the second form

```
ssss:oooo wwww
```

where bb and wwww are the contents of memory in byte and word formats, respectively.

In response to one of the above displays, the operator may choose to alter the memory location or to leave it unchanged. If a valid hexadecimal value is entered, the contents of the byte (or word) in memory is replaced with the value. If no value is entered, the contents of memory are unaffected and the contents of the next address are displayed. In either case, DDT-86 continues to display successive memory addresses and values until either a period or an invalid value is entered.

DDT-86 issues an error message if the value stored in memory cannot be read back successfully, indicating faulty or non-existent RAM at the location indicated.

6.2.12 The T (Trace) Command

The T command traces program execution for 1 to 0FFFFH program steps. The forms are:

```
T
Tn
TS
TSn
```

where n is the number of instructions to execute before returning control to the console.

Before an instruction is executed, DDT-86 displays the current CPU state and the disassembled instruction. In the first two forms, the segment registers are not displayed, which allows the entire CPU state to be displayed on one line. The next two forms are analogous to the first two, except that all the registers are displayed, which forces the disassembled instruction to be displayed on the next line as in the X command.

In all of the forms, control transfers to the program under test at the address indicated by the CS and IP registers. If n is not specified, one instruction is executed. Otherwise DDT-86 executes n instructions, displaying the CPU state before each step. A long trace may be aborted before n steps have been executed by typing any character at the console.

After a T command, the list address used in the L command is set to the address of the next instruction to be executed.

Note that DDT-86 does not trace through a BDOS interrupt instruction, since DDT-86 itself makes BDOS calls and the BDOS is not reentrant. Instead, the entire sequence of instructions from the BDOS interrupt through the return from BDOS is treated as one traced instruction.

6.2.13 The U (Untrace) Command

The U command is identical to the T command except that the CPU state is displayed only before the first instruction is executed, rather than before every step. The forms are:

```
U
Un
US
USn
```

where n is the number of instructions to execute before returning control to the console. The U command may be aborted before n steps have been executed by striking any key at the console.

6.2.14 The V (Value) Command

The V command displays information about the last file loaded with the E or R commands. The form is:

```
V
```

If the last file was loaded with the E command, the V command displays the start and end addresses of each of the segments contained in the file. If the last file was read with the R command, the V command displays the start and end addresses of the block of memory where the file was read. If neither the R nor E commands have been used, DDT-86 responds to the V command with a question mark, ?.

6.2.15 The W (Write) Command

The W command writes the contents of a contiguous block of memory to disk. The forms are:

W<*filename*>
W<*filename*>,s,f

where <*filename*> is the filename and file type of the disk file to receive the data, and s and f are the 20-bit first and last addresses of the block to be written. If the segment is not specified in f, DDT-86 uses the same value that was used for s.

If the first form is used, DDT-86 assumes the s and f values from the last file read with an R command. If no file was read with an R command, DDT-86 responds with a question mark, ?. This first form is useful for writing out files after patches have been installed, assuming the overall length of the file is unchanged.

In the second form where s and f are specified as 20-bit addresses, the low four bits of s are assumed to be 0. Thus the block being written must always start on a paragraph boundary.

If a file by the name specified in the W command already exists, DDT-86 deletes it before writing a new file.

6.2.16 The X (Examine CPU State) Command

The X command allows the operator to examine and alter the CPU state of the program under test. The forms are:

X
Xr
Xf

where r is the name of one of the 8086 CPU registers and f is the abbreviation of one of the CPU flags. The first form displays the CPU state in the format:

```
          AX   BX   CX  ...   SS   ES   IP
--------- xxxx xxxx xxxx ... xxxx xxxx xxxx
<instruction>
```

The nine hyphens at the beginning of the line indicate the state of the nine CPU flags. Each position may be either a hyphen, indicating that the corresponding flag is not set (0), or a 1-character abbreviation of the flag name, indicating that the flag is set (1). The abbreviations of the flag names are shown in Table 6-2. *<instruction>* is the disassembled instruction at the next location to be executed, which is indicated by the CS and IP registers.

Table 6-2. Flag Name Abbreviations

Character	*Name*
O	Overflow
D	Direction
I	Interrupt Enable
T	Trap
S	Sign
Z	Zero
A	Auxiliary Carry
P	Parity
C	Carry

The second form allows the operator to alter the registers in the CPU state of the program being tested. The r following the X is the name of one of the 16-bit CPU registers. DDT-86 responds by displaying the name of the register followed by its current value. If a carriage return is typed, the value of the register is not changed. If a valid value is typed, the contents of the register are changed to that value. In either case, the next register is then displayed. This process continues until a period or an invalid value is entered, or the last register is displayed.

The third form allows the operator to alter one of the flags in the CPU state of the program being tested. DDT-86 responds by displaying the name of the flag followed by its current state. If a carriage return is typed, the state of the flag is not changed. If a valid value is typed, the state of the flag is changed to that value. Only one flag may be examined or altered with each Xf command. Set or reset flags by entering a value of 1 or 0.

6.3 Default Segment Values

DDT-86 has an internal mechanism that keeps track of the current segment value, making segment specification an optional part of a DDT-86 command. DDT-86 divides the command set into two types of commands, according to which segment a command defaults if no segment value is specified in the command line.

The first type of command pertains to the code segment: A (Assemble), L (List Mnemonics) and W (Write). These commands use the internal type-1 segment value if no segment value is specified in the command.

When invoked, DDT-86 sets the type-1 segment value to 0, and changes it when one of the following actions is taken:

- When a file is loaded by an E command, DDT-86 sets the type-1 segment value to the value of the CS register.
- When a file is read by an R command, DDT-86 sets the type-1 segment value to the base segment where the file was read.
- When an X command changes the value of the CS register, DDT-86 changes the type-1 segment value to the new value of the CS register.
- When DDT-86 regains control from a user program after a G, T or U command, it sets the type-1 segment value to the value of the CS register.
- When a segment value is specified explicitly in an A or L command, DDT-86 sets the type-1 segment value to the segment value specified.

The second type of command pertains to the data segment: D (Display), F (Fill), M (Move) and S (Set). These commands use the internal type-2 segment value if no segment value is specified in the command.

When invoked, DDT-86 sets the type-2 segment value to 0, and changes it when one of the following actions is taken:

- When a file is loaded by an E command, DDT-86 sets the type-2 segment value to the value of the DS register.
- When a file is read by an R command, DDT-86 sets the type-2 segment value to the base segment where the file was read.
- When an X command changes the value of the DS register, DDT-86 changes the type-2 segment value to the new value of the DS register.

- When DDT-86 regains control from a user program after a G, T or U command, it sets the type-2 segment value to the value of the DS register.
- When a segment value is specified explicitly in an D, F, M or S command, DDT-86 sets the type-2 segment value to the segment value specified.

When evaluating programs that use identical values in the CS and DS registers, all DDT-86 commands default to the same segment value unless explicitly overridden.

Note that the G (Go) command does not fall into either group, since it defaults to the CS register.

Table 6-3 summarizes DDT-86's default segment values.

Table 6-3. DDT-86 Default Segment Values

Command	*type-1*	*type-2*
A	x	
D		x
E	c	c
F		x
G	c	c
H		
I		
L	x	
M		x
R	c	c
S		x
T	c	c
U	c	c
V		
W	x	
X	c	c

x — use this segment default if none specified; change default if specified explicitly
c — change this segment default

6.4 Assembly Language Syntax for A and L Commands

In general, the syntax of the assembly language statements used in the A and L commands is standard 8086 assembly language. Several minor exceptions are listed below.

- DDT-86 assumes that all numeric values entered are hexadecimal.
- Up to three prefixes (LOCK, repeat, segment override) may appear in one statement, but they all must precede the opcode of the statement. Alternately, a prefix may be entered on a line by itself.
- The distinction between byte and word string instructions is made as follows:

byte	word
LODSB	LODSW
STOSB	STOSW
SCASB	SCASW
MOVSB	MOVSW
CMPSB	CMPSW

- The mnemonics for near and far control transfer instructions are as follows:

short	normal	far
JMPS	JMP	JMPF
CALL	CALLF	
RET	RETF	

- If the operand of a CALLF or JMPF instruction is a 20-bit absolute address, it is entered in the form:

  ssss:oooo

  where ssss is the segment and oooo is the offset of the address.

- Operands that could refer to either a byte or word are ambiguous, and must be preceded either by the prefix "BYTE" or "WORD". These prefixes may be abbreviated to "BY" and "WO". For example:

```
INC     BYTE [BP]
NOT     WORD [1234]
```

  Failure to supply a prefix when needed results in an error message.

- Operands which address memory directly are enclosed in square brackets to distinguish them from immediate values. For example:

```
ADD     AX,5        ;add 5 to register AX
ADD     AX,[5]      ;add the contents of location 5 to AX
```

- The forms of register indirect memory operands are:

```
[pointer register]
[index register]
[pointer register + index register]
```

  where the pointer registers are BX and BP, and the index registers are SI and DI. Any of these forms may be preceded by a numeric offset. For example:

```
ADD     BX,[BP+SI]
ADD     BX,3[BP+SI]
ADD     BX,1D47[BP+SI]
```

6.5 DDT-86 Sample Session

In the following sample session, the user interactively debugs a simple sort program. Comments in italic type explain the steps involved.

Source file of program to test.

```
A>type sort.a86
;
;       simple sort program
;
sort:
        mov     si,0            ;initialize index
        mov     bx,offset nlist ;bx = base of list
        mov     sw,0            ;clear switch flag
comp:
        mov     al,[bx+si]      ;get byte from list
        cmp     al,1[bx+si]     ;compare with next byte
        jna     inci            ;don't switch if in order
        xchg    al,1[bx+si]     ;do first part of switch
        mov     [bx+si],al      ;do second part
        mov     sw,1            ;set switch flag
inci:
        inc     si              ;increment index
        cmp     si,count        ;end of list?
        jnz     comp            ;no, keep going
        test    sw,1            ;done - any switches?
        jnz     sort            ;yes, sort some more
done:
        jmp     done            ;get here when list ordered
;
        dseg
        org     100h            ;leave space for base page
;
nlist   db      3,8,4,6,31,6,4,1
count   equ     offset $ - offset nlist
sw      db      0
        end
```

Assemble program.

```
A>asm86 sort

CP/M 8086 ASSEMBLER VER 1.1
END OF PASS 1
END OF PASS 2
END OF ASSEMBLY. NUMBER OF ERRORS:   0
```

Type listing file generated by ASM-86.

```
A>type sort.lst

CP/M ASM86 1.1  SOURCE: SORT.A86                                    PAGE   1


                        ;
                        ;       simple sort program
                        ;
                        sort:
 0000 BE0000                    mov     si,0            ;initialize index
 0003 BB0001                    mov     bx,offset nlist ;bx = base of list
 0006 C606080100                mov     sw,0            ;clear switch flag
                        comp:
 000B 8A00                      mov     al,[bx+si]      ;get byte from list
 000D 3A4001                    cmp     al,1[bx+si]     ;compare with next byte
 0010 760A                      jna     inci            ;don't switch if in order
 0012 864001                    xchg    al,1[bx+si]     ;do first part of switch
 0015 8800                      mov     [bx+si],al      ;do second part
 0017 C606080101                mov     sw,1            ;set switch flag
                        inci:
 001C 46                        inc     si              ;increment index
 001D 83FE08                    cmp     si,count        ;end of list?
 0020 75E9                      jnz     comp            ;no, keep going
 0022 F606080101                test    sw,1            ;done - any switches?
 0027 75D7                      jnz     sort            ;yes, sort some more
                        done:
 0029 E9FDFF                    jmp     done            ;get here when list ordered
                        ;
                                dseg
                                org     100h            ;leave space for base page
                        ;
 0100 030804061F06 nlist        db      3,8,4,6,31,6,4,1
      0401
   0008                 count   equ     offset $ - offset nlist
 0108 00                sw      db      0
                                end


END OF ASSEMBLY.  NUMBER OF ERRORS:   0
```

Type symbol table file generated by ASM-86.

```
A>type sort.sym
0000 VARIABLES
0100 NLIST      0108 SW

0000 NUMBERS
0008 COUNT

0000 LABELS
000B COMP       0029 DONE       001C INCI       0000 SORT
```

Type hex file generated by ASM-86.

```
A>type sort.h86
:04000003000000000F9
:1B000081BE0000BB0001CB060B0100BA003A4001760A8B40018800CB0608016C
:11001B81014683FE0875E9FB060B010175D7E9FDFFEE
:0901008203080406 1F0B04010035
:00000001FF
```

Generate CMD file from .H86 file.

```
A>gencmd sort

BYTES READ    0039
RECORDS WRITTEN 04
```

Invoke DDT-86 and load SORT.CMD.

```
A>ddt86 sort

DDT86 1.0
     START      END
CS 047D:0000 047D:002F
DS 0480:0000 0480:010F
```

Display initial register values.

```
-x
           AX   BX   CX   DX   SP   BP   SI   DI   CS   DS   SS   ES   IP
--------- 0000 0000 0000 0000 119E 0000 0000 0000 047D 0480 0491 0480 0000
MOV    SI,0000
```

Disassemble the beginning of the code segment.

```
-l
047D:0000 MOV     SI,0000
047D:0003 MOV     BX,0100
047D:0006 MOV     BYTE [0108],00
047D:000B MOV     AL,[BX+SI]
047D:000D CMP     AL,01[BX+SI]
047D:0010 JBE     001C
047D:0012 XCHG    AL,01[BX+SI]
047D:0015 MOV     [BX+SI],AL
047D:0017 MOV     BYTE [0108],01
047D:001C INC     SI
047D:001D CMP     SI,0008
047D:0020 JNZ     000B
```

Display the start of the data segment.

```
-d100,10f
0480:0100 03 08 04 06 1F 06 04 01 00 00 00 00 00 00 00 00 ................
```

Disassemble the rest of the code.

```
-l
047D:0022 TEST    BYTE [0108],01
047D:0027 JNZ     0000
047D:0029 JMP     0029
047D:002C ADD     [BX+SI],AL
047D:002E ADD     [BX+SI],AL
047D:0030 DAS
047D:0031 ADD     [BX+SI],AL
047D:0033 ??=     6C
047D:0034 POP     ES
047D:0035 ADD     [BX],CL
047D:0037 ADD     [BX+SI],AX
047D:0039 ??=     6F
```

Execute program from IP (=0) setting breakpoint at 29H.

```
-g,29
```

```
*047D:0029
```

Breakpoint encountered.

Display sorted list.

```
-d100,10f
0480:0100 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
```

Doesn't look good; reload file.

```
-esort
     START      END
CS 047D:0000 047D:002F
DS 0480:0000 0480:010F
```

Trace 3 instructions.

```
-t3
            AX   BX   CX   DX   SP   BP   SI   DI   IP
-----Z-P- 0000 0100 0000 0000 119E 0000 0008 0000 0000 MOV    SI,0000
-----Z-P- 0000 0100 0000 0000 119E 0000 0000 0000 0003 MOV    BX,0100
-----Z-P- 0000 0100 0000 0000 119E 0000 0000 0000 0006 MOV    BYTE [0108],00
*047D:000B
```

Trace some more.

```
-t3
            AX   BX   CX   DX   SP   BP   SI   DI   IP
-----Z-P- 0000 0100 0000 0000 119E 0000 0000 0000 000B MOV    AL,[BX+SI]
-----Z-P- 0003 0100 0000 0000 119E 0000 0000 0000 000D CMP    AL,01[BX+SI]
----S-A-C 0003 0100 0000 0000 119E 0000 0000 0000 0010 JBE    001C
*047D:001C
```

Display unsorted list.

```
-d100,10f
0480:0100 03 08 04 06 1F 06 04 01 00 00 00 00 00 00 00 00 ................
```

Display next instructions to be executed.

```
-l
047D:001C INC    SI
047D:001D CMP    SI,0008
047D:0020 JNZ    000B
047D:0022 TEST   BYTE [0108],01
047D:0027 JNZ    0000
047D:0029 JMP    0029
047D:002C ADD    [BX+SI],AL
047D:002E ADD    [BX+SI],AL
047D:0030 DAS
047D:0031 ADD    [BX+SI],AL
047D:0033 ??=    6C
047D:0034 POP    ES
```

Trace some more.

```
-t3
          AX   BX   CX   DX   SP   BP   SI   DI   IP
----S-A-C 0003 0100 0000 0000 119E 0000 0000 0000 001C INC    SI
--------C 0003 0100 0000 0000 119E 0000 0001 0000 001D CMP    SI,0008
----S-APC 0003 0100 0000 0000 119E 0000 0001 0000 0020 JNZ    000B
*047D:000B
```

Display instructions from current IP.

```
-l
047D:000B MOV    AL,[BX+SI]
047D:000D CMP    AL,01[BX+SI]
047D:0010 JBE    001C
047D:0012 XCHG   AL,01[BX+SI]
047D:0015 MOV    [BX+SI],AL
047D:0017 MOV    BYTE [0108],01
047D:001C INC    SI
047D:001D CMP    SI,0008
047D:0020 JNZ    000B
047D:0022 TEST   BYTE [0108],01
047D:0027 JNZ    0000
047D:0029 JMP    0029


-t3
          AX   BX   CX   DX   SP   BP   SI   DI   IP
----S-APC 0003 0100 0000 0000 119E 0000 0001 0000 000B MOV    AL,[BX+SI]
----S-APC 0008 0100 0000 0000 119E 0000 0001 0000 000D CMP    AL,01[BX+SI]
--------- 0008 0100 0000 0000 119E 0000 0001 0000 0010 JBE    001C
*047D:0012


-l
047D:0012 XCHG   AL,01[BX+SI]
047D:0015 MOV    [BX+SI],AL
047D:0017 MOV    BYTE [0108],01
047D:001C INC    SI
047D:001D CMP    SI,0008
047D:0020 JNZ    000B
047D:0022 TEST   BYTE [0108],01
047D:0027 JNZ    0000
047D:0029 JMP    0029
047D:002C ADD    [BX+SI],AL
047D:002E ADD    [BX+SI],AL
047D:0030 DAS
```

Go until switch has been performed.

```
-g,20
*047D:0020
```

Display list.

```
-d100,10f
0480:0100 03 04 08 06 1F 06 04 01 01 00 00 00 00 00 00 00 ................
```

Looks like 4 and 8 were switched okay. (And toggle is true.)

```
-t
          AX   BX   CX   DX   SP   BP   SI   DI   IP
----S-APC 0004 0100 0000 0000 119E 0000 0002 0000 0020 JNZ    000B
*047D:000B
```

Display next instructions.

```
-l
047D:000B MOV    AL,[BX+SI]
047D:000D CMP    AL,01[BX+SI]
047D:0010 JBE    001C
047D:0012 XCHG   AL,01[BX+SI]
047D:0015 MOV    [BX+SI],AL
047D:0017 MOV    BYTE [0108],01
047D:001C INC    SI
047D:001D CMP    SI,0008
047D:0020 JNZ    000B
047D:0022 TEST   BYTE [0108],01
047D:0027 JNZ    0000
047D:0029 JMP    0029
```

Since switch worked, let's reload and check boundary conditions.

```
-esort
     START      END
CS 047D:0000 047D:002F
DS 0480:0000 0480:010F
```

Make it quicker by setting list length to 3. (Could also have used s47d=1e to patch.)

```
-a1d
047D:001D cmp si,3
047D:0020
```

Display unsorted list.

```
-d100
0480:0100 03 08 04 06 1F 06 04 01 00 00 00 00 00 00 00 00 ................
0480:0110 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0480:0120 00 00 00 00 00 00 00 00 00 00 00 00 00 20 20 20 ............
```

Set breakpoint when first 3 elements of list should be sorted.

```
-g,29
*047D:0029
```

See if list is sorted.

```
-d100,10f
0480:0100 03 04 06 08 1F 06 04 01 00 00 00 00 00 00 00 00 ................
```

Interesting, the fourth element seems to have been sorted in.

```
-esort
     START      END
CS 047D:0000 047D:002F
DS 0480:0000 0480:010F
```

Let's try again with some tracing.

```
-a1d
047D:001D cmp si,3
047D:0020 .

-t9
           AX   BX   CX   DX   SP   BP   SI   DI   IP
-----Z-P- 0006 0100 0000 0000 119E 0000 0003 0000 0000 MOV    SI,0000
-----Z-P- 0006 0100 0000 0000 119E 0000 0000 0000 0003 MOV    BX,0100
-----Z-P- 0006 0100 0000 0000 119E 0000 0000 0000 0006 MOV    BYTE [0108],00
-----Z-P- 0006 0100 0000 0000 119E 0000 0000 0000 000B MOV    AL,[BX+SI]
-----Z-P- 0003 0100 0000 0000 119E 0000 0000 0000 000D CMP    AL,01[BX+SI]
----S-A-C 0003 0100 0000 0000 119E 0000 0000 0000 0010 JBE    001C
----S-A-C 0003 0100 0000 0000 119E 0000 0000 0000 001C INC    SI
--------C 0003 0100 0000 0000 119E 0000 0001 0000 001D CMP    SI,0003
----S-A-C 0003 0100 0000 0000 119E 0000 0001 0000 0020 JNZ    000B
*047D:000B
```

```
-l
047D:000B MOV    AL,[BX+SI]
047D:000D CMP    AL,01[BX+SI]
047D:0010 JBE    001C
047D:0012 XCHG   AL,01[BX+SI]
047D:0015 MOV    [BX+SI],AL
047D:0017 MOV    BYTE [0108],01
047D:001C INC    SI
047D:001D CMP    SI,0003
047D:0020 JNZ    000B
047D:0022 TEST   BYTE [0108],01
047D:0027 JNZ    0000
047D:0029 JMP    0029

-t3
           AX   BX   CX   DX   SP   BP   SI   DI   IP
----S-A-C 0003 0100 0000 0000 119E 0000 0001 0000 000B MOV    AL,[BX+SI]
----S-A-C 0008 0100 0000 0000 119E 0000 0001 0000 000D CMP    AL,01[BX+SI]
--------- 0008 0100 0000 0000 119E 0000 0001 0000 0010 JBE    001C
*047D:0012

-l
047D:0012 XCHG   AL,01[BX+SI]
047D:0015 MOV    [BX+SI],AL
047D:0017 MOV    BYTE [0108],01
047D:001C INC    SI
047D:001D CMP    SI,0003
047D:0020 JNZ    000B
047D:0022 TEST   BYTE [0108],01

-t3
           AX   BX   CX   DX   SP   BP   SI   DI   IP
--------- 0008 0100 0000 0000 119E 0000 0001 0000 0012 XCHG   AL,01[BX+SI]
--------- 0004 0100 0000 0000 119E 0000 0001 0000 0015 MOV    [BX+SI],AL
--------- 0004 0100 0000 0000 119E 0000 0001 0000 0017 MOV    BYTE [0108],01
*047D:001C


-d100,10f
0480:0100 03 04 08 06 1F 06 04 01 01 00 00 00 00 00 00 00 ................
```

So far, so good.

```
-t3
           AX   BX   CX   DX   SP   BP   SI   DI   IP
--------- 0004 0100 0000 0000 119E 0000 0001 0000 001C INC    SI
--------- 0004 0100 0000 0000 119E 0000 0002 0000 001D CMP    SI,0003
----S-APC 0004 0100 0000 0000 119E 0000 0002 0000 0020 JNZ    000B
*047D:000B
```

```
-1
047D:000B MOV    AL,[BX+SI]
047D:000D CMP    AL,01[BX+SI]
047D:0010 JBE    001C
047D:0012 XCHG   AL,01[BX+SI]
047D:0015 MOV    [BX+SI],AL
047D:0017 MOV    BYTE [0108],01
047D:001C INC    SI
047D:001D CMP    SI,0003
047D:0020 JNZ    000B
047D:0022 TEST   BYTE [0108],01
047D:0027 JNZ    0000
047D:0029 JMP    0029


-t3
           AX   BX   CX   DX   SP   BP   SI   DI   IP
----S-APC 0004 0100 0000 0000 119E 0000 0002 0000 000B MOV    AL,[BX+SI]
----S-APC 0008 0100 0000 0000 119E 0000 0002 0000 000D CMP    AL,01[BX+SI]
--------- 0008 0100 0000 0000 119E 0000 0002 0000 0010 JBE    001C
*047D:0012
```

Sure enough, it's comparing the third and fourth elements of the list. Reload the program.

```
-esort
     START      END
CS 047D:0000 047D:002F
DS 0480:0000 0480:010F


-1
047D:0000 MOV    SI,0000
047D:0003 MOV    BX,0100
047D:0006 MOV    BYTE [0108],00
047D:000B MOV    AL,[BX+SI]
047D:000D CMP    AL,01[BX+SI]
047D:0010 JBE    001C
047D:0012 XCHG   AL,01[BX+SI]
047D:0015 MOV    [BX+SI],AL
047D:0017 MOV    BYTE [0108],01
047D:001C INC    SI
047D:001D CMP    SI,0008
047D:0020 JNZ    000B
```

Patch length.

```
-a1d
047D:001D cmp si,7
047D:0020 .
```

Try it out.

```
-g,29
*047D:0029
```

See if list is sorted.

```
-d100,10f
0480:0100 01 03 04 04 06 06 08 1F 00 00 00 00 00 00 00 00 ................
```

Looks better; let's install patch in disk file. To do this, we must read CMB file including header, so we use R command.

```
-rsort.cmd
  START      END
2000:0000 2000:01FF
```

First 80h bytes contain header, so code starts at 80h.

```
-180
2000:0080 MOV    SI,0000
2000:0083 MOV    BX,0100
2000:0086 MOV    BYTE [0108],00
2000:008B MOV    AL,[BX+SI]
2000:008D CMP    AL,01[BX+SI]
2000:0090 JBE    009C
2000:0092 XCHG   AL,01[BX+SI]
2000:0095 MOV    [BX+SI],AL
2000:0097 MOV    BYTE [0108],01
2000:009C INC    SI
2000:009D CMP    SI,0008
2000:00A0 JNZ    008B
```

Install patch.

```
-a9d
2000:009D cmp si,7
2000:00A0
```

Write file back to disk. (Length of file assumed to be unchanged since no length specified.)

```
-wsort.cmd
```

Reload file.

```
-esort

     START      END
CS 047D:0000 047D:002F
DS 0480:0000 0480:010F
```

Verify that patch was installed.

```
-l
047D:0000 MOV    SI,0000
047D:0003 MOV    BX,0100
047D:0006 MOV    BYTE [0108],00
047D:000B MOV    AL,[BX+SI]
047D:000D CMP    AL,01[BX+SI]
047D:0010 JBE    001C
047D:0012 XCHG   AL,01[BX+SI]
047D:0015 MOV    [BX+SI],AL
047D:0017 MOV    BYTE [0108],01
047D:001C INC    SI
047D:001D CMP    SI,0007
047D:0020 JNZ    000B
```

Run it.

```
-g,29
*047D:0029
```

Still looks good. Ship it!

```
-d100,10f
0480:0100 01 03 04 04 06 06 08 1F 00 00 00 00 00 00 00 00 ................
-^C
A>
```

End of Section 6

Appendix A
ASM-86 Invocation

Command: ASM86

Syntax: ASM86 <*filename*> { $ <*parameters*> }

where

<*filename*> is the 8086 assembly source file. Drive and extension are optional. The default file extension is .A86.

<*parameters*> are a one-letter type followed by a one-letter device from the table below.

Parameters:

form: $ Td where T = type and d = device

Table A-1. Parameter Types and Devices

Devices	*Parameters*				
	A	*H*	*P*	*S*	*F*
A - P	x	x	x	x	
X		x	x	x	
Y		x	x	x	
Z		x	x	x	
I					x
D					d

x = valid, d = default

Valid Parameters

Except for the F type, the default device is the the current default drive.

Table A-2. Parameter Types

A	controls location of ASSEMBLER source file
H	controls location of HEX file
P	controls location of PRINT file
S	controls location of SYMBOL file
F	controls type of hex output FORMAT

Table A-3. Device Types

A - P	Drives A - P
X	console device
Y	printer device
Z	byte bucket
I	Intel hex format
D	Digital Research hex format

Table A-4. Invocation Examples

ASM86 IO	Assemble file IO.A86, produce IO.HEX IO.LST and IO.SYM.
ASM86 IO.ASM $ AD SZ	Assemble file IO.ASM on device D, produce IO.LST and IO.HEX, no symbol file.
ASM86 IO $ PY SX	Assemble file IO.A86, produce IO.HEX, route listing directly to printer, output symbols on console.
ASM86 IO $ FD	Produce Digital Research hex format.
ASM86 IO $ FI	Produce Intel hex format.

End of Appendix A

Appendix B
Mnemonic Differences from the Intel Assembler

The CP/M 8086 assembler uses the same instruction mnemonics as the INTEL 8086 assembler except for explicitly specifying far and short jumps, calls and returns. The following table shows the four differences:

Table B-1. Mnemonic Differences

Mnemonic Function	*CP/M*	*INTEL*
Intra segment short jump:	JMPS	JMP
Inter segment jump:	JMPF	JMP
Inter segment return:	RETF	RET
Inter segment call:	CALLF	CALL

End of Appendix B

Appendix C
ASM-86 Hexadecimal Output Format

At the user's option, ASM-86 produces machine code in either Intel or Digital Research hexadecimal format. The Intel format is identical to the format defined by Intel for the 8086. The Digital Research format is nearly identical to the Intel format, but adds segment information to hexadecimal records. Output of either format can be input to GENCMD, but the Digital Research format automatically provides segment identification. A segment is the smallest unit of a program that can be relocated.

Table C-1 defines the sequence and contents of bytes in a hexadecimal record. Each hexadecimal record has one of the four formats shown in Table C-2. An example of a hexadecimal record is shown below.

```
Byte number=>  0 1 2 3 4 5 6 7 8 9 . . . . . n

Contents=>  : l l a a a a t t d d d . . . . . c c CR LF
```

Table C-1. Hexadecimal Record Contents

Byte	*Contents*	*Symbol*
0	record mark	:
1—2	record length	l l
3—6	load address	a a a a
7—8	record type	t t
9—(n−1)	data bytes	d d . . . . . d
n—(n+1)	check sum	c c
n+2	carriage return	CR
n+3	line feed	LF

Table C-2. Hexadecimal Record Formats

Record type	*Content*	*Format*
00	Data record	: ll aaaa DT <data . . .> cc
01	End-of-file	: 00 0000 01 FF
02	Extended address mark	: 02 0000 ST ssss cc
03	Start address	: 04 0000 03 ssss iiii cc

ll	=>	record length—number of data bytes
cc	=>	check sum—sum of all record bytes
aaaa	=>	16 bit address
ssss	=>	16 bit segment value
iiii	=>	offset value of start address
DT	=>	data record type
ST	=>	segment address record type

It is in the definition of record types 00 and 02 that Digital Research's hexadecimal format differs from Intel's. Intel defines one value each for the data record type and the segment address type. Digital Research identifies each record with the segment that contains it, as shown in Table C-3.

Table C-3. Segment Record Types

Symbol	*Intel's Value*	*Digital's Value*	*Meaning*
DT	00		for data belonging to all 8086 segments
		81H	for data belonging to the CODE segment
		82H	for data belonging to the DATA segment
		83H	for data belonging to the STACK segment
		84H	for data belonging to the EXTRA segment
ST	02		for all segment address records
		85H	for a CODE absolute segment address
		86H	for a DATA segment address
		87H	for a STACK segment address
		88H	for a EXTRA segment address

End of Appendix C

Appendix D
Reserved Words

Table D-1. Reserved Words

Predefined Numbers				
BYTE	WORD	DWORD		
Operators				
EQ	GE	GT	LE	LT
NE	OR	AND	MOD	NOT
PTR	SEG	SHL	SHR	XOR
LAST	TYPE	LENGTH	OFFSET	
Assembler Directives				
DB	DD	DW	IF	RS
RB	RW	END	ENDM	EQU
ORG	CSEG	DSEG	ESEG	SSEG
EJECT	ENDIF	TITLE	LIST	NOLIST
INCLUDE	SIMFORM	PAGESIZE	CODEMACRO	PAGEWIDTH
Code-macro directives				
DB	DD	DW	DBIT	RELB
RELW	MODRM	SEGFIX	NOSEGFIX	
8086 Registers				
AH	AL	AX	BH	BL
BP	BX	CH	CL	CS
CX	DH	DI	DL	DS
DX	ES	SI	SP	SS

Instruction Mnemonics—See Appendix E.

End of Appendix D

Appendix E
ASM-86 Instruction Summary

Table E-1. ASM-86 Instruction Summary

Mnemonic	*Description*	*Section*
AAA	ASCII adjust for Addition	4.3
AAD	ASCII adjust for Division	4.3
AAM	ASCII adjust for Multiplication	4.3
AAS	ASCII adjust for Subtraction	4.3
ADC	Add with Carry	4.3
ADD	Add	4.3
AND	And	4.3
CALL	Call (intra segment)	4.5
CALLF	Call (inter segment)	4.5
CBW	Convert Byte to Word	4.3
CLC	Clear Carry	4.6
CLD	Clear Direction	4.6
CLI	Clear Interrupt	4.6
CMC	Complement Carry	4.6
CMP	Compare	4.3
CMPS	Compare Byte or Word (of string)	4.4
CWD	Convert Word to Double Word	4.3
DAA	Decimal Adjust for Addition	4.3
DAS	Decimal Adjust for Subtraction	4.3
DEC	Decrement	4.3
DIV	Divide	4.3
ESC	Escape	4.6
HLT	Halt	4.6
IDIV	Integer Divide	4.3
IMUL	Integer Multiply	4.3
IN	Input Byte or Word	4.2
INC	Increment	4.3
INT	Interrupt	4.5
INTO	Interrupt on Overflow	4.5

Table E-1. (continued)

Mnemonic	*Description*	*Section*
IRET	Interrupt Return	4.5
JA	Jump on Above	4.5
JAE	Jump on Above or Equal	4.5
JB	Jump on Below	4.5
JBE	Jump on Below or Equal	4.5
JC	Jump on Carry	4.5
JCXZ	Jump on CX Zero	4.5
JE	Jump on Equal	4.5
JG	Jump on Greater	4.5
JGE	Jump on Greater or Equal	4.5
JL	Jump on Less	4.5
JLE	Jump on Less or Equal	4.5
JMP	Jump (intra segment)	4.5
JMPF	Jump (inter segment)	4.5
JMPS	Jump (8 bit displacement)	4.5
JNA	Jump on Not Above	4.5
JNAE	Jump on Not Above or Equal	4.5
JNB	Jump on Not Below	4.5
JNBE	Jump on Not Below or Equal	4.5
JNC	Jump on Not Carry	4.5
JNE	Jump on Not Equal	4.5
JNG	Jump on Not Greater	4.5
JNGE	Jump on Not Greater or Equal	4.5
JNL	Jump on Not Less	4.5
JNLE	Jump on Not Less or Equal	4.5
JNO	Jump on Not Overflow	4.5
JNP	Jump on Not Parity	4.5
JNS	Jump on Not Sign	4.5
JNZ	Jump on Not Zero	4.5
JO	Jump on Overflow	4.5
JP	Jump on Parity	4.5
JPE	Jump on Parity Even	4.5
JPO	Jump on Parity Odd	4.5
JS	Jump on Sign	4.5
JZ	Jump on Zero	4.5
LAHF	Load AH with Flags	4.2

Table E-1. (continued)

Mnemonic	*Description*	*Section*
LDS	Load Pointer into DS	4.2
LEA	Load Effective Address	4.2
LES	Load Pointer into ES	4.2
LOCK	Lock Bus	4.6
LODS	Load Byte or Word (of string)	4.4
LOOP	Loop	4.5
LOOPE	Loop While Equal	4.5
LOOPNE	Loop While Not Equal	4.5
LOOPNZ	Loop While Not Zero	4.5
LOOPZ	Loop While Zero	4.5
MOV	Move	4.2
MOVS	Move Byte or Word (of string)	4.4
MUL	Multiply	4.3
NEG	Negate	4.3
NOT	Not	4.3
OR	Or	4.3
OUT	Output Byte or Word	4.2
POP	Pop	4.2
POPF	Pop Flags	4.2
PUSH	Push	4.2
PUSHF	Push Flags	4.2
RCL	Rotate through Carry Left	4.3
RCR	Rotate through Carry Right	4.3
REP	Repeat	4.4
RET	Return (intra segment)	4.5
RETF	Return (inter segment)	4.5
ROL	Rotate Left	4.3
ROR	Rotate Right	4.3
SAHF	Store AH into Flags	4.2
SAL	Shift Arithmetic Left	4.3
SAR	Shift Arithmetic Right	4.3
SBB	Subtract with Borrow	4.3
SCAS	Scan Byte or Word (of string)	4.4
SHL	Shift Left	4.3
SHR	Shift Right	4.3
STC	Set Carry	4.6

Table E-1. (continued)

Mnemonic	*Description*	*Section*
STD	Set Direction	4.6
STI	Set Interrupt	4.6
STOS	Store Byte or Word (of string)	4.4
SUB	Subtract	4.3
TEST	Test	4.3
WAIT	Wait	4.6
XCHG	Exchange	4.2
XLAT	Translate	4.2
XOR	Exclusive Or	4.3

End of Appendix E

Appendix F
Sample Program

```
CP/M ASM86 1.1  SOURCE: APPF.A86      Terminal Input/Output          PAGE   1


                        title "Terminal Input/Output"
                        pagesize 50
                        pagewidth 79
                        simform
                        ;
                        ;****** Terminal I/O subroutines ********
                        ;
                        ;       The following subroutines
                        ;       are included:
                        ;
                        ;       CONSTAT   -  console status
                        ;       CONIN     -  console input
                        ;       CONOUT    -  console output
                        ;
                        ;       Each routine requires CONSOLE NUMBER
                        ;       in the BL - register
                        ;
                        ;
                        ;       *****************
                        ;       *  Jump table:  /
                        ;       ****************
                        ;
                        CSEG            ; start of code segment
                        ;
                        jmp  tab:
0000 E90600                     jmp     constat
0003 E91900                     jmp     conin
0006 E92B00                     jmp     conout
                        ;
                        ;
                        ;       ************************
                        ;       *  I/O port numbers   /
                        ;       ************************
```

Listing F-1. Sample Program APPF.A86

```
CP/M ASM86 1.1  SOURCE: APPF.A86      Terminal Input/Output          PAGE   2


                ;
                ;         Terminal 1:
                ;
  0010          instat1         equ     10h     ; input status port
  0011          indata1         equ     11h     ; input port
  0011          outdata1        equ     11h     ; output port
  0001          readyinmask1    equ     01h     ; input ready mask
  0002          readyoutmask1   equ     02h     ; output ready mask
                ;
                ;         Terminal 2:
                ;
  0012          instat2         equ     12h     ; input status port
  0013          indata2         equ     13h     ; input port
  0013          outdata2        equ     13h     ; output port
  0004          readyinmask2    equ     04h     ; input ready mask
  0008          readyoutmask2   equ     08h     ; output ready mask
                ;
                ;
                ;       ***********
                ;       * CONSTAT /
                ;       ***********
                ;
                ;       Entry: BL - reg = terminal no
                ;       Exit:  AL - reg = 0 if not ready
                ;                         0ffh if ready
                ;
                constat:
0009 53E83F00           push bx ! call okterminal
                constat1:
000D 52                 push dx
000E B600               mov  dh,0                   ; read status port
0010 8A17               mov  dl,instatustab [BX]
0012 EC                 in   al,dx
0013 224706             and  al,readyinmasktab [bx]
0016 7402               jz   constatout
0018 B0FF               mov  al,0ffh
```

Listing F-1. (continued)

```
CP/M ASM86 1.1  SOURCE: APPF.A86      Terminal Input/Output          PAGE   3


                        constatout:
001A 5A5B0AC0C3                 pop dx ! pop bx ! or al,al ! ret
                        ;
                        ;
                        ;       *********
                        ;       * CONIN /
                        ;       *********
                        ;
                        ;       Entry: BL - reg = terminal no
                        ;       Exit:  AL - reg = read character
                        ;
001F 53E82900           conin:  push bx ! call okterminal !
0023 E8E7FF             conin1: call constat1               ; test status
0026 74FB                       jz   conin1
0028 52                         push dx                     ; read character
0029 B600                       mov  dh,0
002B 8A5702                     mov  dl,indatatab [BX]
002E EC                         in   al,dx
002F 247F                       and  al,7fh                 ; strip parity bit
0031 5A5BC3                     pop dx ! pop bx ! ret
                        ;
                        ;
                        ;       **********
                        ;       * CONOUT /
                        ;       **********
                        ;
                        ;       Entry:  BL - reg = terminal no
                        ;               AL - reg = character to print
                        ;
0034 53E81400           conout: push bx ! call okterminal
0038 52                         push dx
0039 50                         push ax
003A B600                       mov  dh,0                   ; test status
003C 8A17                       mov  dl,instatustab [BX]
                        conout1:
003E EC                         in   al,dx
```

Listing F-1. (continued)

```
CP/M ASM86 1.1  SOURCE: APPF.A86      Terminal Input/Output          PAGE   4


 003F 224708                and  al,readyoutmasktab [BX]
 0042 74FA                  jz   conout1
 0044 58                    pop  ax                     ; write byte
 0045 8A5704                mov  dl,outdatatab [BX]
 0048 EE                    out  dx,al
 0049 5A5BC3                pop dx ! pop bx ! ret
                    ;
                    ;
                    ;       ++++++++++++++
                    ;       + OKTERMINAL +
                    ;       ++++++++++++++
                    ;
                    ;       Entry:  BL - reg = terminal no
                    ;
                    okterminal:
 004C 0ADB                  or   bl,bl
 004E 740A                  jz   error
 0050 80FB03                cmp  bl,length instatustab + 1
 0053 7305                  jae  error
 0055 FECB                  dec  bl
 0057 B700                  mov  bh,0
 0059 C3                    ret
                    ;
 005A 5B5BC3        error:  pop bx ! pop bx ! ret       ; do nothing
                    ;
                    ;*************** end of code segment ***************
                    ;
                    ;       ****************
                    ;       * Data segment *
                    ;       ****************
                    ;
                            dseg

                    ;       ***************************
                    ;       * Data for each terminal *
                    ;       ***************************
```

Listing F-1. (continued)

```
CP/M ASM86 1.1  SOURCE: APPF.A86      Terminal Input/Output          PAGE   5


                ;

 0000 1012      instatustab     db      instat1,instat2
 0002 1113      indatatab       db      indata1,indata2
 0004 1113      outdatatab      db      outdata1,outdata2
 0006 0104      readyinmasktab  db      readyinmask1,readyinmask2
 0008 0208      readyoutmasktab db      readyoutmask1,readyoutmask2
                ;
                ;*************** end of file **********************
                end

END OF ASSEMBLY, NUMBER OF ERRORS:   0
```

Listing F-1. (continued)

End of Appendix F

Appendix G
Code-Macro Definition Syntax

<*codemacro*> ::= CODEMACRO <*name*> [<*formal$list*>]
[<*listofmacro$directives*>]
ENDM

<*name*> ::= IDENTIFIER

<*formal$list*> ::= <*parameter$descr*>[{,<*parameter$descr*>}]

<*parameter$descr*> ::= <*form$name*>:<*specifier$letter*>
<*modifier$letter*>[(<*range*>)]

<*specifier$letter*> ::= A | C | D | E | M | R | S | X

<*modifier$letter*> ::= b | w | d | sb

<*range*> ::= <*single$range*>|<*double$range*>

<*single$range*> ::= REGISTER | NUMBERB

<*double$range*> ::= NUMBERB,NUMBERB | NUMBERB,REGISTER |
REGISTER,NUMBERB | REGISTER,REGISTER

<*listofmacro$directives*> ::= <*macro$directive*>
{<*macro$directive*>}

<*macro$directive*> ::= <*db*> | <*dw*> | <*dd*> | <*segfix*> |
<*nosegfix*> | <*modrm*> | <*relb*> |
<*relw*> | <*dbit*>

<*db*> ::= DB NUMBERB | DB <*form$name*>

<*dw*> ::= DW NUMBERW | DW <*form$name*>

<*dd*> ::= DD <*form$name*>

<*segfix*> ::= SEGFIX <*form$name*>

<*nosegfix*> ::= NOSEGFIX <*form$name*>

<*modrm*> ::= MODRM NUMBER7,<*form$name*> |
MODRM <*form$name*>,<*form$name*>

<*relb*> ::= RELB <*form$name*>

<*relw*> ::= RELW <*form$name*>

<*dbit*> ::= DBIT <*field$descr*>{,<*field$descr*>}

<*field$descr*> ::= NUMBER15 (NUMBERB) |
NUMBER15 (<*form$name*> (NUMBERB))

<*form$name*> ::= IDENTIFIER

NUMBERB is 8-bits
NUMBERW is 16-bits
NUMBER7 are the values 0, 1,. . , 7
NUMBER15 are the values 0, 1,. . , 15

End of Appendix G

Appendix H
ASM-86 Error Messages

There are two types of error messages produced by ASM-86: fatal errors and diagnostics. Fatal errors occur when ASM-86 is unable to continue assembling. Diagnostic messages report problems with the syntax and semantics of the program being assembled. The following messages indicate fatal errors encountered by ASM-86 during assembly:

```
NO FILE
DISK FULL
DIRECTORY FULL
DISK READ ERROR
CANNOT CLOSE
SYMBOL TABLE OVERFLOW
PARAMETER ERROR
```

ASM-86 reports semantic and syntax errors by placing a numbered ASCII message in front of the erroneous source line. If there is more than one error in the line, only the first one is reported. Table H-1 summarizes ASM-86 diagnostic error messages.

Table H-1. ASM-86 Diagnostic Error Messages

Number	*Meaning*
0	ILLEGAL FIRST ITEM
1	MISSING PSEUDO INSTRUCTION
2	ILLEGAL PSEUDO INSTRUCTION
3	DOUBLE DEFINED VARIABLE
4	DOUBLE DEFINED LABEL
5	UNDEFINED INSTRUCTION
6	GARBAGE AT END OF LINE - IGNORED
7	OPERAND(S) MISMATCH INSTRUCTION
8	ILLEGAL INSTRUCTION OPERANDS
9	MISSING INSTRUCTION
10	UNDEFINED ELEMENT OF EXPRESSION
11	ILLEGAL PSEUDO OPERAND
12	NESTED "IF" ILLEGAL - "IF" IGNORED

Table H-1. (continued)

Number	*Meaning*
13	ILLEGAL "IF" OPERAND - "IF" IGNORED
14	NO MATCHING "IF" FOR "ENDIF"
15	SYMBOL ILLEGALLY FORWARD REFERENCED - NEGLECTED
16	DOUBLE DEFINED SYMBOL - TREATED AS UNDEFINED
17	INSTRUCTION NOT IN CODE SEGMENT
18	FILE NAME SYNTAX ERROR
19	NESTED INCLUDE NOT ALLOWED
20	ILLEGAL EXPRESSION ELEMENT
21	MISSING TYPE INFORMATION IN OPERAND(S)
22	LABEL OUT OF RANGE
23	MISSING SEGMENT INFORMATION IN OPERAND
24	ERROR IN CODEMACROBUILDING

End of Appendix H

Appendix I
DDT-86 Error Messages

Table I-1. DDT-86 Error Messages

Error Message	*Meaning*
AMBIGUOUS OPERAND	An attempt was made to assemble a command with an ambiguous operand. Precede the operand with the prefix "BYTE" or "WORD".
CANNOT CLOSE	The disk file written by a W command cannot be closed.
DISK READ ERROR	The disk file specified in an R command could not be read properly.
DISK WRITE ERROR	A disk write operation could not be successfully performed during a W command, probably due to a full disk.
INSUFFICIENT MEMORY	There is not enough memory to load the file specified in an R or E command.
MEMORY REQUEST DENIED	A request for memory during an R command could not be fulfilled. Up to eight blocks of memory may be allocated at a given time.
NO FILE	The file specified in an R or E command could not be found on the disk.
NO SPACE	There is no space in the directory for the file being written by a W command.

Table I-1. (continued)

Error Message	*Meaning*
VERIFY ERROR AT s:o	The value placed in memory by a Fill, Set, Move, or Assemble command could not be read back correctly, indicating bad RAM or attempting to write to ROM or non-existent memory at the indicated location.

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