Burroughs

Macro Assembler Manual

B 20 Systems

MS™-DOS Operating System

(Relative to Release Level 2.0)

Priced Item
Printed in U.S.A.
March 1984

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Comments about this documentation may be sent to:

Microsoft Corporation
Microsoft Building
10700 Northup Way
Bellevue, WA 98004

Contents

1 disk, with the following files:

M86.EXE
LINK.EXE
LIB.EXE
CREF.EXE
DEBUG.EXE

1 binder (titled <u>Microsoft Macro Assembler Manual</u>) with 5 manuals:

Microsoft Macro Assembler Utility Manual
Microsoft LINK Linker Utility Manual (Technical Information Only)
Microsoft LIB Library Manager Manual
Microsoft CREF Cross-Reference Utility Manual
Microsoft DEBUG Utility Manual

System Requirements

Each utility requires different amounts of memory.

Macro Assembler - 96K bytes of memory minimum:
64K bytes for code and static data
32K bytes for run space

Microsoft LINK - 50K bytes of memory minimum:
40K bytes for code
10K bytes for run space

Microsoft LIB - 38K bytes of memory minimum:
28K bytes for code
10K bytes for run space

Microsoft CREF - 24K bytes of memory minimum:
14K bytes for code
10K bytes for run space

Microsoft DEBUG - Memory minimum program-dependent
13K bytes for code
Run space program-dependent

Disk drive(s)

One disk drive if and only if output is sent to the same physical disk from which the input was taken. None of the utility programs allows time to swap disks during operation on a one-drive configuration. Therefore, two disk drives is a more practical configuration.

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Welcome to the Microsoft(R) family of products.

Microsoft Corporation continues to supply consistently high-quality software for all types of users.

In addition to the Macro Assembler and Microsoft BASIC interpreter, Microsoft sells other full-feature language compilers, language subsets, and operating system products. Microsoft offers a "family" of software products that both look alike from one product to the next, and can be used together for effective program development.

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Contents

Microsoft LIB Library Manager

Microsoft CREF Cross Reference Utility

Microsoft DEBUG Utility

GENERAL INTRODUCTION

The Microsoft Macro Assembler Manual includes utility programs used for developing assembly language programs. In addition, the Microsoft LINK Linker Utility and DEBUG are used with of Microsoft's 16-bit language compilers.

Major Features

Macro Assembler Utility

Microsoft's Macro Assembler is a powerful assembler for 8086 based computers.

Macro Assembler supports most of the directives found in Microsoft's Macro Assembler for the 8080. Macros and conditionals are Intel 8080 standard.

Macro Assembler is upward compatible with Intel's ASM-86, except Intel codemacros, macros, and a few $ directives.

Macro Assembler offers relaxed typing so that if you enter a typeless operand for an instruction that accepts only one type of operand, Macro Assembler assembles the statement correctly instead of returning an error message.

Microsoft LINK Linker Utility (Technical Information Only)

MS-LINK is a virtual linker, which can link programs that are larger than available memory.

MS-LINK produces relocatable executable object code.

MS-LINK processes overlays that you define.

MS-LINK can perform multiple library searches, using a dictionary library search method.

MS-LINK prompts you for input and output modules and other link session parameters.

MS-LINK can be run with an automatic response file to answer the Linker prompts.

Microsoft LIB Library Manager

MS-LIB can add, delete, and extract modules in your library of program files.

MS-LIB prompts you for input and output file and module names.

MS-LIB can be run with an automatic response file to answer the library prompts.

MS-LIB produces a cross-reference of symbols in the library modules.

Microsoft CREF Cross-Reference Utility

MS-CREF produces a cross-reference listing of all symbolic names in the Macro Assembler source program, giving both the source line number of the definition and the source line numbers of all other references to the symbols.

Microsoft DEBUG Utility

DEBUG provides a controlled testing environment for binary and executable object files.

DEBUG eliminates the need to reassemble a program to see if a problem has been fixed by a minor change.

DEBUG allows you to alter the contents of a file or the contents of a CPU register, and then immediately reexecute a program to check on the validity of the changes.

Using These Manuals

These manuals are designed to be used as a set and individually. Each manual is mostly self-contained and refers to the other manuals only at junctures in the software. The overview given below describes the flow of program development from creating a source file through program execution. The processes described in this overview are echoed and expanded in overviews in each of the manuals contained in the Microsoft Macro Assembler Manual.

Also, note that each manual has its own index.

Figure 1 illustrates an overview of the Microsoft Macro Assembler Manual.

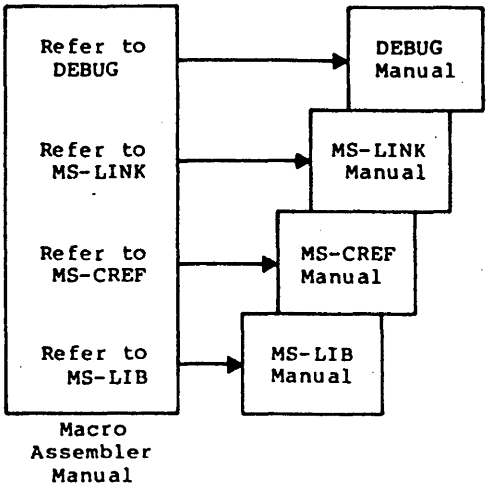


Figure 1. Overview, Macro Assembler Manual

Each of these manuals is used independently. References between manuals reflect junctures in the software.

Syntax Notation

The following notation is used throughout this manual in descriptions of command and statement syntax:

- [ ] Square brackets indicate that the enclosed entry is optional.
- < > Angle brackets indicate data you must enter. When the angle brackets enclose lower case text, you must type in an entry defined by the text; for example, <filename>. When the angle brackets enclose upper case text, you must press the key named by the text; for example, <RETURN>.
- { } Braces indicate that you have a choice between two or more entries. At least one of the entries enclosed in braces must be chosen unless the entries are also enclosed in square brackets.
- ... Ellipses indicate that an entry may be repeated as many times as needed or desired.
- CAPS Capital letters indicate portions of statements or commands that must be entered, exactly as shown.

All other punctuation, such as commas, colons, slash marks, and equal signs, must be entered exactly as shown.

Figure 2 illustrates the syntax notation used in this manual.

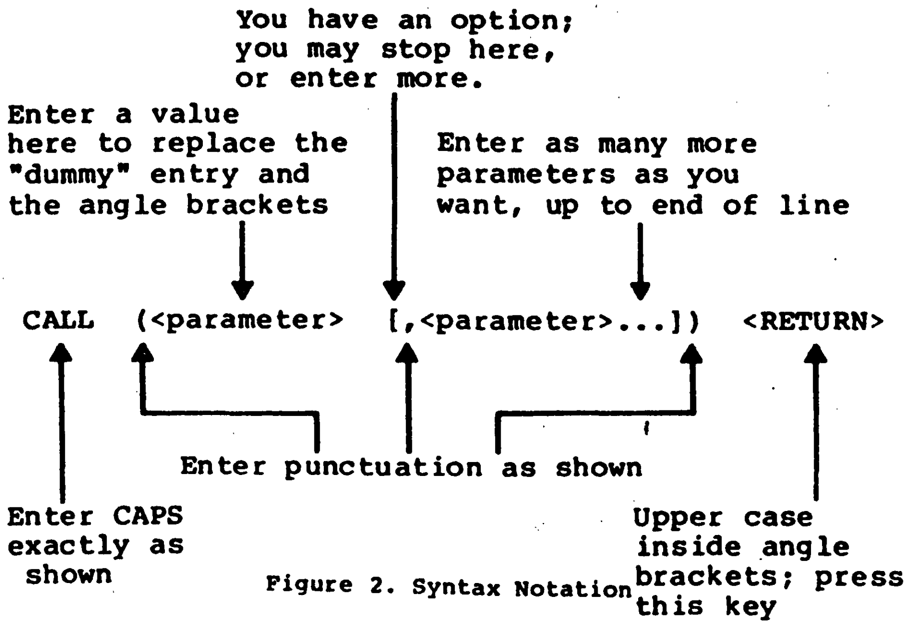


Figure 2. Syntax Notation

Learning More about Assembly Language Programming

These manuals explain how to use MS-DOS utilities and features, but they do not teach you how to program in assembly language.

We assume that you have had some experience programming in assembly language. If you do not have any experience, we suggest two courses:

1. Gain some experience on a less sophisticated assembler.

2. Refer to any or all of the following books for assistance:

Morse, Stephen P. The 8086 Primer. Rochelle Park, NJ: Hayden Publishing Co., 1980.

Rector, Russell and George Alexy. The 8086 Book. Berkeley, CA: Osbourne/McGraw-Hill, 1980.

The 8086 Family User's Manual. Santa Clara, CA: Intel Corporation, 1979.

8086/8087/8088 Macro Assembly Language Reference Manual. Santa Clara, CA: Intel Corporation, 1980.

NOTE

Some of the information in these books was based on preliminary data and may not reflect the final functional state of the microprocessors. Information in your Microsoft manuals was based on Microsoft's development of its 16-bit software for the 8086 and 8088.

Overview of Program Development

This overview describes generally the steps of program development. Each step is described fully in the individual product manuals. The numbers in the descriptions match the numbers in the facing diagram.

1. Use EDLIN (the editor in Microsoft's MS-DOS), or other MS-DOS editor, to create an 8086 assembly language source file. Give the source file the filename extension .ASM (Macro Assembler recognizes .ASM as the default).

2. Assemble the source file with Macro Assembler, which outputs an assembled object file with the default filename extension .OBJ (2a). Assembled files, your program files (2b), can be linked together in step 3.

   Macro Assembler (optionally) creates two types of listing file:

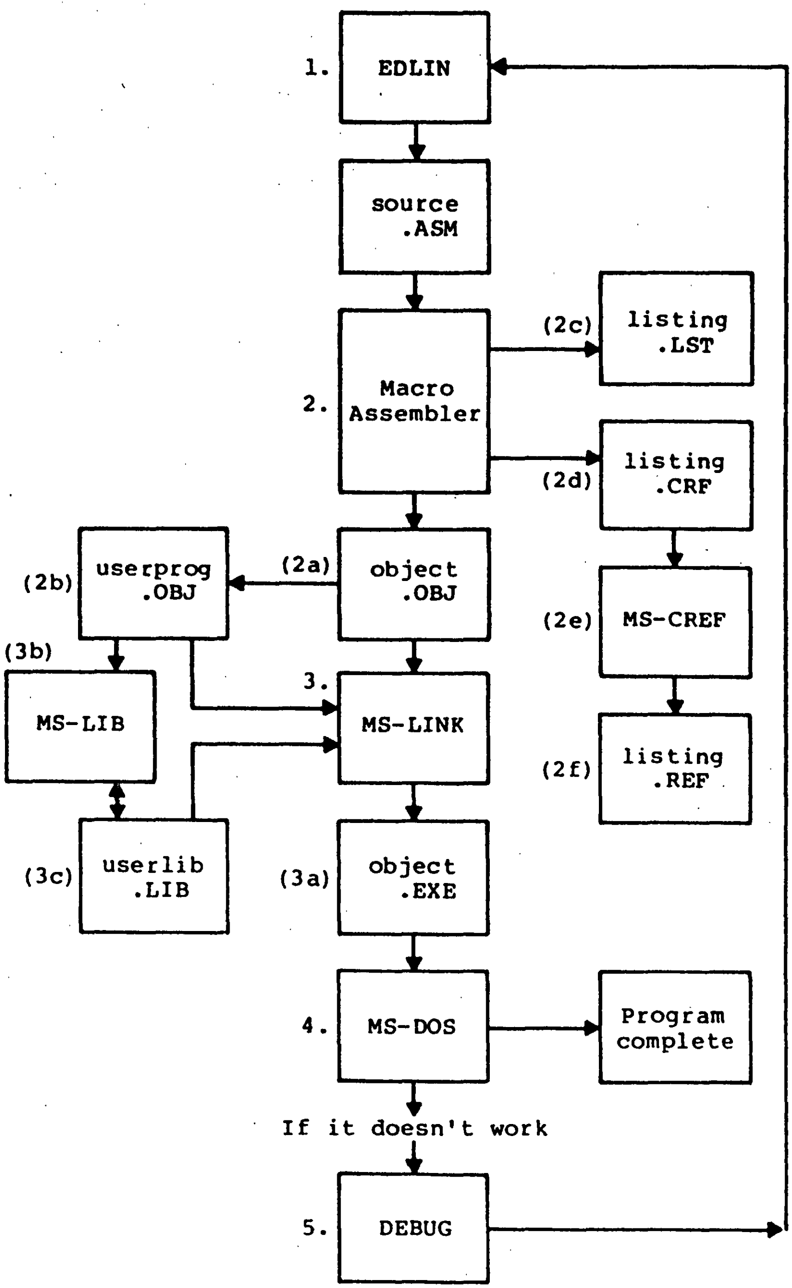
   (2c) a normal listing file which shows assembled code with relative addresses, source statements, and full symbol table;

   (2d) a cross-reference file, a special file with special control characters that allow MS-CREF (2e) to create a list showing the source line number of every symbol's definition and all references to it (2f). When a cross-reference file is created, the normal listing file (with the .LST extension) has line numbers placed into it as references for line numbers following symbols in the cross-reference listing.

3. Link one or more .OBJ modules together, using MS-LINK, to produce an executable object file with the default filename extension .EXE (3a).

   While developing your program, you may want to create a library file for MS-LINK to search to resolve external references. Use MS-LIB (3b) to create user library file(s) (3c) from existing library files (3c) and/or user program object files (2b).

4. Run your assembled and linked program, the .EXE file (3a), under MS-DOS (4). If your program does not run properly, use the DEBUG utility to locate any errors.


1.
EDLIN
source .ASM
2.
Macro Assembler
(2c)
listing .LST
(2d)
listing .CRF
(2e)
MS-CREF
(2f)
listing .REF
(2a)
object .OBJ
(2b)
userprog .OBJ
(3b)
MS-LIB
3.
MS-LINK
(3c)
userlib .LIB
(3a)
object .EXE
4.
MS-DOS
Program complete
If it doesn't work
5.
DEBUG

Microsoft®
Macro Assembler

Utility

for 8086 and 8088 Microprocessors

Microsoft Corporation

System Requirements

The Macro Assembler Utility requires 96K bytes of memory minimum:

64K bytes for code and static data
32K bytes for run space

Disk drive(s)
: One disk drive if and only if output is sent to the same physical disk from which the input was taken. The Macro Assembler Utility does not allow time to swap disks during operation on a one-drive configuration. Therefore, two disk drives is a more practical configuration.

Contents

INTRODUCTION

Features of Macro Assembler

Microsoft's Macro Assembler is a very powerful assembler for 8086-based computers. Macro Assembler incorporates many features usually found only in large computer assemblers. Macro assembly, conditional assembly, and a variety of assembler directives provide all the tools necessary to derive full use and full power from an 8086, 8087, or 8088 microprocessor. Although Macro Assembler is more complex than any other microcomputer assembler, it is easy to use.

Macro Assembler produces relocatable object code. Each instruction and directive statement is given a relative offset from its segment base. The assembled code can then be linked using Microsoft's MS-LINK utility to produce relocatable, executable object code. Relocatable code can be loaded anywhere in memory. Thus, the program can execute where it is most efficient, instead of in some fixed range of memory addresses.

In addition, relocatable code means that programs can be created in modules, each of which can be assembled, tested, and perfected individually. This saves recoding time because testing and assembly are performed on smaller pieces of program code. Also, all modules can be error-free before being linked together into larger modules or into the whole program.

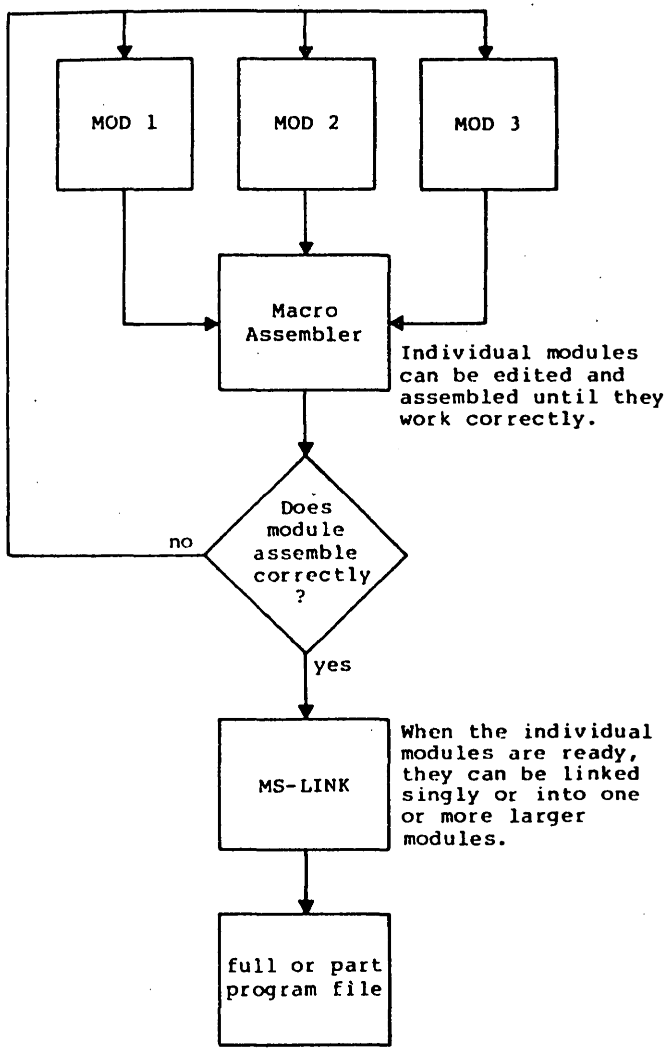


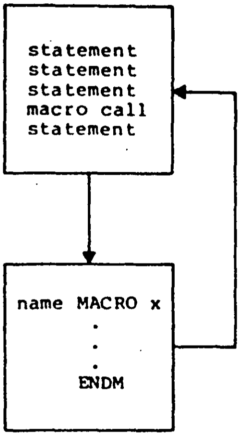
Figure 1. The Assembly Process

Macro Assembler supports Microsoft's complete 8080 macro facility, which is Intel 8080 standard. The macro facility permits the writing of blocks of code for a set of instructions used frequently. The need for recoding these instructions each time they are required in the program is eliminated.

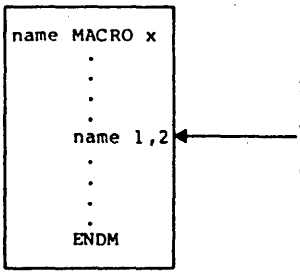
These blocks of code are called macros. The instructions are the macro definition. Each time the set of instructions is needed, instead of recoding the set of instructions, a simple "call" to a macro is placed in the source file. Macro Assembler expands the macro call by assembling the block of instructions into the program automatically. The macro call also passes parameters to the assembler for use during macro expansion. The use of macros reduces the size of a source module because the macro definitions are given only once; other occurrences are one-line calls.

Macros can be "nested," that is, a macro can be called from inside another macro block. Nesting of macros is limited only by memory.

The macro facility includes repeat, indefinite repeat, and indefinite repeat character directives for programming repeat block operations. The MACRO directive can also be used to alter the action of any instruction or directive by using its name as the macro name. When any instruction or directive statement is placed in the program, Macro Assembler first checks the symbol table it created to see if the instruction or directive is a macro name. If it is, Macro Assembler "expands" the macro call statement by replacing it with the body of instructions in the macro's definition. If the name is not defined as a macro, Macro Assembler tries to match the name with an instruction or directive. The MACRO directive also supports local symbols and conditional exiting from the block if further expansion is unnecessary.



When the assembler encounters a macro call, it finds the MACRO block and replaces the call with the block of statements that define the macro.



Nested MACRO call: name defined elsewhere as a macro, is "expanded" during assembly, as shown above.

Figure 2. Assembler Macros

Macro Assembler supports an expanded set of conditional directives. Directives for evaluating a variety of assembly conditions can test assembly results and branch where required. Unneeded or unwanted portions of code will be left unassembled. Macro Assembler can test for blank or nonblank arguments, for defined or undefined symbols, for equivalence, for first assembly pass or second, and can compare strings for identity or difference. The conditional directives simplify the evaluation of assembly results, and make programming the testing code for conditions easier.

Macro Assembler's conditional assembly facility also supports conditionals inside conditionals ("nesting"). Conditional assembly blocks can be nested up to 255 levels.

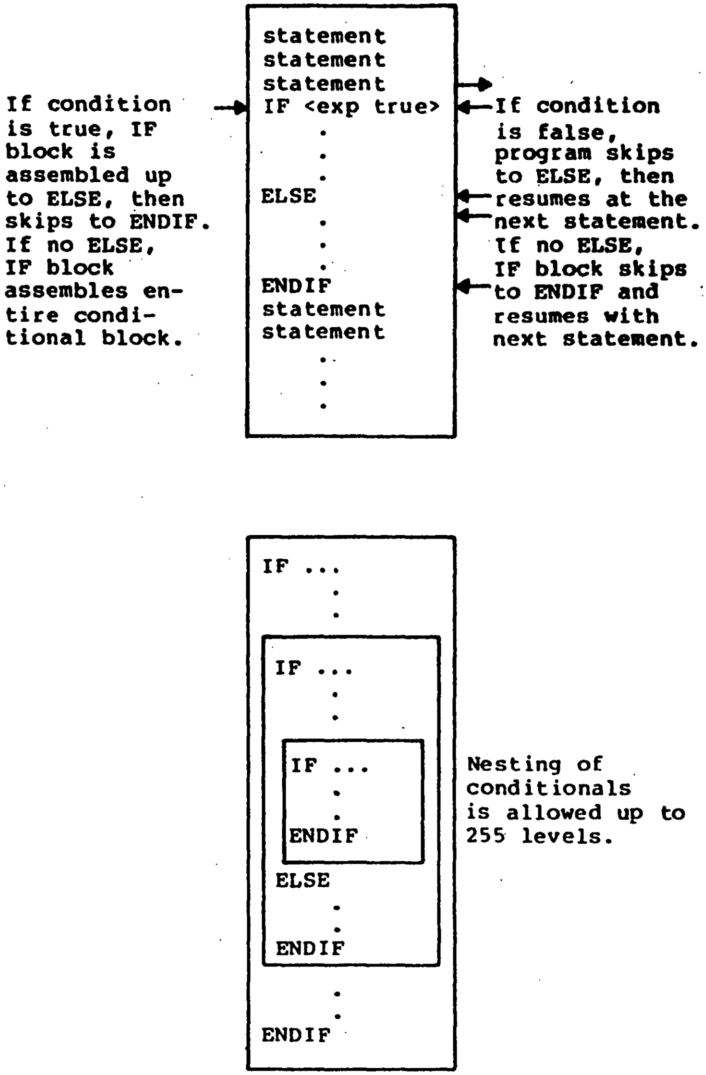


Figure 3. Conditional Statements

Macro Assembler supports all the major 8080 directives found in Microsoft's Macro Assembler for the 8080 processor. This means that any conditional, macro, or repeat blocks programmed under the 8080 Macro Assembler can be used under Macro Assembler for the 8086. Processor instructions and some directives (e.g., .PHASE, CSEG, DSEG) within the blocks will need to be converted to the 8086 instruction set. All the major Macro Assembler directives (pseudo-ops) for the 8080 that are supported under Macro Assembler for the 8086 will assemble as is, as long as the expressions to the directives are correct for the processor and the program. The syntax of directives is unchanged. Macro Assembler is upwardly-compatible, Macro Assembler for the 8080 processor and with Intel's ASM86(R), except Intel codemacros and macros.

Some 8086 instructions take only one operand type. If a typeless operand is entered for an instruction that accepts only one type of operand (e.g., in the instruction PUSH [BX], [BX] has no size, but PUSH only takes a word), it would be wasteful to return an error for a lapse of memory or a typographical error. When the wrong type choice is given, Macro Assembler displays an error message but generates the "correct" code. That is, it always outputs instructions, not just NOP instructions. For example, if you enter:

```
                          MOV    AL,WORDLBL
                                /  |  \
You may have                   /   |   \(2)
meant one of                  /    |    MOV AL,BYTE PTR WORDLBL
three instructions:          /     |(3)
                            /     MOV AL,<other>
                       (1) /
                          MOV AX,WORDLBL
```

Macro Assembler generates instruction (2) because it assumes that when you specify a register, you mean that register and that size; therefore, the other operand is the "wrong size." Macro Assembler accordingly modifies the "wrong" operand to fit the register size (in this case) or the size of whatever is the most likely "correct" operand in an expression. This eliminates some mundane debugging chores. An error message is still returned, however, because you may have misstated the operand the Macro Assembler assumes is "correct."

Overview of Macro Assembler Operation

The first task in developing a program is to create a source file. Use EDLIN (the resident editor in Microsoft's MS-DOS operating system), or any other 8086 editor compatible with your operating system, to create the Macro Assembler source file. Macro Assembler assumes a default filename extension of .ASM for the source file. Creating the source file involves creating instruction and directive statements that follow the rules and constraints described in Chapters 1-4 in this manual.

When the source file is ready, run Macro Assembler as described in Chapter 5, "Assembling a Macro Assembler Source File." Refer to Chapter 7, "Macro Assembler Messages," for explanations of any messages displayed during or immediately after assembly.

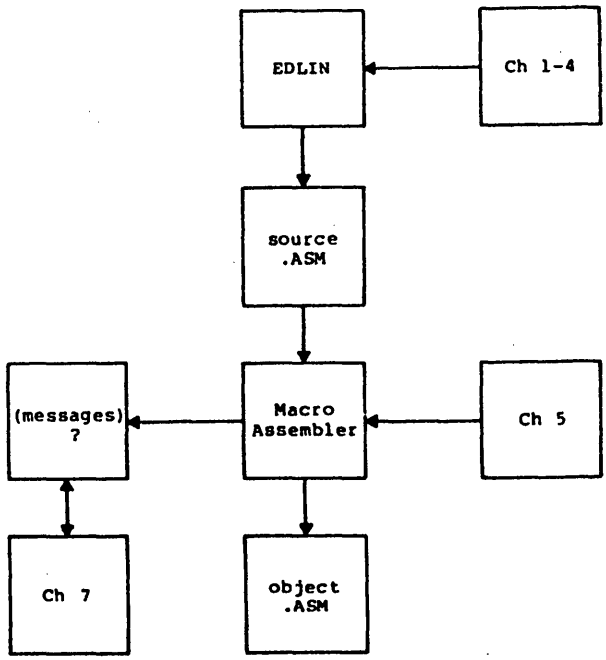


Figure 4. Overview of Macro Assembler Operation

Macro Assembler is a two-pass assembler. This means that the source file is assembled twice. But slightly different actions occur during each pass. During the first pass, the assembler:

evaluates the statements and expands macro call statements

calculates the amount of code it will generate

builds a symbol table where all symbols, variables, labels, and macros are assigned values

During the second pass, the assembler

fills in the symbol, variable, label, and expression values from the symbol table

expands macro call statements

emits the relocatable object code into a file with the default filename extension .OBJ

The .OBJ file is suitable for processing with the Microsoft LINK utility (MS-LINK). The .OBJ file can be stored as part of the user's library of object programs, which later can be linked with one or more .OBJ modules by MS-LINK (refer to the MS-LINK utility for further explanation and instructions). The .OBJ modules can also be processed with the Microsoft LIB Library Manager (refer to the *Microsoft LIB Library Manager Manual* for further explanation and instructions).

The source file can also be assembled without creating an .OBJ file. All the other assembly steps are performed, but the object code is not sent to disk. Only erroneous source statements are displayed on the terminal screen. This practice is useful for checking the source code for errors. It is faster than creating an .OBJ file because no file is created or written. Modules can be test assembled quickly and errors corrected before the object code is put on disk. Modules that assemble without errors do not clutter the disk.

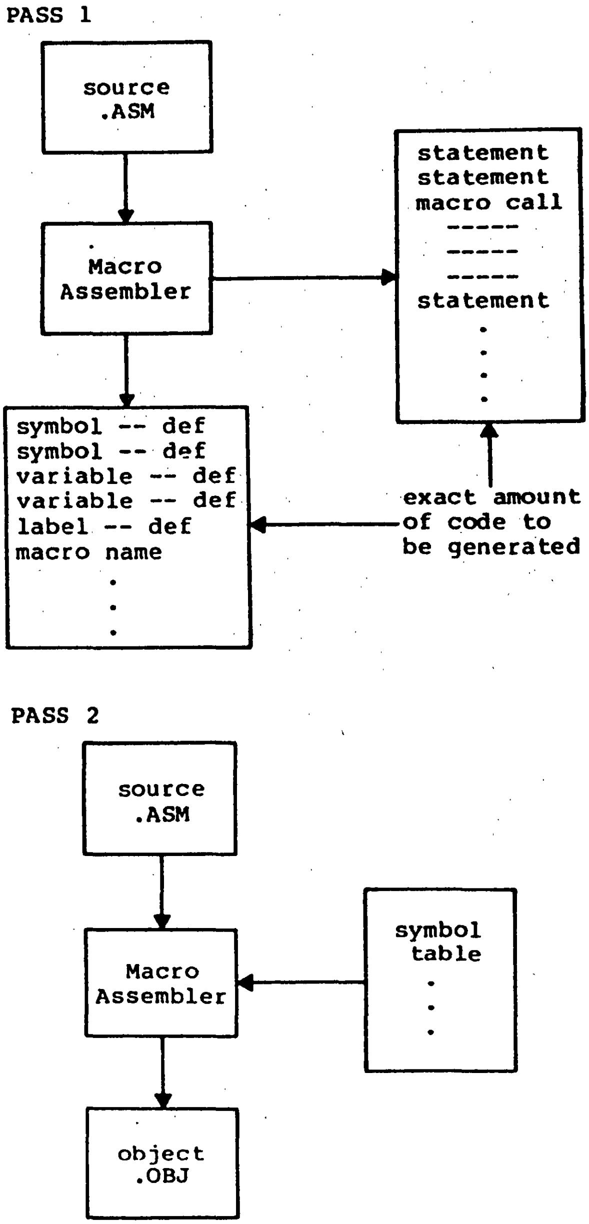


Figure 5. Pass 1 and Pass 2

Macro Assembler will create, on command, a listing file and a cross-reference file. The listing file contains the beginning relative addresses (offsets from segment base) assigned to each instruction, the machine code translation of each statement (in hexadecimal values), and the statement itself. The listing also contains a symbol table which shows the values of all symbols, labels, and variables, plus the names of all macros. The listing file receives the default filename extension .LST.

The cross-reference file contains a compact representation of variables, labels, and symbols. The cross-reference file receives the default filename extension .CRF. When this cross-reference file is processed by Microsoft CREF (MS-CREF), the file is converted into an expanded symbol table that lists all the variables, labels, and symbols in alphabetical order; followed by the line number in the source program where each is defined; followed by the line numbers where each is used in the program. The final cross-reference listing receives the filename extension .REF. (Refer to the Microsoft CREF Cross-Reference Utility Manual for further explanation and instructions.)

Figure 6 illustrates the files that Macro Assembler can produce.

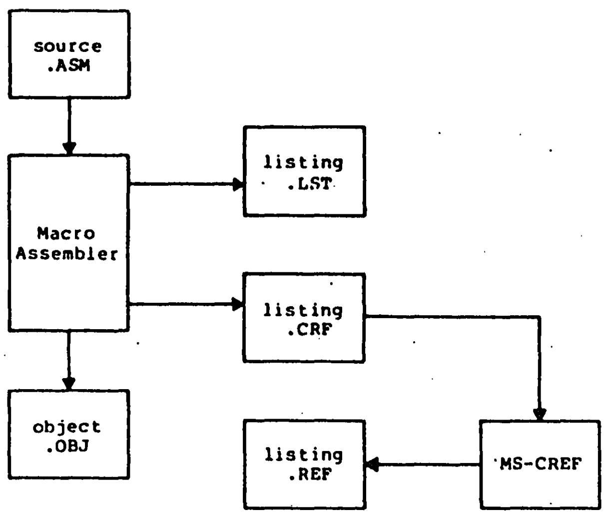


Figure 6. Files That Macro Assembler Produces

Contents

CHAPTER 1

CREATING A MACRO ASSEMBLER SOURCE FILE

To create a source file for Macro Assembler, you need to use an editor program, such as EDLIN in Microsoft's MS-DOS. You simply create a program file as you would for any other assembly or high-level programming language. Use the general facts and specific descriptions in this chapter and the three following chapters when creating the file.

This chapter discusses the statement format and introduces descriptions of its components. In Chapter 2, you will find full descriptions of names: variables, labels, and symbols. Chapter 3 provides full descriptions of expressions and their components, operands and operators. Chapter 4 includes full descriptions of the assembler directives.

1.1 GENERAL FACTS ABOUT SOURCE FILES

Naming Your Source File

When you create a source file, you must name it. A filename may be any name that is legal for your operating system. When you run Macro Assembler to assemble your source file, Macro Assembler assumes that your source filename has the extension .ASM.

You do not need to give your source filename the .ASM extension. However, if your source filename has has an extension other than .ASM, you must specify the extension name when you run Macro Assembler. (You do not need to specify the .ASM extension if your source filename has an extension of .ASM. Macro Assembler will supply the default extension for you.)

Note that Macro Assembler gives the object file it outputs the default extension .OBJ. To avoid confusion or the destruction of your source file, you should avoid giving a source file an extension of .OBJ. For similar reasons, you should also avoid the extensions .EXE, .LST, .CRF, and .REF.

Legal Characters

The legal characters for your symbol names are:

A-Z 0-9 ? @ _ $

Only the numerals (0-9) cannot appear as the first character of a name (a numeral must appear as the first character of a numeric value).

Additional special characters act as operators or delimiters:

- : (colon)--segment override operator
- . (period)--operator for field name of Record or Structure; may be used in a filename only if it is the first character
- [ ] (square brackets--around register names to indicate value in address in register, not value (data) in register
- ( ) (parentheses)--operator in DUP expressions and operator to change precedence of operator evaluation
- < > (angle brackets) operators used around initialization values for Records or Structure, around parameters in IRP macro blocks, and to indicate literals

The square brackets and angle brackets are also used for syntax notation in the discussions of the assembler directives (Section 4.2, "Directives"). When these characters are operators and not syntax notation, you are told explicitly; for example, "angle brackets must be coded as shown."

Numeric Notation

The default input radix for all numeric values is decimal. The output radix for all listings is hexadecimal for code and data items and decimal for line numbers. The output radix can only be changed to octal radix by giving the /O switch when Macro Assembler is run (see Section 5.4, "Macro Assembler Command Switches"). There are two ways to change the input radix:

1. With the .RADIX directive (see Section 4.2.1, "Memory Directives")

2. By special notation appended to a numeric value:

Radix	Range	Notation	Example
Binary	0-1	B	01110100B
Octal	0-7	Q or O	735Q or 621O
Decimal	0-9	none or D	9384 (default) 8149D*
Hexadecimal	0-9 A-F	H	OFFH or 80H**

* When .RADIX directive changes default radix to not decimal.
**First character must be numeral from 0-9.

What's in a Source File?

A source file for Macro Assembler consists of instruction statements and directive statements. Instruction statements are made of 8086 instruction mnemonics and their operands, which command specific processes directly to the 8086 processor. Directive statements are commands to Macro Assembler to prepare data for use in and by instructions.

Statement line format is described in Section 1.2. The parts of a statement are described in Sections 1.3-1.6 and in Chapters 2-4. Statements are usually placed in blocks of code assigned to a specific segment (code, data, stack, extra). The segments may appear in any order in the source file. Within the segments, generally speaking, statements may appear in any order that creates a valid program. Some exceptions to random ordering do exist, which will be discussed under the affected assembler directives.

Every segment must end with an end segment statement (ENDS); every procedure must end with an end procedure statement (ENDP); and every structure must end with an end structure statement (ENDS). Likewise, the source file must end with an END statement that tells Macro Assembler where program execution should begin.

Section 3.1, "Memory Organization," describes how segments, groups, the ASSUME directive, and the SEG operator relate to one another and to your programming as a whole. This information is important and helpful for developing your programs. The information is presented in Chapter 3 as a prelude to the discussion of operands and operators.

1.2 STATEMENT LINE FORMAT

Statements in source files follow a strict format, which allows some variation.

Macro Assembler directive statements consist of four "fields": Name, Action, Expression, Comment. For example:

```
FOO      DB      0D5E             ;create variable FOO
                                  ;containing the value 0D5EH
 |        |       |
Name     Action  Expression       ;Comment
```

Macro Assembler instruction statements usually consist of three "fields": Action, Expression, Comment. For example:

```
         MOV     CX,FOO           ;here's the count number
          |        |                  |
         Action  Expression       ;Comment
```

An instruction statement may have a Name field under certain circumstances; see the discussion in Section 1.3, "Names."

1.3 NAMES

The name field, when present, is the first entry on the statement line. The name may begin in any column, although normally names are started in column 1.

Names may be any length you choose. However, Macro Assembler considers only the first 31 characters significant when your source file is assembled.

One other significant use for names is with the MACRO directive. Although all the rules covering names, described in Chapter 2, apply to MACRO names, the discussion of macro names is better left to the section describing the macro facility.

Macro Assembler supports the use of names in a statement line for three purposes: to represent code, to represent data, and to represent constants.

To make a name represent code, use:

NAME: followed by a directive, instruction, or nothing at all
NAME LABEL NEAR (for use inside its own segment only)

NAME LABEL FAR (for use outside its own segment)

EXTRN NAME:NEAR (for use outside its own module but inside its own segment only)

EXTRN NAME:FAR (for use outside its own module and segment)

To make a name represent data, use:

NAME LABEL <size> (BYTE, WORD, etc.)

NAME Dx <exp>

EXTRN NAME:<size> (BYTE, WORD, etc.)

To make a name represent a constant, use:

```
NAME EQU <constant>

NAME = <constant>

NAME SEGMENT <attributes>

NAME GROUP <segment-names>
```

1.4 COMMENTS

Comments are never required for the successful operation of an assembly language program, but they are strongly recommended.

If you use comments in your program, every comment on every line must be preceded by a semicolon. If you want to place a very long comment in your program, you can use the COMMENT directive. The COMMENT directive releases you from the required semicolon on every line (refer to COMMENT in Section 4.2.1, "Memory Directives").

Comments document the processing that is supposed to happen at a particular point in a program. When comments are used in this manner, they can be useful for debugging, for altering code, or for updating code. Consider putting comments at the beginning of each segment, procedure, structure, module, and after each line in the code that begins a step in the processing.

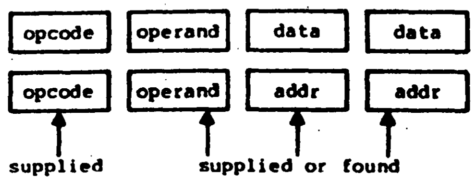
Comments are ignored by Macro Assembler. Comments do not add to the memory required to assemble or to run your program, except in macro blocks where comments are stored with the code.

1.5 ACTION

The action field contains either an 8086 instruction mnemonic or a Macro Assembler assembler directive. Refer to Section 4.1, "Instructions," for a general discussion and to Appendix C for a list of 8086 instruction mnemonics. The Macro Assembler directives are described in detail in Section 4.2, "Directives."

If the name field is blank, the action field will be the first entry in the statement format. In this case, the action may appear in any column, 1 through maximum line length (minus columns for action and expression).

The entry in the action field either directs the processor to perform a specific function or it directs the assembler to perform one of its functions. Instructions tell the processor to perform some action. An instruction may have the data and/or addresses it needs built into it, or data and/or addresses may be found in the expression part of an instruction. For example:



supplied = part of the instruction

found = assembler inserts data and/or address from the information provided by expression in instruction statements

(opcode is the action part of an instruction)

Directives give the assembler directions for I/O, memory organization, conditional assembly, listing and cross-reference control, and definitions.

1.6 EXPRESSIONS

The expression field contains entries which are operands and/or combinations of operands and operators.

Some instructions take no operands; some take one, and others take two. For two-operand instructions, the expression field consists of a destination operand and a source operand, in that order, separated by a comma. For example:

```
opcode  dest-operand , source-operand
```

For one-operand instructions, the operand is a source or a destination operand, depending on the instruction. If one or both of the operands is omitted, the instruction carries that information in its internal coding.

Source operands are immediate operands, register operands, memory operands, or attribute operands. Destination operands are register operands and memory operands.

For directives, the expression field usually consists of a single operand. For example:

```
directive  operand
```

A directive operand is a data operand, a code (addressing) operand, or a constant, depending on the nature of the directive.

For many instructions and directives, operands may be connected with operators to form a longer operand that looks like a mathematical expression. These operands are called complex operands. Use of a complex operand permits you to specify addresses or data derived from several places. For example:

```
MOV   FOO[BX],AL
```

The destination operand is the result of adding the address represented by the variable FOO and the address found in register BX. The processor is instructed to move the value in register AL to the destination calculated from these two operand elements. Another example:

```
MOV    AX,FOO+5[BX]
```

In this case, the source operand is the result of adding the value represented by the symbol FOO plus 5 plus the value found in the BX register.

Macro Assembler supports the following operands and operators in the expression field (shown in order of precedence):

Operands

- Immediate
  - (incl. symbols)
- Register
- Memory
  - label
  - variables
    - simple
    - indexed
    - structures
- Attribute
  - override
    - PTR
    - :(seg)
    - SHORT
    - HIGH
    - LOW
  - value returning
    - OFFSET
    - SEG
    - THIS
    - TYPE
    - .TYPE
    - LENGTH
    - SIZE
  - record specifying
    - FIELD
    - MASK
    - WIDTH

Operators

- LENGTH, SIZE, WIDTH, MASK, FIELD [ ], ( ), < >
- segment override(:)
- PTR, OFFSET, SEG, TYPE, THIS
- HIGH, LOW
- *, /, MOD, SHL, SHR
- +, -(unary), -(binary)
- EQ, NE, LT, LE, GT, GE
- NOT
- AND
- OR, XOR
- SHORT, .TYPE

NOTE

Some operators can be used as operands or as part of an operand expression. Refer to Sections 3.2, "Operands," and 3.3, "Operators," for details of operands and operators.

Contents

CHAPTER 2

NAMES: LABELS, VARIABLES, AND SYMBOLS

Names are used in several ways throughout Macro Assembler, wherever any naming is allowed or required.

Names are symbolic representations of values. The values may be addresses, data, or constants.

Names may be any length you choose. However, Macro Assembler will truncate names longer than 31 characters when your source file is assembled.

Names may be defined and used in a number of ways. This chapter introduces you to the basic ways to define and use names. You will discover additional uses as you study the chapters on Expressions and Action, and as you use Macro Assembler.

Macro Assembler supports three types of names in statement lines: labels, variables, and symbols. This chapter covers how to define and use these three types of names.

2.1 LABELS

Labels are names used as targets for JMP, CALL, and LOOP instructions. Macro Assembler assigns an address to each label as it is defined. When you use a label as an operand for JMP, CALL, or LOOP, Macro Assembler can substitute the attributes of the label for the label name, sending processing to the appropriate place.

Labels are defined in one of four ways:

1. <name>:

   Use a name followed immediately by a colon. This defines the name as a NEAR label. <name>: may be prefixed to any instruction and to all directives that allow a Name field. <name>: may also be placed on a line by itself.

   Examples:

   ```
   CLEAR_SCREEN:   MOV   AL,20H
   FOO:   DB   0FH
   SUBROUTINE3:
   ```

2. <name> LABEL NEAR
   <name> LABEL FAR

   Use the LABEL directive. Refer to the discussion of the LABEL directive in Section 4.2.1, "Memory Directives."

   NEAR and FAR are discussed under the Type Attribute below.

   Examples:

   ```
   FOO   LABEL   NEAR
   GOO   LABEL   FAR
   ```

3. <name> PROC NEAR
   <name> PROC FAR

   Use the PROC directive. Refer to the discussion of the PROC directive in Section 4.2.1, "Memory Directives."

   NEAR is optional because it is the default if you enter only <name> PROC. NEAR and FAR are discussed under the Type Attribute below.

Examples:

```
REPEAT    PROC   NEAR
CHECKING    PROC    ;same as CHECKING PROC NEAR
FIND_CHR    PROC    FAR
```

4. EXTRN <name>:NEAR
   EXTRN <name>:FAR

   Use the EXTRN directive.

   NEAR and FAR are discussed under the Type Attribute below.

   Refer to the discussion of the EXTRN directive in Section 4.2.1, "Memory Directives."

   Examples:

```
EXTRN FOO:NEAR
EXTRN ZOO:FAR
```

A label has four attributes: segment, offset, type, and the CS ASSUME in effect when the label is defined. Segment is the segment where the label is defined. Offset is the distance from the beginning of the segment to the label's location. Type is either NEAR or FAR.

Segment

Labels are defined inside segments. The segment must be assigned to the CS segment register to be addressable. The segment may be assigned to a group, in which case the group must be addressable through CS. Macro Assembler requires that a label be addressable through the CS register. Therefore, the segment (or group) attribute of a symbol is the base address of the segment (or group) where it is defined.

Offset

The offset attribute is the number of bytes from the beginning of the label's segment to where the label is defined. The offset is a 16-bit unsigned number.

Type

Labels are one of two types: NEAR or FAR. NEAR labels are used for references from within the segment where the label is defined. NEAR labels may be referenced from more than one module, as long as the references are from a segment with the same name and attributes and have the same CS ASSUME.

FAR labels are used for references from segments with a different CS ASSUME, or when there are more than 64K bytes between the label reference and the label definition.

NEAR and FAR cause Macro Assembler to generate slightly different code. NEAR labels supply their offset attribute only (a 2-byte pointer). FAR labels supply both their segment and offset attributes (a 4-byte pointer).

2.2 VARIABLES

Variables are names used in expressions as operands to instructions and directives. A variable represents an address where a specified value may be found.

Variables look much like labels and are defined alike in some ways. The differences are important.

Variables are defined three ways:

1.
```
<name> <define-dir>           ;no colon!
<name> <struc-name> <expression>
<name> <rec-name> <expression>
```

   <define-dir> is any of the five Define directives: DB, DW, DD, DQ, DT

   Example:

```
    START_MOVE   DW   ?
```

   <struc-name> is a structure name defined by the STRUC directive.

   <rec-name> is a record name defined by the RECORD directive.

   Examples:

```
    CORRAL  STRUC
            .
            .
            .
            ENDS
    HORSE   CORRAL  <'SADDLE'>
```

   Note that HORSE will have the same size as the structure CORRAL.

```
    GARAGE  RECORD  CAR:8='P'

    SMALL   GARAGE  10 DUP(<'Z'>)
```

   Note that SMALL will have the same size as the record GARAGE.

   See the DEFINE, STRUC, and RECORD directives in Section 4.2.1, "Memory Directives."

2. <name> LABEL <size>

   Use the LABEL directive with one of the size specifiers.

<size> is one of the following size specifiers:

```
BYTE  - specifies 1 byte
WORD  - specifies 2 bytes
DWORD - specifies 4 bytes
QWORD - specifies 8 bytes
TBYTE - specifies 10 bytes
```

Example:

```
CURSOR   LABEL   WORD
```

See LABEL directive in Section 4.2.1, "Memory Directives."

3. EXTRN <name>:<size>

Use the EXTRN directive with one of the size specifiers described above. See EXTRN directive in Section 4.2.1, "Memory Directives."

Example:

```
EXTRN FOO:DWORD
```

Variables also have the three attributes segment, offset, and type (as do labels).

Segment and Offset are the same for variables as for labels. The Type attribute is different.

Type

The type attribute is the size of the variable's location, as specified when the variable is defined. The size depends on which Define directive was used or which size specifier was used to define the variable.

Directive	Type	Size
DB	BYTE	1 byte
DW	WORD	2 bytes
DD	WORD	4 bytes
DQ	QWORD	8 bytes
DT	TBYTE	10 bytes

2.3 SYMBOLS

Symbols are names defined without reference to a Define directive or to code. Like variables, symbols are also used in expressions as operands to instructions and directives.

Symbols are defined three ways:

1. <name> EQU <expression>

   Use the EQU directive. See EQU directive in Section 4.2.1, "Memory Directives."

   <expression> may be another symbol, an instruction mnemonic, a valid expression, or any other entry (such as text or indexed references).

   Examples:

   ```
   FOO    EQU    7H
   ZOO    EQU    FOO
   ```

2. <name> = <expression>

   Use the equal sign directive. See Equal Sign directive in Section 4.2.1, "Memory Directives."

   <expression> may be any valid expression.

   Examples:

   ```
   GOO    =    0FH
   GOO    =    $+2
   GOO    =    GOO+FOO
   ```

3. EXTRN <name>:ABS

   Use the EXTRN directive with type ABS. See EXTRN directive in Section 4.2.1, "Memory Directives."

   Example:

   ```
   EXTRN BAZ:ABS
   ```

   BAZ must be defined by an EQU or = directive to a valid expression.

Contents

CHAPTER 3

EXPRESSIONS: OPERANDS AND OPERATORS

Chapter 1 provided a brief introduction to expressions. Basically, expression is the term used to indicate values on which an instruction or directive performs its functions.

Every expression consists of at least one operand (a value). An expression may consist of two or more operands. Multiple operands are joined by operators. The result is a series of elements that looks like a mathematical expression.

This chapter describes the types of operands and operators that Macro Assembler supports. The discussion of memory organization in a Macro Assembler program acts as a preface to the descriptions of operands and operators, and as a link to topics discussed in Chapter 2.

3.1 MEMORY ORGANIZATION

Most of your assembly language program is written in segments. In the source file, a segment is a block of code that begins with a SEGMENT directive statement and ends with an ENDS directive. In an assembled and linked file, a segment is any block of code that is addressed through the same segment register and is not more than 64K bytes long.

You should note that Macro Assembler leaves everything relating to segments to MS-LINK. MS-LINK resolves all references. For that reason, Macro Assembler does not check (because it cannot) to see if your references are entered with the correct distance type. Values such as OFFSET are also left to MS-LINK to resolve.

Although a segment may not be more than 64K bytes long, you may, as long as you observe the 64K limit, divide a segment among two or more modules. (The SEGMENT statement in each module must be the same.)

When the modules are linked together, the several segments become one. References to labels, variables, and symbols within each module acquire the offset from the beginning of the whole segment, not just from the beginning of their portion of the whole segment. (All divisions are removed.)

You have the option of grouping several segments into a group using the GROUP directive. When you group segments, you tell Macro Assembler that you want to be able to refer to all of these segments as a single entity. (This does not eliminate segment identity, nor does it make values within a particular segment less immediately accessible. It does make value relative to a group base.) The advantage of grouping is that you can refer to data items without worrying about segment overrides or changing segment registers.

With this in mind, you should note that references within segments or groups are relative to a segment register. Thus, until linking is completed, the final offset of a reference is relocatable. For this reason, the OFFSET operator does not return a constant. The major purpose of OFFSET is to cause Macro Assembler to generate an immediate instruction; that is, to use the address of the value instead of the value itself.

There are two kinds of references in a program:

1. Code references - JMP, CALL, LOOPxx - These references are relative to the address in the CS register. (You cannot override this assignment.)

2. Data references - all other references - These references are usually relative to the DS register, but this assignment may be overridden.

When you give a forward reference in a program statement, for example:

```
MOV AX,<ref>
```

Macro Assembler first looks for the segment of the reference. Macro Assembler scans the segment registers for the SEGMENT of the reference, then the GROUP (if any) of the reference.

However, the use of the OFFSET operator always returns the offset relative to the segment. If you want the offset relative to a GROUP, you must override this restriction by using the GROUP name and the colon operator. For example:

```
MOV AX,OFFSET <group-name>:<ref>
```

If you set a segment register to a group with the ASSUME directive, then you may also override the restriction on OFFSET by using the register name. For example:

```
MOV AX,OFFSET DS:<ref>
```

The result of both of these statements is the same.

Code labels have four attributes:

1. Segment - what segment the label belongs to

2. Offset - the number of bytes from the beginning of its segment

3. Type - NEAR or FAR

4. CS ASSUME - the CS ASSUME the label was coded under

When you enter a NEAR JMP or NEAR CALL, you are changing the offset (IP) in CS. Macro Assembler compares the CS ASSUME of the target (where the label is defined) with the current CS ASSUME. If they are different, Macro Assembler returns an error (you must use a FAR JMP or FAR CALL).

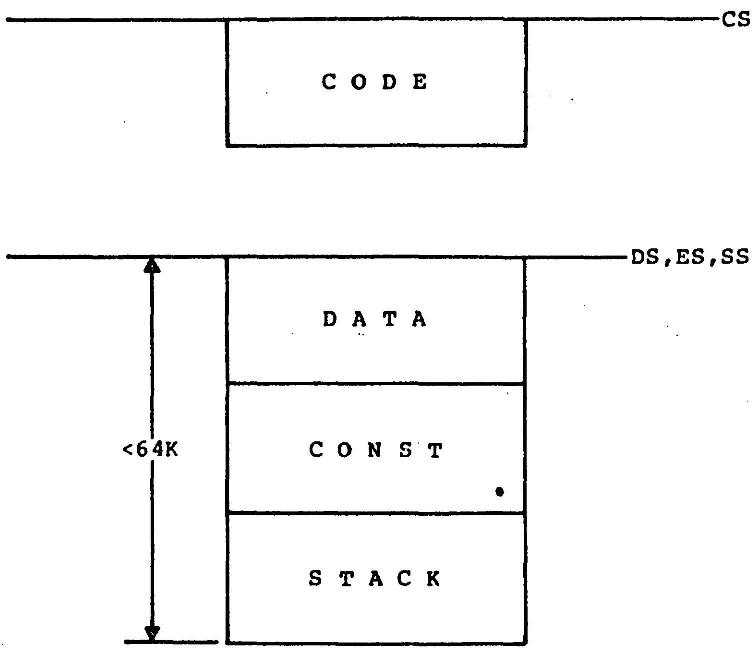
When you enter a FAR JMP or FAR CALL, you are changing both the offset (IP) in CS and the paragraph number. The paragraph number is changed to the CS ASSUME of the target address.

Let's take a common case, a segment called CODE, and a group (called DGROUP) that contains three segments (called DATA, CONST, and STACK).

The program statements would be:

```
DGROUP  GROUP   DATA,CONST,STACK
        ASSUME  CS:CODE,DS:DGROUP,SS:DGROUP,ES:DGROUP
        MOV     AX,DGROUP           ;CS initialized by entry;
        MOV     DS,AX               ;you initialize DS, do this
                                    ;as soon as possible,
                                    ;especially before any
                                    ;DS relative references
          .
          .
          .
```

As a diagram, this arrangement could be represented as follows:



Given this arrangement, a statement like

```
MOV AX,<variable>
```

causes Macro Assembler to find the best segment register to reach this variable. (The "best" register is the one that requires no segment overrides.)

A statement like

```
MOV AX,OFFSET <variable>
```

tells Macro Assembler to return the offset of the variable relative to the beginning of the variable's segment.

If this <variable> is in the CONST segment and you want to reference its offset from the beginning of DGROUP, you need a statement like the following:

```
MOV AX,OFFSET DGROUP:<variable>
```

Macro Assembler is a two-pass assembler. During pass 1, it builds a symbol table and calculates how much code is generated, but does not produce object code. If undefined items are found (including forward references), assumptions are made about the reference so that the correct number of bytes are generated on pass 1. Only certain types of errors are displayed: errors involving items that must be defined on pass 1. No listing is produced unless a /D switch is given when you run the assembler. The /D switch produces a listing for both passes.

On pass 2, the assembler uses the values defined in pass 1 to generate the object code. Definitions of references during pass 2 are checked against the pass 1 value, which is in the symbol table. Also, the amount of code generated during pass 1 must match the amount generated during pass 2. If either is different, Macro Assembler returns a phase error.

Because pass 1 must keep correct track of the relative offset, some references must be known on pass 1. If they are not known, the relative offset will not be correct.

The following references must be known on pass 1:

1. IF/IFE <expression>
   If <expression> is not known on pass 1, Macro Assembler does not know to assemble the conditional block (or which part to assemble if ELSE is used). On pass 2, the assembler would know and would assemble, resulting in a phase error.

2. <expression> DUP(...)
   This operand explicitly changes the relative offset, so <expression> must be known on pass 1. The value in parentheses need not be known because it does not affect the number of bytes generated.

3. .RADIX <expression>
   Because this directive changes the input radix, constants could have a different value, which could cause Macro Assembler to evaluate IF or DUP statements incorrectly.

The biggest problem for the assembler is handling forward references. How can it know the kind of a reference when it still has not seen the definition? This is one of the main reasons for two passes. And, unless Macro Assembler can tell from the statement containing the forward reference what the size, the distance, or any other of its attributes are, the assembler can only take the safe route (generate the largest possible instruction in some cases, except for segment override or FAR). This results in extra code that does nothing. (Macro Assembler figures this out by pass 2, but it cannot reduce the size of the instructions without causing an error, so it puts out NOP instructions (90H).

For this reason, Macro Assembler includes a number of operators to help the assembler. These operators tell Macro Assembler what size instruction to generate when it is faced with an ambiguous choice. As a benefit, you can also reduce the size of your program by using these operators to change the nature of the arguments to the instructions.

Examples:

```
MOV AX,FOO ;FOO = forward constant
```

This statement causes Macro Assembler to generate a move from memory instruction on pass 1. By using the OFFSET operator, we can cause Macro Assembler to generate an immediate operand instruction.

```
MOV AX,OFFSET FOO   ;OFFSET says use the address
                    ;of FOO
```

Because OFFSET tells Macro Assembler to use the address of FOO, the assembler knows that the value is immediate. This method saves a byte of code.

Similarly, if you have a CALL statement that calls to a label that may be in a different CS ASSUME, you can prevent problems by attaching the PTR operator to the label:

```
CALL FAR PTR <forward-label>
```

At the opposite extreme, you may have a JMP forward that is less than 127 bytes. You can save yourself a byte if you use the SHORT operator.

```
JMP SHORT <forward-label>
```

However, you must be sure that the target is indeed within 127 bytes or Macro Assembler will not find it.

The PTR operator can be used another way to save yourself a byte when using forward references. If you defined FOO as a forward constant, you might enter the statement:

```
MOV [BX],FOO
```

You may want to refer to FOO as a byte immediate. In this case, you could enter either of these statements (they are equivalent):

```
MOV BYTE PTR [BX],FOO

MOV [BX],BYTE PTR FOO
```

These statements tell Macro Assembler that FOO is a byte immediate. A smaller instruction is generated.

3.2 OPERANDS

An operand may be any one of three types: Immediate, Register, or Memory operands. There is no restriction on combining the types of operands.

The following list shows all the types and the items that comprise them:

- Immediate operands
    - Data items
    - Symbols
- Register operands
- Memory operands
    - Direct
        - Labels
        - Variables
        - Offset (fieldname)
    - Indexed
        - Base register
        - Index register
        - [constant]
        - ±displacement
    - Structure

3.2.1 Immediate Operands

Immediate operands are constant values that you supply when you type a statement line. The value may be typed either as a data item or as a symbol.

Instructions that take two operands permit an immediate cperand as the source operand only (the second operand in an instruction statement). For example:

```
MOV AX,9
```

Data Items

Macro Assembler recognizes values in forms other than decimal when special notation is appended. The default input radix is decimal. Any numeric values entered without numeric notation appended will be treated as a decimal value. These other values include ASCII characters as well as numeric values.

Data Form	Format	Example
Binary	xxxxxxxxB	01110001B
Octal	xxxO xxxQ	735O (letter O) 412Q
Decimal	xxxxx xxxxxD	65535 (default) 1000D (when .RADIX changes input radix to nondecimal)
Hexadecimal	xxxxH	0FFFFH (1st digit must be 0-9)
ASCII	'xx' "xx"	'OM' (more than two with DB only; "OM" both forms are synonymous)
10 real	xx.xxE&+xx	25.23E-7 (floating point format)
16 real	x...xR	8F76DEA9R (1st digit must be 0-9; the total number of digits must be 8, 16, or 20; or 9, 17, 21 if first digit is 0)

Symbols

Symbol names equated with some form of constant information (see Section 2.3, "Symbols") may be used as immediate operands. Using a symbol constant in a statement is the same as using a numeric constant. Therefore, using the sample statement above, you could type:

```
MOV AX,FOO
```

assuming FOO was defined as a constant symbol. For example:

```
FOO EQU 9
```

3.2.2 Register Operands

The 8086 processor contains a number of registers. These registers are identified by two-letter symbols that the processor recognizes (the symbols are reserved).

The registers are appropriated to different tasks: general registers, pointer registers, counter registers, index registers, segment registers, and a flag register.

The general registers are two sizes: 8-bit and 16-bit. All other registers are 16-bit.

The general registers are both 8-bit and 16-bit registers. Actually, the 16-bit general registers are composed of a pair of 8-bit registers, one for the low byte (bits 0-7) and one for the high byte (bits 8-15). Note, however, that each 8-bit general register can be used independently from its mate. In this case, each 8-bit register contains bits 0-7.

Segment registers are initialized by the user and contain segment base values. The segment register names (CS, DS, SS, ES) can be used with the colon segment override operator to inform Macro Assembler that an operand is in a different segment than specified in an ASSUME statement. (See the segment override operator in Section 3.3.1, "Attribute Operators.)"

The flag register is one 16-bit register containing nine 1-bit flags (six arithmetic flags and three control flags).

Each of the registers (except segment registers and flags) can be an operand in arithmetic and logical operations.

Register/Memory Field Encoding:

Register Mode

MOD=11		
R/M	W=0	W=1
000	AL	AX
001	CL	CX
010	DL	DX
011	BL	BX
100	AH	SP
101	CH	BP
110	DH	SI
111	BH	DI

EFFECTIVE ADDRESS CALCULATION			
R/M	MOD=00	MOD=01	MOD=10
000	[BX]+[SI]	[BX]+[SI]+D8	[BX]+[SI]+D16
001	[BX]+[DI]	[BX]+[DI]+D8	[BX]+[DI]+D16
010	[BP]+[SI]	[BP]+[SI]+D8	[BP]+[SI]+D16
011	[BP]+[DI]	[BP]+[DI]+D8	[BP]+[DI]+D16
100	[SI]	[SI]+D8	[SI]+D16
101	[DI]	[DI]+D8	[DI]+D16
110	DIRECT ADDRESS	[BP]+D8	[BP]+D16
111	[BX]	[BX]+D8	[BX]+D16

Note: D8 = a byte value; D16 = a word value

Other Registers:

Segment:	CS	code segment
	DS	data segment
	SS	stack segment
	ES	extra segment

Flags:

1-bit arithmetic flags		3 1-bit control flags	
CF	carry flag	DF	direction flag
PF	parity flag	IF	interrupt-enable flag
AF	auxiliary flag	TF	trap flag
ZF	zero flag		
SF	sign flag		

NOTE

The BX, BP, SI, and DI registers are also used as memory operands. The distinction is: when these registers are enclosed in square brackets [ ], they are memory operands; when they are not enclosed in square brackets, they are register operands (see Section 3.2.3, "Memory Operands").

3.2.3 Memory Operands

A memory operand represents an address in memory. When you use a memory operand, you direct Macro Assembler to an address to find some data or instruction.

A memory operand always consists of an offset from a base address.

Memory operands fit into three categories: those that do not use a register (direct memory operands), those that use a base or index register (indexed memory operands), and structure operands.

Direct Memory Operands

Direct memory operands do not use a register, and consist of a single offset value. Direct memory operands are labels, simple variables, and offsets.

Memory operands can be used as destination operands as well as source operands for instructions that take two operands. For example:

```
MOV AX,FOO
MOV FOO,CX
```

Indexed Memory Operands

Indexed memory operands use base and index registers, constants, displacement values, and variables, often in combination. When you combine indexed operands, you create an address expression.

Indexed memory operands use square brackets to indicate indexing (by a register or by registers) or subscripting (for example, FOO[5]). The square brackets are treated like plus signs (+). Therefore,

```
FOO[5] is equivalent to FOO+5
5[FOO] is equivalent to 5+FOO
```

The only difference between square brackets and plus signs occurs when a register name appears inside the square brackets. Then, the operand is indexed.

The types of indexed memory operands are:

Base registers: [BX] [BP]

BP has SS as its default segment register;
all others have DS as default.

Index registers: [DI] [SI]

[constant] Immediate in square brackets [8], [FOO]

±Displacement 8-bit or 16-bit value.
Used only with another indexed operand.

These elements may be combined in any order. The only restriction is that two base registers and two indexed registers cannot be combined:

```
[BX+BP] ;illegal
[SI+DI] ;illegal
```

Some examples of indexed memory operand combinations:

```
[BP+8]
[SI+BX][4]
16[DI+BP+3]
8[FOO]-8
```

More examples of equivalent forms:

```
5[BX][SI]
BX+5][SI]
[BX+SI+5]
[BX]5[SI]
```

Structure Operands

Structure operands take the form <variable>.<field>.

<variable> is any name you give when coding a statement line that initializes a Structure field. The <variable> may be an anonymous variable, such as an indexed memory operand.

<field> is a name defined by a DEFINE directive within a STRUC block. <field> is a typed constant.

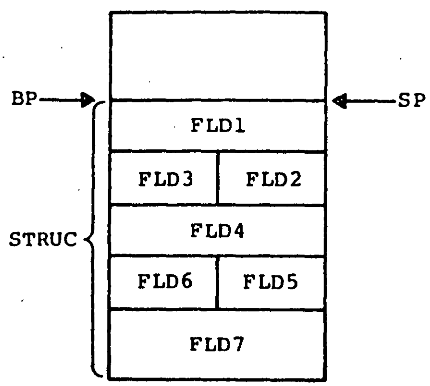
The period (.) must be included.

Example:

```
ZOO       STRUC
GIRAFFE   DB  ?
ZOO       ENDS

LONG_NECK  ZOO <16>

MOV AL,LONG_NECK.GIRAFFE

MOV AL,[BX].GIRAFFE   ;anonymous variable
```

The use of structure operands can be helpful in stack operations. If you set up the stack segment as a structure, setting BP to the top of the stack (BP equal to SP), then you can access any value in the stack structure by field name indexed through BP; for example:

```
[BP].FLD6
```



This method makes all values on the stack available all the time, not just the value at the top. Therefore, this method makes the stack a handy place to pass parameters to subroutines.

3.3 OPERATORS

An operator may be one of four types: attribute, arithmetic, relational, or logical.

Attribute operators are used with operands to override their attributes, return the value of the attributes, or to isolate fields of records.

Arithmetic, relational, and logical operators are used to combine or compare operands.

3.3.1 Attribute Operators

Attribute operators used as operands perform one of three functions:

Override an operand's attributes

Return the values of operand attributes

Isolate record fields (record specific operators)

The following list shows all the attribute operators by type:

Override operators
- PTR
- colon (:) (segment override)
- SHORT
- THIS
- HIGH
- LOW

Value returning operators
- SEG
- OFFSET
- TYPE
- .TYPE
- LENGTH
- SIZE

Record specific operators
- Shift count (Field name)
- WIDTH
- MASK

Override Operators

These operators are used to override the segment, offset, type, or distance of variables and labels.

Pointer (PTR)

<attribute> PTR <expression>

The PTR operator overrides the type (BYTE, WORD, DWORD) or the distance (NEAR, FAR) of an operand.

<attribute> is the new attribute; the new type or new distance.

<expression> is the operand whose attribute is to be overridden.

The most important and frequent use for PTR is to assure that Macro Assembler understands what attribute the expression is supposed to have. This is especially true for the type attribute. Whenever you place forward references in your program, PTR will make clear the distance or type of the expression. This way you can avoid phase errors.

The second use of PTR is to access data by type other than the type in the variable definition. Most often this occurs in structures. If the structure is defined as WORD but you want to access an item as a byte, PTR is the operator for this. However, a much easier method is to enter a second statement that defines the structure in bytes, too. This eliminates the need to use PTR for every reference to the structure. Refer to the LABEL directive in Section 4.2.1, "Memory Directives."

Examples:

```
CALL WORD PTR [BX][SI]
MOV BYTE PTR ARRAY

ADD BYTE PTR FOO,9
```

Segment Override (:) (colon)

```
<segment-register>:<address-expression>
<segment-name>:<address-expression>
<group-name>:<address-expression>
```

The segment override operator overrides the assumed segment of an address expression (which may be a label, a variable, or other memory operand).

The colon operator helps with forward references by telling the assembler to what a reference is relative (segment, group, or segment register).

Macro Assembler assumes that labels are addressable through the current CS register. Macro Assembler also assumes that variables are addressable through the current DS register, or possibly the ES register, by default. If the operand is in another segment and you have not alerted Macro Assembler through the ASSUME directive, you will need to use a segment override operator. Also, if you want to use a nondefault relative base (that is, not the default segment register), you will need to use the segment override operator for forward references. Note that if Macro Assembler can reach an operand through a nondefault segment register, it will use it, but the reference cannot be forward in this case.

<segment-register> is one of the four segment register names: CS, DS, SS, ES.

<segment-name> is a name defined by the SEGMENT directive.

<group-name> is a name defined by the GROUP directive.

Examples:

```
MOV AX,ES:[BX+SI]

MOV CSEG:FAR_LABEL,AX

MOV AX,OFFSET DGROUP:VARIABLE
```

SHORT

SHORT <label>

SHORT overrides NEAR distance attributes of labels used as targets for the JMP instruction. SHORT tells Macro Assembler that the distance between the JMP statement and the <label> specified as its operand is not more than 127 bytes either direction.

The major advantage of using the SHORT operator is to save a byte. Normally, the <label> carries a 2-byte pointer to its offset in its segment. Because a range of 256 bytes can be handled in a single byte, the SHORT operator eliminates the need for the extra byte (which would carry 00 or FF anyway). However, you must be sure that the target is within ±127 bytes of the JMP instruction before using SHORT.

Example:

```
             JMP SHORT REPEAT
              .
              .
              .
    REPEAT:
```

THIS

THIS <distance>
THIS <type>

The THIS operator creates an operand. The value of the operand depends on which argument you give THIS.

The argument to THIS may be:

1. A distance (NEAR or FAR)

2. A type (BYTE, WORD, or DWORD)

THIS <distance> creates an operand with the distance attribute you specify, an offset equal to the current location counter, and the segment attribute (segment base address) of the enclosing segment.

THIS <type> creates an operand with the type attribute you specify, an offset equal to the current location counter, and the segment attribute (segment base address) of the enclosing segment.

Examples:

```
TAG EQU THIS BYTE same as TAG LABEL BYTE

SPOT_CHECK = THIS NEAR same as
SPOT_CHECK LABEL NEAR
```

HIGH,LOW

HIGH <expression>
LOW <expression>

HIGH and LOW are provided for 8080 assembly language compatibility. HIGH and LOW are byte isolation operators.

HIGH isolates the high 8 bits of an absolute 16-bit value or address expression.

LOW isolates the low 8 bits of an absolute 16-bit value or address expression.

Examples:

```
MOV AH,HIGH WORD_VALUE ;get byte with sign bit

MOV AL,LOW 0FFFFH
```

Value Returning Operators

These operators return the attribute values of the operands that follow them but do not override the attributes.

The value returning operators take labels and variables as their arguments.

Because variables in Macro Assembler have three attributes, you need to use value returning operators to isolate single attributes, as follows:

```
SEG     isolates the segment base address
OFFSET  isolates the offset value
TYPE    isolates either type or distance
LENGTH and SIZE isolate the memory allocation
```

<u>SEG</u>

SEG <label>
SEG <variable>

SEG returns the segment value (segment base address) of the segment enclosing the label or variable.

Example:

```
MOV AX,SEG VARIABLE_NAME
MOV AX,<segment-variable>:<variable>
```

OFFSET

OFFSET <label>
OFFSET <variable>

OFFSET returns the offset value of the variable or label within its segment (the number of bytes between the segment base address and the address where the label or variable is defined).

OFFSET is chiefly used to tell the assembler that the operand is an immediate operand.

NOTES

OFFSET does not make the value a constant. Only MS-LINK can resolve the final value.

OFFSET is not required with uses of the DW or DD directives. The assembler applies an implicit OFFSET to variables in address expressions following DW and DD.

Example:

```
MOV BX,OFFSET FOO
```

If you use an ASSUME to GROUP, OFFSET will not automatically return the offset of a variable from the base address of the group. Rather, OFFSET will return the segment offset, unless you use the segment override operator (group-name version). If the variable GOB is defined in a segment placed in DGROUP, and you want the offset of GOB in the group, you need to enter a statement like:

```
MOV BX,OFFSET DGROUP:GOB
```

You must be sure that the GROUP directive precedes any reference to a group name, including its use with OFFSET.

TYPE

TYPE <label>
TYPE <variable>

If the operand is a variable, the TYPE operator returns a value equal to the number of bytes of the variable type, as follows:

```
BYTE  = 1
WORD  = 2
DWORD = 4
QWORD = 8
TBYTE = 10
STRUC = the number of bytes declared by STRUC
```

If the operand is a label, the TYPE operator returns NEAR (FFFFH) or FAR (FFFEH).

Examples:

```
MOV AX,(TYPE FOO_BAR) PTR [BX+SI]
```

.TYPE

.TYPE <variable>

The .TYPE operator returns a byte that describes two characteristics of the <variable>: 1) the mode, and 2) whether it is External or not. The argument to .TYPE may be any expression (string, numeric, logical). If the expression is invalid, .TYPE returns zero.

The byte that is returned is configured as follows:

The lower two bits are the mode. If the lower two bits are:

0	the mode is Absolute
1	the mode is Program Related
2	the mode is Data Related

The high bit (80H) is the External bit. If the high bit is on, the expression contains an External. If the high bit is off, the expression is not External.

The Defined bit is 20H. This bit is on if the expression is locally defined, and it is off if the expression is undefined or external. If neither bit is on, the expression is invalid.

.TYPE is usually used inside macros, where an argument type may need to be tested to make a decision regarding program flow; for example, when conditional assembly is involved.

Example:

```
FOO     MACRO   X
        LOCAL   Z
Z       =   .TYPE X
IF      Z...
```

.TYPE tests the mode and type of X. Depending on the evaluation of X, the block of code beginning with IF Z... may be assembled or omitted.

<u>LENGTH</u>

LENGTH <variable>

LENGTH accepts only one variable as its argument.

LENGTH returns the number of type units (BYTE, WORD, DWORD, QWORD, TBYTE) allocated for that variable.

If the variable is defined by a DUP expression, LENGTH returns the number of type units duplicated; that is, the number that precedes the first DUP in the expression.

If the variable is not defined by a DUP expression, LENGTH returns 1.

Examples:

```
FOO DW 100 DUP(1)

MOV CX,LENGTH FOO ;get number of elements
                  ;in array
                  ;LENGTH returns 100


BAZ DW 100 DUP(1,10 DUP(?))
```

LENGTH BAZ is still 100, regardless of the expression following DUP.

```
GOO DD (?)
```

LENGTH GOO returns 1 because only one unit is involved.

SIZE

SIZE <variable>

SIZE returns the total number of bytes allocated for a variable.

SIZE is the product of the value of LENGTH times the value of TYPE.

Example:

```
FOO DW 100 DUP(1)

MOV BX,SIZE FOO  ;get total bytes in array

SIZE = LENGTH X TYPE
SIZE =   100  X WORD
SIZE =   100  X 2
SIZE = 200
```

Record Specific Operators

Record specific operators are used to isolate fields in a record.

Records are defined by the RECORD directive (see Section 4.2.1, "Memory Directives"). A record may be up to 16 bits long. The record is defined by fields, which may be from one to 16 bits long. To isolate one of the three characteristics of a record field, you use one of the record specific operators, as follows:

Shift count	Number of bits from low end of record to low end of field (number of bits to right shift the record to lowest bits of record)
WIDTH	The number of bits wide the field or record is (number of bits the field or record contains)
MASK	Value of record if field contains its maximum value and all other fields are zero (all bits in field contain 1; all other bits contain 0)

In the following discussions of the record specific operators, the following symbols are used:

FOO a record defined by the RECORD directive
FOO RECORD FIELD1:3,FIELD2:6,FIELD3:7

BAZ a variable used to allocate FOO
BAZ FOO < >

FIELD1, FIELD2, and FIELD3 are the fields of the record FOO.

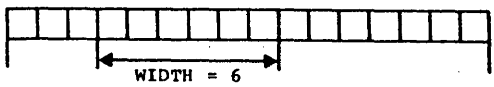
Shift-count - (record-fieldname)

<record-fieldname>

The shift count is derived from the record fieldname to be isolated.

The shift count is the number of bits the field must be shifted right to place the lowest bit of the field in the lowest bit of the record byte or word.

If a 16-bit record (FOO) contains three fields (FIELD1, FIELD2, and FIELD3), the record can be diagrammed as follows:



FIELD1 has a shift count of 13.
FIELD2 has a shift count of 7.
FIELD3 has a shift count of 0.

When you want to isolate the value in one of these fields, you enter its name as an operand.

Example:

```
MOV DX,BAZ
MOV CL,FIELD2
SHR DX,CL
```

FIELD2 is now right shifted, ready for access.

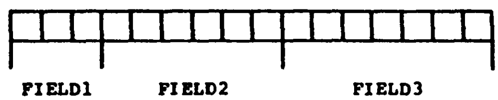
WIDTH

WIDTH <record-fieldname>
WIDTH <record>

When a <record-fieldname> is given as the argument, WIDTH returns the width of a record field as the number of bits in the record field.

When a <record> is given as the argument, WIDTH returns the width of a record as the number of bits in the record.

Using the diagram under shift count, WIDTH can be diagrammed as:



The WIDTH of FIELD1 equals 3.
The WIDTH of FIELD2 equals 6.
The WIDTH of FIELD3 equals 7.

Example:

```
MOV CL,WIDTH FIELD2
```

The number of bits in FIELD2 is now in the count register.

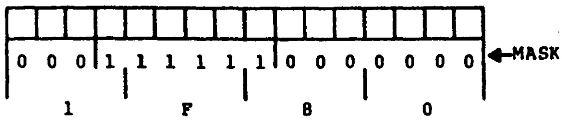
MASK

MASK <record-fieldname>

MASK accepts a field name as its only argument.

MASK returns a bit-mask defined by 1 for bit positions included by the field and 0 for bit positions not included. The value return represents the maximum value for the record when the field is masked.

Using the diagram used for shift count, MASK can be diagrammed as:



The MASK of FIELD2 equals 1F80H.

Example:

```
MOV DX,BAZ
AND DX,MASK FIELD2
```

FIELD2 is now isolated.

3.3.2 Arithmetic Operators

Eight arithmetic operators provide the common mathematical functions (add, subtract, divide, multiply, modulo, negation), plus two shift operators.

The arithmetic operators are used to combine operands to form an expression that results in a data item or an address.

Except for + and - (binary), operands must be constants.

For plus (+), one operand must be a constant.

For minus (-), the first (left) operand may be a nonconstant, or both operands may be nonconstants. The right must be a constant if the left is a constant.

* Multiply

/ Divide

MOD Modulo. Divide the left operand by the right operand and return the value of the remainder (modulo). Both operands must be absolute.

Example:

```
MOV AX,100 MOD 17
```

The value moved into AX will be 0FH (decimal 15).

SHR Shift Right. SHR is followed by an integer which specifies the number of bit positions the value is to be shifted right.

Example:

```
MOV AX,1100000B SHR 5
```

The value moved into AX will be 11B (03).

SHL Shift Left. SHL is followed by an integer which specifies the number of bit positions the value is to be shifted left.

Example:

```
MOV AX,0110B SHL 5
```

The value moved into AX will be 011000000B (0C0H)

- (Unary Minus)	Indicates that following value is negative, as in a negative integer.
+	Add. One operand must be a constant; one may be a nonconstant.
-	Subtract the right operand from the left operand. The first (left) operand may be a nonconstant, or both operands may be nonconstants. But the right may be a nonconstant only if the left is also a nonconstant and in the same segment.

3.3.3 Relational Operators

Relational operators compare two constant operands.

If the relationship between the two operands matches the operator, FFFFH is returned.

If the relationship between the two operands does not match the operator, a zero is returned.

Relational operators are most often used with conditional directives and conditional instructions to direct program control.

EQ	Equal. Returns true if the operands equal each other.
NE	Not Equal. Returns true if the operands are not equal to each other.
LT	Less Than. Returns true if the left operand is less than the right operand.
LE	Less than or Equal. Returns true if the left operand is less than or equal to the right operand.
GT	Greater Than. Returns true if the left operand is greater than the right operand.
GE	Greater than or Equal. Returns true if the left operand is greater than or equal to the right operand.

3.3.4 Logical Operators

Logical operators compare two constant operands bitwise.

Logical operators compare the binary values of corresponding bit positions of each operand to evaluate the logical relationship defined by the logical operator.

Logical operators can be used two ways:

1. To combine operands in a logical relationship. In this case, all bits in the operands will have the same value (either 0000 or FFFFH). In fact, it is best to use these values for true (FFFFH) and false (0000) for the symbols you will use as operands, because in conditionals anything nonzero is true.

2. In bitwise operations. In this case, the bits are different, and the logical operators act the same as the instructions of the same name.

NOT	Logical NOT. Returns true if left operand is true and right is false or if right is true and left is false. Returns false if both are true or both are false.
AND	Logical AND. Returns true if both operators are true. Returns false if either operator is false or if both are false. Both operands must be absolute values.
OR	Logical OR. Returns true if either operator is true or if both are true. Returns false if both operators are false. Both operands must be absolute values.
XOR	Exclusive OR. Returns true if either operator is true and the other is false. Returns false if both operators are true or if both operators are false. Both operands must be absolute values.

3.3.5 Expression Evaluation: Precedence Of Operators

Expressions are evaluated higher precedence operators first, then left to right for equal precedence operators.

Parentheses can be used to alter precedence.

For example:

```
MOV AX,101B SHL 2*2   = MOV AX,00101000B

MOV AX,101B SHL (2*2) = MOV AX,01010000B
```

SHL and * are equal precedence. Therefore, their functions are performed in the order the operators are encountered (left to right).

Precedence of Operators

All operators in a single item have the same precedence, regardless of the order listed within the item. Spacing and line breaks are used for visual clarity, not to indicate functional relations.

1. LENGTH, SIZE, WIDTH, MASK
   Entries inside: parentheses ( )
   angle brackets < >
   square brackets [ ]
   Structure variable operand: <variable>.<field>

2. Segment override operator: colon (:)

3. PTR, OFFSET, SEG, TYPE, THIS

4. HIGH, LOW

5. *, /, MOD, SHL, SHR

6. +, - (both unary and binary)

7. EQ, NE, LT, LE, GT, GE

8. Logical NOT

9. Logical AND

10. Logical OR, XOR

11. SHORT,.TYPE

Contents

CHAPTER 4

ACTION: INSTRUCTIONS AND DIRECTIVES

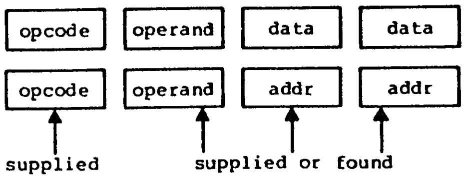
The action field contains either an 8086 instruction mnemonic or a Macro Assembler assembler directive.

Following a name field entry (if any), action field entries may begin in any column. Specific spacing is not required. The only benefit of consistent spacing is improved readability. If a statement does not have a name field entry, the action field is the first entry.

The entry in the action field either directs the processor to perform a specific function or directs the assembler to perform one of its functions.

4.1 INSTRUCTIONS

Instructions tell the command processor to perform some action. An instruction may have the data and/or addresses it needs built into it, or data and/or addresses may be found in the expression part of an instruction. For example:



supplied = part of the instruction

found = assembler inserts data and/or address from the information provided by expressions in instruction statements.

(opcode equates to the binary code for the action of an instruction)

Note that this manual does not contain detailed descriptions of the 8086 instruction mnemonics and their characteristics. For this, you will need to consult other texts. The following texts are recommended:

1. Morse, Stephen P. The 8086 Primer. Rochelle Park, NJ: Hayden Publishing Co., 1980.

2. Rector, Russell and George Alexy. The 8086 Book. Berkeley, CA: Osbourne/McGraw-Hill, 1980.

3. The 8086 Family User's Manual. Santa Clara, CA: Intel Corporation, 1980.

Appendix C contains both an alphabetical listing and a grouped listing of the instruction mnemonics. The alphabetical listing shows the full name of the instruction. Following the alphabetical list is a list that groups the instruction mnemonics by the number and type of arguments they take. Within each group, the instruction mnemonics are arranged alphabetically.

4.2 DIRECTIVES

Directives give the assembler directions and information about input and output, memory organization, conditional assembly, listing and cross-reference control, and definitions.

The directives have been divided into groups by the function they perform. Within each group, the directives are described alphabetically.

The groups are:

Memory Directives
: Directives in this group are used to organize memory. Because there is no "miscellaneous" group, the memory directives group contains some directives that do not, strictly speaking, organize memory (for example, COMMENT).

Conditional Directives
: Directives in this group are used to test conditions of assembly before proceeding with assembly of a block of statements. This group contains all of the IF (and related) directives.

Macro Directives
: Directives in this group are used to create blocks of code called macros. This group also includes some special operators and directives that are used only inside macro blocks. The repeat directives are considered macro directives for descriptive purposes.

Listing Directives
: Directives in this group are used to control the format and, to some extent, the content of listings that the assembler produces.

Appendix B contains a table of assembler directives, also grouped by function. Below is an alphabetical list of all the directives that Macro Assembler supports:

ASSUME	EVEN	IRPC	.RADIX
	EXITM		RECORD
COMMENT	EXTERN	LABEL	REPT
.CREF		.LALL	
	GROUP	.LFCOND	.SALL
DB		.LIST	SEGMENT
DD	IF		.SFCOND
DQ	IFB	MACRO	STRUC
DT	IFDEF		SUBTTL
DW	IFDIF	NAME	
	IFE		.TFCOND
ELSE	IFIDN	ORG	TITLE
END	IFNB	%OUT	
ENDIF	IFNDEF		.XALL
ENDM		PAGE	.XCREF
ENDP	IF1	PROC	.XLIST
ENDS	IF2	PUBLIC	
EQU	IRP	PURGE	

4.2.1 Memory Directives

<u>ASSUME</u>

ASSUME <seg-reg>:<seg-name>[,...]

or

ASSUME NOTHING

ASSUME tells the assembler that the symbols in the segment or group can be accessed using this segment register. When the assembler encounters a variable, it automatically assembles the variable reference under the proper segment register. You may enter from 1 to 4 arguments to ASSUME.

The valid <seg-reg> entries are:

CS, DS, ES, and SS.

The possible entries for <seg-name> are:

1. The name of a segment declared with the SEGMENT directive

2. The name of a group declared with the GROUP directive

3. An expression: either SEG <variable-name> or SEG <label-name> (see SEG operator, Section 3.3)

4. The key word NOTHING. ASSUME NOTHING cancels all register assignments made by a previous ASSUME statement

If ASSUME is not used or if NOTHING is typed for <seg-name>, each reference to variables, symbols, labels, and so forth in a particular segment must be prefixed by a segment register. For example, type DS:FOO instead of simply FOO.

Example:

```
ASSUME DS:DATA,SS:DATA,CS:CGROUP,ES:NOTHING
```

COMMENT

COMMENT<delim><text><delim>

The first non-blank character encountered after COMMENT is the delimiter. The following <text> comprises a comment block which continues until the next occurrence of <delimiter>.

COMMENT permits you to enter comments about your program without entering a semicolon (;) before each line.

If you use COMMENT inside a macro block, the comment block will not appear on your listing unless you also place the .LALL directive in your source file.

Example:

Using an asterisk as the delimiter, the format of the comment block would be:

```
COMMENT  *
any amount of text entered
here as the comment block
  .
  .
  .      *     ;return to normal mode
```

DEFINE BYTE
DEFINE WORD
DEFINE DOUBLEWORD
DEFINE QUADWORD
DEFINE TENBYTES

```
<varname>     DB      <exp>[,<exp>,...]
<varname>     DW      <exp>[,<exp>,...]
<varname>     DD      <exp>[,<exp>,...]
<varname>     DQ      <exp>[,<exp>,...]
<varname>     DT      <exp>[,<exp>,...]
```

The DEFINE directives are used to define variables or to initialize portions of memory.

If the optional <varname> is entered, the DEFINE directives define the name as a variable. If <varname> has a colon, it becomes a NEAR label instead of a variable. (See also, Section 2.1, "Labels," and Section 2.2, "Variables.")

The DEFINE directives allocate memory in units specified by the second letter of the directive (each DEFINE directive may allocate one or more of its units at a time):

DB allocates one byte (8 bits)
DW allocates one word (2 bytes)
DD allocates two words (4 bytes)
DQ allocates four words (8 bytes)
DT allocates ten bytes

<exp> may be one or more of the following:

1. A constant expression

2. The character ? for indeterminate initialization. Usually the ? is used to reserve space without placing any particular value into it. (It is the equivalent of the DS pseudo-op in MACRO-80).

3. An address expression (for DW and DD only)

4. An ASCII string (longer than two characters for DB only)

5. <exp>DUP(?)
When this type of expression is the only argument to a define directive, the define directive produces an uninitialized data block. This expression with the ? instead of a value results in a smaller object file because only the segment offset is changed to reserve space.

6. <exp> DUP(<exp>[,...])
This expression, like item 5, produces a data block, but initialized with the value of the second <exp>. The first <exp> must be a constant greater than zero and must not be a forward reference.

Example - Define Byte (DB):

```
NUM_BASE    DB      16
FILLER      DB      ?                    ;initialize with
                                         ;indeterminate value
ONE_CHAR    DB      'M'
MULT_CHAR   DB      'TOM JEROME EDWARD BOB DEAN'
MSG         DB      'MSGTEST',13,10 ;message, carriage return
                                         ;and linefeed
BUFFER      DB      10 DUP(?)            ;indeterminate block
TABLE       DB      100 DUP(5 DUP(4),7)
                                         ;100 copies of bytes
                                         ;with values 4,4,4,4,4,7
NEW_PAGE    DB      0CH                  ;form feed character
ARRAY       DB      1,2,3,4,5,6,7
```

Example - Define Word (DW):

```
ITEMS       DW      TABLE,TABLE+10,TABLE+20
SEGVAL      DW      0FFF0H
BSIZE       DW      4 * 128
LOCATION    DW      TOTAL + 1
AREA        DW      100 DUP(?)
CLEARED     DW      50 DUP(0)
SERIES      DW      2 DUP(2,3 DUP(BSIZE))
            ;two words with the byte values
            ;2,BSIZE,BSIZE,BSIZE,2,BSIZE,BSIZE,BSIZE
DISTANCE    DW      START_TAB -END_TAB
            ;difference of two labels is a constant
```

Example - Define Doubleword (DD):

```
DBPTR            DD      TABLE          ;16-bit OFFSET,
                                        ;then 16-bit
                                        ;SEG base value
SEC_PER_DAY      DD      60*60*24       ;arithmetic is performed
                                        ;by the assembler
LIST             DD      'XY',2 DUP(?)
HIGH             DD      4294967295     ;maximum
FLOAT            DD      6.735E2        ;floating point
```

Example - Define Quadword (DQ):

```
LONG_REAL        DQ      3.141597                ;decimal makes
                                                 ;it real
STRING           DQ      'AB'                    ;no more than 2
                                                 ;characters
HIGH             DQ      18446744073709661615    ;maximum
LOW              DQ      -18446744073709661615   ;minimum
SPACER           DQ      2 DUP(?)                ;uninit.data
FILLER           DQ      1 DUP(?,?)              ;initalized w_/
                                                 ;indeterminate
                                                 ;value
HEX_REAL         DQ      0FDCBA9A98765432105R
```

Example - Define Tenbytes (DT):

```
ACCUMULATOR      DT      ?
STRING           DT      'CD'           ;no more than 2
                                        ;characters
PACKED_DECIMAL   DT      1234567890
FLOATING_POINT   DT      3.1415926
```

END

END [<exp>]

The END statement specifies the end of the program.

If <exp> is present, it is the start address of the program. If several modules are to be linked, only the main module may specify the start of the program with the END <exp> statement.

If <exp> is not present, then no start address is passed to MS-LINK for that program or module.

Example:

```
END     START   ;START is a label somewhere in the
                ;program
```

EQU

<name> EQU <exp>

EQU assigns the value of <exp> to <name>. If <exp> is an external symbol, an error is generated. If <name> already has a value, an error is generated. If you want to be able to redefine a <name> in your program, use the equal sign (=) directive instead.

In many cases, EQU is used as a primitive text substitution, like a macro.

<exp> may be any one of the following:

1. A symbol. <name> becomes an alias for the symbol in <exp>. Shown as an Alias in the symbol table.

2. An instruction name. Shown as an Opcode in the symbol table.

3. A valid expression. Shown as a Number or L (label) in the symbol table.

4. Any other entry, including text, index references, segment prefix and operands. Shown as Text in the symbol table.

Example:

```
FOO     EQU     BAZ          ;must be defined in this
                             ;module or an error
                             ;results
B       EQU     [BP+8]       ;index reference (Text)
P8      EQU     DS:[BP+8]    ;segment prefix
                             ;and operand (Text)
CBD     EQU     AAD          ;an instruction name
                             ;(Opcode)
ALL     EQU     DEFREC<2,3,4> ;DEFREC = record name
                             ;<2,3,4> = initial values
                             ;for fields of record
EMP     EQU     6            ;constant value
FPV     EQU     6.3E7        ;floating point (text)
```

Equal Sign

<name> = <exp>

<exp> must be a valid expression. It is shown as a Number or L (label) in the symbol table (same as <exp> type 3 under the EQU directive above).

The equal sign (=) allows the user to set and to redefine symbols. The equal sign is like the EQU directive, except the user can redefine the symbol without generating an error. Redefinition may take place more than once, and redefinition may refer to a previous definition.

Example:

```
FOO     =       5       ;the same as FOO EQU 5
FOO     EQU     6;      ;error, FOO cannot be
                        ;redefined by EQU
FOO     =       7       ;FOO can be redefined
                        ;only by another =
FOO     =       FOO+3   ;redefinition may refer
                        ;to a previous definition
```

EVEN

EVEN

The EVEN directive causes the program counter to go to an even boundary; that is, to an address that begins a word. If the program counter is not already at an even boundary, EVEN causes the assembler to add a NOP instruction so that the counter will reach an even boundary.

An error results if EVEN is used with a byte-aligned segment.

Example:

Before: The PC points to 0019 hex (25 decimal)

EVEN

After: The PC points to 1A hex (26 decimal)
0019 hex now contains a NOP instruction

EXTRN

EXTRN <name>:<type>[,...]

<name> is a symbol that is defined in another module. <name> must have been declared PUBLIC in the module where <name> is defined.

<type> may be any one of the following, but must be a valid type for <name>:

1. BYTE, WORD, or DWORD
2. NEAR or FAR for labels or procedures (defined under a PROC directive)
3. ABS for pure numbers (implicit size is WORD, but includes BYTE)

Unlike the 8080 assembler, placement of the EXTRN directive is significant. If the directive is given with a segment, the assembler assumes that the symbol is located within that segment. If the segment is not known, place the directive outside all segments, then use either

```
ASSUME <seg-reg>:SEG <name>
```

or an explicit segment prefix.

NOTE

If a mistake is made and the symbol is not in the segment, MS-LINK will take the offset relative to the given segment, if possible. If the real segment is less than 64K bytes away from the reference, MS-LINK may find the definition. If the real segment is more than 64K bytes away, MS-LINK will fail to make the link between the reference and the definition and will return an error message.

Example:

```
In Same Segment:          In Another Segment:
------------------------------------------------------------
In Module 1:              In Module 1:

CSEG    SEGMENT           CSEGA   SEGMENT
        PUBLIC TAGN                       PUBLIC TAGF
         .                         .
         .                         .
         .                         .
TAGN:                     TAGF:
         .                         .
         .                         .
         .                         .
CSEG    ENDS              CSEGA   ENDS

In Module 2:              In Module 2:

CSEG    SEGMENT                   EXTRN TAGF:FAR
        EXTRN TAGN:NEAR           CSEGB   SEGMENT
         .                         .
         .                         .
         .                         .
        JMP TAGN                          JMP TAGF
CSEG    ENDS              CSEGB   ENDS
```

GROUP

<name> GROUP <seg-name>[,...]

The GROUP directive collects the segments named after GROUP (<seg-name>s) under one name. The GROUP is used by MS-LINK so that it knows which segments should be loaded together (the order the segments are named here does not influence the order in which the segments are loaded. The order in which the segments are loaded is determined by the CLASS designation of the SEGMENT directive, or by the order you name object modules in response to the MS-LINK Object Module: prompt).

All segments in a GROUP must fit into 64K bytes of memory. The assembler does not check this at all, but leaves the checking to MS-LINK.

<seg-name> may be one of the following:

1. A segment name, assigned by a SEGMENT directive. The name may be a forward reference.

2. An expression: either SEG <var>
   or SEG <label>
   Both of these entries resolve themselves to a segment name (see SEG operator, Section 3.3).

Once you have defined a group name, you can use the name:

1. As an immediate value:

```
MOV AX,DGROUP
MOV DS,AX
```

   DGROUP is the paragraph address of the base of DGROUP.

2. In ASSUME statements:

```
ASSUME DS:DGROUP
```

   The DS register can now be used to reach any symbol in any segment of the group.

3. As an operand prefix (for segment override):

```
MOV BX,OFFSET DGROUP:FOO
DW  DGROUP:FOO
DD  DGROUP:FOO
```

DGROUP: forces the offset to be relative to DGROUP, instead of to the segment in which FOO is defined.

Example (Using GROUP to combine segments):

In Module A:

```
CGROUP  GROUP   XXX,YYY
XXX     SEGMENT
        ASSUME  CS:CGROUP
          .
          .
          .
XXX     ENDS
YYY     SEGMENT
          .
          .
          .
YYY     ENDS
        END
```

In Module B:

```
CGROUP  GROUP   ZZZ
ZZZ     SEGMENT
        ASSUME  CS:CGROUP
          .
          .
          .
ZZZ     ENDS
        END
```

INCLUDE

INCLUDE <filename>

The INCLUDE directive inserts source code from an alternate assembly language source file into the current source file during assembly. Use of the INCLUDE directive eliminates the need to repeat an often-used sequence of statements in the current source file.

The <filename> is any valid file specification for the operating system. If the device designation is other than the default, the source filename specification must include it. The default device designation is the currently logged drive or device.

The included file is opened and assembled into the current source file immediately following the INCLUDE directive statement. When end-of-file is reached, assembly resumes with the next statement following the INCLUDE directive.

Nested INCLUDES are allowed (the file inserted with an INCLUDE statement may contain an INCLUDE directive). However, this is not a recommended practice with small systems because of the amount of memory that may be required.

The file specified must exist. If the file is not found, an error is displayed, and the assembly aborts.

On a Macro Assembler listing, the letter C is printed between the assembled code and the source line on each line assembled from an included file. See Section 5.5, "Formats of Listings and Symbol Tables," for a description of listing file formats.

Example:

```
INCLUDE ENTRY
INCLUDE B:RECORD.TST
```

LABEL

<name> LABEL <type>

By using LABEL to define a <name>, you cause the assembler to associate the current segment offset with <name>.

The item is assigned a length of 1.

<type> varies depending on the use of <name>. <name> may be used for code or for data.

1. For code (for example, as a JMP or CALL operand):

   <type> may be either NEAR or FAR. <name> cannot be used in data manipulation instructions without using a type override.

   If you wish, you can define a NEAR label using the <name>: form (the LABEL directive is not used in this case). If you are defining a BYTE or WORD NEAR label, you can place the <name>: in front of a Define directive.

   When using a LABEL for code (NEAR or FAR), the segment must be addressable through the CS register.

   Example - For Code:

```
SUBRTF  LABEL   FAR
SUBRT:  (first instruction)     ;colon = NEAR label
```

2. For data:

   <type> may be BYTE, WORD, DWORD, <structure-name>, or <record-name>. When STRUC or RECORD name is used, <name> is assigned the size of the structure or record.

   Example - For Data:

```
BARRAY  LABEL  BYTE
ARRAY   DW     100 DUP(0)
        .
        .
        .
        ADD    AL,BARRAY[99]   ;ADD 100th byte to AL
        ADD    AX,ARRAY[98]    ;ADD 50th word to AX
```

   By defining the array two ways, you can access entries either by byte or by word. Also, you can use this method for STRUC. It allows you to place your data in memory as a table, and to access it without the offset of the STRUC.

   Defining the array two ways also permits you to avoid using the PTR operator. The double defining method is especially effective if you access the data different ways. It is easier to give the array a second name than to remember to use PTR.

NAME

NAME <module-name>

<module-name> must not be a reserved word. The module name may be any length, but Macro Assembler uses only the first six characters and truncates the rest.

The module name is passed to MS-LINK, but otherwise has no significance for the assembler. Macro Assembler does check to see if more than one module name has been declared.

Every module has a name. Macro Assembler derives the module name from:

1. A valid NAME directive statement

2. If the module does not contain a NAME statement, Macro Assembler uses the first six characters of a TITLE directive statement. The first six characters must be legal as a name.

Example:

```
NAME CURSOR
```

ORG

ORG <exp>

The location counter is set to the value of <exp>, and the assembler assigns generated code starting with that value.

All names used in <exp> must be known on pass 1. The value of <exp> must either evaluate to an absolute or must be in the same segment as the location counter.

Example:

```
ORG     120H     ;2-byte absolute value
                 ;maximum=0FFFFH
ORG     $+2      ;skip two bytes
```

Example - ORG to a boundary (conditional):

```
CSEG    SEGMENT PAGE
BEGIN   =       $
        .
        .
        .
IF ($-BEGIN) MOD 256     ;if not already on
                         ;256-byte boundary
        ORG ($-BEGIN)+256-(($-BEGIN) MOD 256)
ENDIF
```

See Section 4.2.2, "Conditional Directives," for an explanation of conditional assembly.

PROC

```
<procname>      PROC      [NEAR]
                       or  [FAR]
                .
                .
                .
                RET
<procname>      ENDP
```

The default, if no operand is specified, is NEAR. Use FAR if:

1. The procedure name is an operating system entry point

2. The procedure will be called from code which has another ASSUME CS value

Each PROC block should contain a RET statement.

The PROC directive serves as a structuring device to make your programs more understandable.

The PROC directive, through the NEAR/FAR option, informs CALLs to the procedure to generate a NEAR or a FAR CALL, and RETs to generate a NEAR or a FAR RET. PROC is used, therefore, for coding simplification so that the user does not have to worry about NEAR or FAR for CALLs and RETs.

A NEAR CALL or RETURN changes the IP but not the CS register. A FAR CALL or RETURN changes both the IP and the CS registers.

Procedures are executed either in line, from a JMP, or from a CALL.

PROCs may be nested, which means that they are put in line.

Combining the PUBLIC directive with a PROC statement (both NEAR and FAR), permits you to make external CALLs to the procedure or to make other external references to the procedure.

Example:

```
        PUBLIC  FAR_NAME
FAR_NAME        PROC    FAR
        CALL    NEAR_NAME
        RET
FAR_NAME        ENDP

        PUBLIC  NEAR_NAME
NEAR_NAME       PROC    NEAR
        .
        .
        .
        RET
NEAR_NAME       ENDP
```

The second subroutine above can be called directly from a NEAR segment (that is, a segment addressable through the same CS and within 64K):

```
    CALL NEAR_NAME
```

A FAR segment (that is, any other segment that is not a NEAR segment) must call to the first subroutine, which then calls the second (an indirect call):

```
    CALL FAR_NAME
```

PUBLIC

PUBLIC <symbol>[,...]

Place a PUBLIC directive statement in any module that contains symbols you want to use in other modules without defining the symbol again. PUBLIC makes the listed symbol(s), which are defined in the module where the PUBLIC statement appears, available for use by other modules to be linked with the module that defines the symbol(s). This information is passed to MS-LINK.

<symbol> may be a number, a variable, a label (including PROC labels).

<symbol> may not be a register name or a symbol defined (with EQU) by floating point numbers or by integers larger than two bytes.

Example:

```
        PUBLIC  GETINFO
GETINFO PROC    FAR
        PUSH    BP        ;save caller's register
        MOV     BP,SP     ;get address parameters
                          ;body of subroutine
        POP     BP        ;restore caller's reg
        RET               ;return to caller
GETINFO ENDP
```

Example - illegal PUBLIC:

```
        PUBLIC PIE_BALD,HIGH_VALUE
PIE_BALD       EQU     3.1416
HIGH_VALUE EQU 999999999
```

.RADIX

.RADIX <exp>

The default input base (or radix) for all constants is decimal. The .RADIX directive permits you to change the input radix to any base in the range 2 to 16.

<exp> is always in decimal radix, regardless of the current input radix.

Example:

```
MOV     BX,0FFH
.RADIX  16
MOV     BX,0FF
```

The two MOVs in this example are identical.

The .RADIX directive does not affect the generated code values placed in the .OBJ, .LST, or .CRF output files.

The .RADIX directive does not affect the DD, DQ, or DT directives. Numeric values entered in the expression of these directives are always evaluated as decimal unless a data type suffix is appended to the value.

Example:

```
        .RADIX 16
NUM_HAND        DT      773  ;773 = decimal
HOT_HAND        DQ      773Q ;773 = octal here only
COOL_HAND       DD      773H ;now 773 = hexadecimal
```

RECORD

`<recordname> RECORD <fieldname>:<width>[=<exp>],[...]`

<fieldname> is the name of the field. <width> specifies the number of bits in the field defined by <fieldname>. <exp> contains the initial (or default) value for the field. Forward references are not allowed in a RECORD statement.

<fieldname> becomes a value that can be used in expressions. When you use <fieldname> in an expression, its value is the shift count to move the field to the far right. Using the MASK operator with the <fieldname> returns a bit mask for that field.

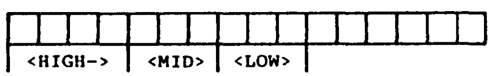
<width> is a constant in the range 1 to 16 that specifies the number of bits contained in the field defined by <fieldname>. The WIDTH operator returns this value. If the total width of all declared fields is larger than 8 bits, then the assembler uses two bytes. Otherwise, only one byte is used.

The first field you declare goes into the most significant bits of the record. Successively declared fields are placed in the succeeding bits to the right. If the fields you declare do not total exactly 8 bits or exactly 16 bits, the entire record is shifted right so that the last bit of the last field is the lowest bit of the record. Unused bits will be in the high end of the record.

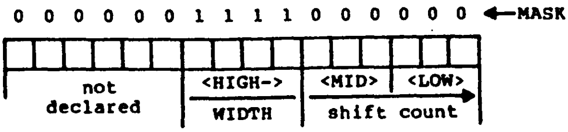
Example:

```
FOO RECORD HIGH:4,MID:3,LOW:3
```

Initially, the bit map would be:



Total bits >8 means use a word; but total bits <16 means right shift, place undeclared bits at high end of word. Thus:



<exp> contains the initial value for the field. If the field is at least 7 bits wide, you can use an ASCII character as the <exp>.

Example:

```
HIGH:7='Q'
```

To initialize records, use the same method used for DB. The format is:

```
[<name>] <recordname> <[exp][,...]>
```

or

```
[<name>] <recordname> [<exp> DUP(<[exp][,...]>)
```

The name is optional. When given, name is a label for the first byte or word of the record storage area.

The recordname is the name used as a label for the RECORD directive.

The [exp] (both forms) contains the values you want placed into the fields of the record. In the latter case, the parentheses and angle brackets are required only around the second [exp] (following DUP). If [exp] is left blank, either the default value applies (the value given in the original record definition), or the value is indeterminate (when not initialized in the original record definition). For fields that are already initialized to values you want, place consecutive commas to skip over (use the default values of) those fields.

For example:

```
FOO <,,7>
```

From the previous example, the 7 would be placed into the LOW field of the record FOO. The fields

HIGH and MID would be left as declared (in this case, uninitialized).

Records may be used in expressions (as an operand) in the form:

```
    recordname<[value[,...]]>
```

The value entry is optional. The angle brackets must be coded as shown, even if the optional values are not given. A value entry is the value to be placed into a field of the record. For fields that are already initialized to values you want, place consecutive commas to skip over (use the default values of) those fields, as shown above.

Example:

```
FOO     RECORD  HIGH:5,MID:3,LOW:3
          .
          .
          .
BAX     FOO     <>  ;leave undeterminate here
JANE    FOO     10 DUP(<16,8>)   ;HIGH=16,MID=8,
                ;LOW=?
          .
          .
          .
        MOV     DX,OFFSET JANE[2]
                ;get beginning record address
        AND     DX,MASK MID
        MOV     CL,MID
        SHR     DX,CL
        MOV     CL,WIDTH MID
```

SEGMENT

```
<segname>       SEGMENT [<align>] [<combine>] [<'class'>]
                   .
                   .
                   .
<segname>       ENDS
```

At runtime, all instructions that generate code and data are in (separate) segments. Your program may be a segment, part of a segment, several segments, parts of several segments, or a combination of these. If a program has no SEGMENT statement, an MS-LINK error (invalid object) will result at link time.

The <segment name> must be a unique, legal name. The segment name must not be a reserved word.

<align> may be PARA (paragraph - default), BYTE, WORD, or PAGE.

<combine> may be PUBLIC, COMMON, AT <exp>, STACK, MEMORY, or no entry (which defaults to not combinable, called Private in the Microsoft LINK section of the Macro Assembler Manual).

<class> name is used to group segments at link time.

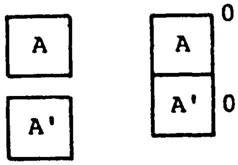
All three operands are passed to MS-LINK.

The alignment type tells the Linker on what kind of boundary you want the segment to begin. The first address of the segment will be, for each alignment type:

```
PAGE - address is xxx00H (low byte is 0)
PARA - address is xxxx0H (low nibble is 0)
    bit map - |x|x|x|x|0|0|0|0|
WORD - address is xxxxeH (e=even number;low bit
    is 0)
    bit map - |x|x|x|x|x|x|x|0|
BYTE - address is xxxxxH (place anywhere)
```

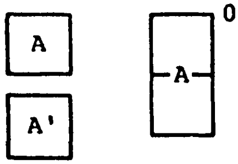
The combine type tells MS-LINK how to arrange the segments of a particular class name. The segments are mapped as follows for each combine type:

None (not combinable or Private)



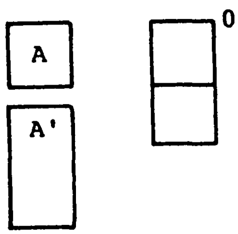
Private segments are loaded separately and remain separate. They may be physically contiguous but not logically, even if the segments have the same name. Each private segment has its own base address.

Public and Stack



Public segments of the same name and class name are loaded contiguously. Offset is from beginning of first segment loaded through last segment loaded. There is only one base address for all public segments of the same name and class name. (Combine type stack is treated the same as public. However, the Stack Pointer is set to the first address of the first stack segment. MS-LINK requires at least one stack segment.)

Common



Common segments of the same name and class name are loaded overlapping one another. There is only one base address for all common segments of the same name. The length of the common area is the length of the longest segment.

Memory

The memory combine type causes the segment(s) to be placed as the highest segments in memory. The first memory combinable segment encounter is placed as the highest segment in memory. Subsequent segments are treated the same as Common segments.

NOTE

This feature is not supported by MS-LINK. MS-LINK treats Memory segments the same as Public segments.

AT <exp>

The segment is placed at the PARAGRAPH address specified in <exp>. The expression may not be a forward reference. Also, the AT type may not be used to force loading at fixed addresses. Rather, the AT combine type permits labels and variables to be defined at fixed offsets within fixed areas of storage, such as ROM or the vector space in low memory.

NOTE

This restriction is imposed by MS-LINK and MS-DOS.

Class names must be enclosed in quotation marks. Class names may be any legal name. Refer to Chapter 9 in the MS-DOS User's Guide for more discussion.

Segment definitions may be nested. When segments are nested, the assembler acts as if they are not and handles them sequentially by appending the second part of the split segment to the first. At ENDS for the split segment, the assembler takes up the nested segment as the next segment, completes it, and goes on to subsequent segments. Overlapping segments are not permitted.

For example:

```
A        SEGMENT    |       |A SEGMENT
           .        |       |    .
           .        |       |    .
           .        |       |    .
B        SEGMENT    |       |A ENDS
           .        |       |B          SEGMENT
           .        | --->  |    .
           .        |       |    .
B        ENDS       |       |    .
           .        |       |B          ENDS
           .        |       |A          SEGMENT
           .        |       |    .
A        ENDS       |       |    .
                            |    .
                            |A ENDS
```

The following arrangement is not allowed:

```
A        SEGMENT
           .
           .
B        SEGMENT
           .
           .
A        ENDS      ;This is illegal!
           .
           .
B        ENDS
```

Example:

In module A:

```
SEGA     SEGMENT PUBLIC 'CODE'
         ASSUME  CS:SEGA
           .
           .
           .
SEGA     ENDS
         END
```

In module B:

```
SEGA     SEGMENT PUBLIC 'CODE'
         ASSUME  CS:SEGA
           .      ;MS-LINK adds this segment to same
           .      ;named segment in module A (and
           .      ;others) if class name is the same.
SEGA     ENDS
         END
```

STRUC

```
<structurename>     STRUC
                      .
                      .
                      .
<structurename>     ENDS
```

The STRUC directive is very much like RECORD, except STRUC has a multiple byte capability. The allocation and initialization of a STRUC block are the same as for RECORDs.

Inside the STRUC/ENDS block, the Define directives (DB, DW, DD, DQ, DT) may be used to allocate space. The Define directives and Comments set off by semicolons (;) are the only statement entries allowed inside a STRUC block.

Any label on a Define directive inside a STRUC/ENDS block becomes a <fieldname> of the structure. (This is how structure fieldnames are defined.) Initial values given to fieldnames in the STRUC/ENDS block are default values for the various fields. These field values are of two types: overridable or not overridable. A simple field, a field with only one entry (but not a DUP expression), is overridable. A multiple field, a field with more than one entry, is not overridable. For example:

```
FOO     DB      1,2             ;is not
overridable
BAZ     DB      10 DUP(?)       ;is not
overridable
ZOO     DB      5               ;is overridable
```

If the <exp> following the Define directive contains a string, it may be overridden by another string. However, if the overriding string is shorter than the initial string, the assembler will pad with spaces. If the overriding string is longer, the assembler will truncate the extra characters.

Usually, structure fields are used as operands in some expression. The format for a reference to a structure field is:

```
<variable>.<field>
```

<variable> represents an anonymous variable, usually set up when the structure is allocated. To allocate a structure, use the structure name as a directive with a label (the anonymous variable of a structure reference) and any override values in angle brackets:

```
FOO     STRUCTURE
          .
          .
          .
FOO     ENDS

GOO     FOO      <,7,,'JOE'>
```

.<field> represents a label given to a DEFINE directive inside a STRUC/ENDS block (the period must be coded as shown). The value of <field> will be the offset within the addressed structure.

Example:

To define a structure:

```
S  STRUC
FIELD1  DB     1,2              ;not overridable
FIELD2  DB     10 DUP(?)        ;not overridable
FIELD3  DB     5                ;overridable
FIELD4  DB     'DOBOSKY'        ;overridable
S       ENDS
```

The Define directives in this example define the fields of the structure, and the order corresponds to the order values are given in the initialization list when the structure is allocated. Every Define directive statement line inside a STRUC block defines a field, whether or not the field is named.

To allocate the structure:

```
DBAREA  S     <,,7,'ANDY'>    ;overrides 3rd and
4th
                              ;fields only
```

To refer to a structure:

```
MOV     AL,[BX].FIELD3
MOV     AL,DBAREA.FIELD3
```

4.2.2 Conditional Directives

Conditional directives allow users to design blocks of code which test for specific conditions.

All conditionals follow the format:

```
IFxxxx [argument]
  .
  .
  .
[ELSE
  .
  .
  . ]
ENDIF
```

Each IFxxxx must have a matching ENDIF to terminate the conditional. Otherwise, an 'Unterminated conditional' message is generated at the end of each pass. An ENDIF without a matching IF causes a Code 8, "Not in conditional block" error.

Each conditional block may include the optional ELSE directive, which allows alternate code to be generated when the opposite condition exists. Only one ELSE is permitted for a given IF. An ELSE is always bound to the most recent, open IF. A conditional with more than one ELSE or an ELSE without a conditional will cause a Code 7, "Already had ELSE clause" error.

Conditionals may be nested up to 255 levels. Any argument to a conditional must be known on pass 1 to avoid Phase errors and incorrect evaluation. For IF and IFE the expression must involve values which were previously defined, and the expression must be absolute. If the name is defined after an IFDEF or IFNDEF, pass 1 considers the name to be undefined, but it will be defined on pass 2.

The assembler evaluates the conditional statement to TRUE (which equals any non-zero value), or to FALSE (which equals 0000H). If the evaluation matches the condition defined in the conditional statement, the assembler either assembles the whole conditional block or, if the conditional block contains the optional ELSE directive, assembles from IF to ELSE; the ELSE to ENDIF portion of the block is ignored. If the evaluation does not match, the assembler either ignores the conditional block completely or, if the conditional block contains the optional ELSE directive, assembles only the ELSE to ENDIF portion; the IF to ELSE portion is ignored.

The following is a list of Macro Assembler conditional directives: IF <exp>

If <exp> evaluates to nonzero, the statements within the conditional block are assembled.

IFE <exp>

If <exp> evaluates to 0, the statements in the conditional block are assembled.

IF1 Pass 1 Conditional

If the assembler is in pass 1, the statements in the conditional block are assembled. IF1 takes no expression.

IF2 Pass 2 Conditional

If the assembler is in pass 2, the statements in the conditional block are assembled. IF2 takes no expression.

IFDEF <symbol>

If the <symbol> is defined or has been declared External, the statements in the conditional block are assembled.

IFNDEF <symbol>

If the <symbol> is not defined or not declared External, the statements in the conditional block are assembled.

IFB <arg>

The angle brackets around <arg> are required.

If the <arg> is blank (none given) or null (two angle brackets with nothing in between, <>), the statements in the conditional block are assembled.

IFB (and IFNB) are normally used inside macro blocks. The expression following the IFB directive is typically a dummy symbol. When the macro is called, the dummy will be replaced by a parameter passed by the macro call. If the macro call does not specify a parameter to replace the dummy following IFB, the expression is blank, and the block will be assembled. (IFNB is the opposite case.) Refer to Section 4.2.3, "Macro Directives," for a full explanation.

IFNB <arg>

The angle brackets around <arg> are required.

If <arg> is not blank, the statements in the conditional block are assembled.

IFNB (and IFB) are normally used inside macro blocks. The expression following the IFNB directive is typically a dummy symbol. When the macro is called, the dummy will be replaced by a parameter passed by the macro call. If the macro call specifies a parameter to replace the dummy following IFNB, the expression is not blank, and the block will be assembled. (IFB is the opposite case.) Refer to Section 4.2.3, "Macro Directives," for a full explanation.

IFIDN <arg1>,<arg2>

The angle brackets around <arg1> and <arg2> are required.

If the string <arg1> is identical to the string <arg2>, the statements in the conditional block are assembled.

IFIDN (and IFDIF) are normally used inside macro blocks. The expression following the IFIDN directive is typically two dummy symbols. When the macro is called, the dummys will be replaced by parameters passed by the macro call. If the macro call specifies two identical parameters to replace the dummys, the block will be assembled. (IFDIF is the opposite case.) Refer to Section 4.2.3, "Macro Directives," for a full explanation.

IFDIF <arg1>,<arg2>

The angle brackets around <arg1> and <arg2> are required.

If the string <arg1> is different from the string <arg2>, the statements in the conditional block are assembled.

IFDIF (and IFIDN) are normally used inside macro blocks. The expression following the IFDIF directive is typically two dummy symbols. When the macro is called, the dummys will be replaced by parameters passed by the macro call. If the macro call specifies two different parameters to replace the dummys, the block will be assembled. (IFIDN is the opposite case.)

ELSE

The ELSE directive allows you to generate alternate code when the opposite condition exists. ELSE may be used with any of the conditional directives. Only one ELSE is allowed for each IFxxxx conditional directive. ELSE takes no expression.

ENDIF

This directive terminates a conditional block. An ENDIF directive must be given for every IFxxxx directive used. ENDIF takes no expression. ENDIF closes the most recent, unterminated IF.

4.2.3 Macro Directives

The macro directives allow you to write blocks of code which can be repeated without recoding. The blocks of code begin with either the macro definition directive or one of the repetition directives, and end with the ENDM directive. All of the macro directives may be used inside a macro block. In fact, nesting of macros is limited only by memory.

The macro directives of the Macro Assembler include:

```
macro definition:
    MACRO

termination:
    ENDM
    EXITM

unique symbols within macro blocks:
    LOCAL

undefine a macro:
    PURGE

repetitions:
    REPT  (repeat)
    IRP   (indefinite repeat)
    IRPC  (indefinite repeat character)
```

The macro directives also include some special macro operators:

- & (ampersand)
- ;; (double semicolon)
- ! (exclamation mark)
- % (percent sign)

Macro Definition

```
<name> MACRO [<dummy>,...]
          .
          .
          .
          ENDM
```

The block of statements from the MACRO statement line to the ENDM statement line comprises the body of the macro, or the macro's definition.

<name> is like a label and conforms to the rules for forming symbols. After the macro has been defined, <name> is used to invoke the macro.

A <dummy> is formed as any other name is formed. A <dummy> is a place holder that is replaced by a parameter in a one-for-one text substitution when the macro block is used. You should include all <dummy>s used inside the macro block on this line. The number of <dummy>s is limited only by the length of a line. If you specify more than one <dummy>, they must be separated by commas. Macro Assembler interprets a series of <dummy>s the same as any list of symbol names.

NOTE

A <dummy> is always recognized exclusively as a dummy. Even if a register name (such as AX or BH) is used as a <dummy>, it will be replaced by a parameter during expansion.

One alternative is to list no <dummy>s:

```
<name> MACRO
```

This type of macro block allows you to call the block repeatedly, even if you do not want or need to pass parameters to the block. In this case, the block will not contain any <dummy>s.

A macro block is not assembled when it is encountered. Rather, when you call a macro, the assembler "expands" the macro call statement by bringing in and assembling the appropriate macro block.

MACRO is an extremely powerful directive. With it, you can change the value and effect of any instruction mnemonic, directive, label, variable, or symbol. When Macro Assembler evaluates a statement, it first looks at the macro table it builds during pass 1. If it sees a name there that matches an entry in a statement, it acts accordingly. (Remember: Macro Assembler evaluates macros, then instruction mnemonics/directives.)

If you want to use the TITLE, SUBTTL, or NAME directives for the portion of your program where a macro block appears, you should be careful about the form of the statement. If, for example, you enter SUBTTL MACRO DEFINITIONS, Macro Assembler will assemble the statement as a macro definition with SUBTTL as the macro name and DEFINITIONS as the dummy. To avoid this problem, alter the word MACRO in some way; e.g., - MACRO, MACROS, and so on.

Calling a Macro

To use a macro, enter a macro call statement:

```
<name> [<parameter>,...]
```

<name> is the <name> of the macro block. A <parameter> replaces a <dummy> on a one-for-one basis. The number of parameters is limited only by the length of a line. If you enter more than one parameter, they must be separated by commas, spaces, or tabs. If you place angle brackets around parameters separated by commas, the assembler will pass all the items inside the angle brackets as a single parameter. For example:

```
FOO 1,2,3,4,5
```

passes five parameters to the macro, but

```
FOO <1,2,3,4,5>
```

passes only one.

The number of parameters in the macro call statement need not be the same as the number of <dummy>s in the MACRO definition. If there are more parameters than <dummy>s, the extras are ignored. If there are fewer, the extra <dummy>s will be made null. The assembled code will include the macro block after each macro call statement.

Example:

```
GEN     MACRO   XX,YY,ZZ
        MOV     AX,XX
        ADD     AX,YY
        MOV     ZZ,AX
        ENDM
```

If you then enter a macro call statement:

```
GEN     DUCK,DON,FOO
```

the assembler generates the statements:

```
        MOV     AX,DUCK
        ADD     AX,DON
        MOV     FOO,AX
```

On your program listing, these statements will be preceded by a plus sign (+) to indicate that they came from a macro block.

End Macro

ENDM

ENDM tells the assembler that the MACRO or Repeat block is ended.

Every MACRO, REPT, IRP, and IRPC must be terminated with the ENDM directive. Otherwise, the "Unterminated REPT/IRP/IRPC/MACRO" message is generated at the end of each pass. An unmatched ENDM also causes an error.

If you wish to be able to exit from a MACRO or repeat block before expansion is completed, use EXITM.

Exit Macro

EXITM

The EXITM directive is used inside a MACRO or Repeat block to terminate an expansion when some condition makes the remaining expansion unnecessary or undesirable. Usually EXITM is used in conjunction with a conditional directive.

When an EXITM is assembled, the expansion is exited immediately. Any remaining expansion or repetition is not generated. If the block containing the EXITM is nested within another block, the outer level continues to be expanded.

Example:

```
FOO     MACRO   X
X       =       0
        REPT    X
X       =       X+1
        IFE     X-0FFH  ;test X
        EXITM   ;if true, exit REPT
        ENDIF
        DB      X
        ENDM
        ENDM
```

LOCAL

LOCAL <dummy>[,<dummy>...]

The LOCAL directive is allowed only inside a macro definition block. A LOCAL statement must precede all other types of statements in the macro definition.

When LOCAL is executed, the assembler creates a unique symbol for each <dummy> and substitutes that symbol for each occurrence of the <dummy> in the expansion. These unique symbols are usually used to define a label within a macro, thus eliminating multiple-defined labels on successive expansions of the macro. The symbols created by the assembler range from ??0000 to ??FFFF. Users should avoid the form ??nnnn for their own symbols.

Example:

```
0000                FUN     SEGMENT
                            ASSUME CS:FUN,DS:FUN
                    FOO     MACRO    NUM,Y
                            LOCAL    A,B,C,D,E
                    A:      DB       7
                    B:      DB       8
                    C:      DB       Y
                    D:      DW       Y+1
                    E:      DW       NUM+1
                            JMP      A
                            ENDM
                            FOO      0C00H,0BEH
0000   07         + ??0000:          DB      7
0001   08         + ??0001:          DB      8
0002   BE         + ??0002:          DB      0BEH
0003   00BF       + ??0003:          DW      0BEH+1
0005   0C01       + ??0004:          DW      0C00H+1
0007   EB F7      +         JMP      ??0000
                            FOO      03C0H,0FFH
0009   07         + ??0005:          DB      7
000A   08         + ??0006:          DB      8
000B   FF         + ??0007:          DB      0FFH
000C   0100       + ??0008:          DW      0FFH+1
000E   03C1       + ??0009:          DW      03C0H+1
0010   EB F7      +         JMP      ??0005
0012                FUN     ENDS
                            END
```

Notice that Macro Assembler has substituted LABEL names in the form ??nnnn for the instances of the dummy symbols.

PURGE

PURGE <macro-name>[,...]

PURGE deletes the definition of the macro(s) listed after it.

PURGE provides three benefits:

1. It frees text space of the macro body.

2. It returns any instruction mnemonics or directives that were redefined by macros to their original function.

3. It allows you to "edit out" macros from a macro library file. You may find it useful to create a file that contains only macro definitions. This method allows you to use macros repeatedly with easy access to their definitions. Typically, you would then place an INCLUDE statement in your program file. Following the INCLUDE statement, you could place a PURGE statement to delete any macros you will not use in this program.

   It is not necessary to PURGE a macro before redefining it. Simply place another MACRO statement in your program, reusing the macro name.

Example:

```
INCLUDE MACRO.LIB
PURGE   MAC1
MAC1              ;tries to invoke purged macro
                  ;returns a syntax error
```

Repeat Directives

The directives in this group allow the operations in a block of code to be repeated for the number of times you specify. The major differences between the Repeat directives and MACRO directive are:

1. MACRO gives the block a name by which to call in the code wherever and whenever needed; the macro block can be used in many different programs by simply entering a macro call statement.

2. MACRO allows parameters to be passed to the macro block when a MACRO is called; hence, parameters can be changed.

Repeat directive parameters must be assigned as a part of the code block. If the parameters are known in advance and will not change, and if the repetition is to be performed for every program execution, then Repeat directives are convenient. With the MACRO directive, you must call in the MACRO each time it is needed.

Note that each Repeat directive must be matched with the ENDM directive to terminate the repeat block.

Repeat

```
REPT <exp>
  .
  .
  .
ENDM
```

Repeat block of statements between REPT and ENDM <exp> times. <exp> is evaluated as a 16-bit unsigned number. If <exp> contains an External symbol or undefined operands, an error is generated.

Example:

```
                X       =       0
                        REPT    10      ;generates
                                        ;DB 1 - DB
10
                X       =       X+1
                        DB      X
                        ENDM
```

assembles as:

```
0000            X       =       0
                        REPT    10      ;generates
                                        ;DB 1 - DB
10
                X       =       X+1
                        DB      X
                        ENDM
0000'   01      +       DB      X
0001'   02      +       DB      X
0002'   03      +       DB      X
0003'   04      +       DB      X
0004'   05      +       DB      X
0005'   06      +       DB      X
0006'   07      +       DB      X
0007'   08      +       DB      X
0008'   09      +       DB      X
0009'   0A      +       DB      X
                        END
```

Indefinite Repeat

```
IRP <dummy>,<parameters inside angle brackets>
 .
 .
 .
ENDM
```

Parameters must be enclosed in angle brackets. Parameters may be any legal symbol, string, numeric, or character constant. The block of statements is repeated for each parameter. Each repetition substitutes the next parameter for every occurrence of <dummy> in the block. If a parameter is null (i.e., <>), the block is processed once with a null parameter.

Example:

```
IRP     X,<1,2,3,4,5,6,7,8,9,10>
DB      X
ENDM
```

This example generates the same bytes (DB 1 to DB 10) as the REPT example.

When IRP is used inside a MACRO definition block, angle brackets around parameters in the macro call statement are removed before the parameters are passed to the macro block. An example, which generates the same code as above, illustrates the removal of one level of brackets from the parameters:

```
FOO     MACRO   X
        IRP     Y,<X>
        DB      Y
        ENDM
        ENDM
```

When the macro call statement

```
FOO <1,2,3,4,5,6,7,8,9,10>
```

is assembled, the macro expansion becomes:

```
IRP     Y,<1,2,3,4,5,6,7,8,9,10>
DB      Y
ENDM
```

The angle brackets around the parameters will be removed, and all items are passed as a single parameter.

Indefinite Repeat Character

```
IRPC <dummy>,<string>
  .
  .
  .
ENDM
```

The statements in the block are repeated once for each character in the string. Each repetition substitutes the next character in the string for every occurrence of <dummy> in the block.

Example:

```
IRPC    X,0123456789
DB      X+1
ENDM
```

This example generates the same code (DB 1 to DB 10) as the two previous examples.

Special Macro Operators

Several special operators can be used in a macro block to select additional assembly functions.

& Ampersand concatenates text or symbols. (The ampersand may not be used in a macro call statement.) A dummy parameter in a quoted string will not be substituted in expansion unless preceded immediately by an ampersand. To form a symbol from text and a dummy, put an ampersand between them.

For example:

```
ERRGEN  MACRO   X
ERROR&X:        PUSH    BX
        MOV     BX,'&X'
        JMP     ERROR
        ENDM
```

The call ERRGEN A will then generate:

```
ERRORA: PUSH    B
        MOV     BX,'A'
        JMP     ERROR
```

In Macro Assembler, the ampersand will not appear in the expansion. One ampersand is removed each time a dummy& or &dummy is found. For complex macros, where nesting is involved, extra ampersands may be needed. You need to supply as many ampersands as there are levels of nesting.

For example:

Correct form			Incorrect form		
FOO	MACRO	X	FOO	MACRO	X
	IRP	Z,<1,2,3>		IRP	Z,<1,2,3>
X&&Z	DB	Z	X&Z	DB	Z
	ENDM			ENDM	
	ENDM			ENDM	

When called, for example, by FOO BAZ, the expansion would be (correctly in the left column, incorrectly in the right):

1. MACRO build, find <dummy>s and change to dl

```
         IRP      Z,<1,2,3>          IRP      Z,<1,2,3>
dl&Z DB        Z  dlZ    DB   Z
         ENDM                   ENDM
```

2. MACRO expansion, substitute parameter text for dl

```
         IRP      Z,<1,2,3>         IRP      Z,<1,2,3>
BAZ&Z   DB       ZBAZZ     DB   Z
         ENDM                   ENDM
```

3. IRP build, find dummys and change to dl

```
BAZ&dl        DB        dl     BAZZ     DB       dl
```

4. IRP expansion, substitute parameter text for dl

```
BAZ1     DB       1        BAZZ     DB       1
BAZ2     DB       2        BAZZ     DB       2<-+
BAZ3     DB       3        BAZZ     DB       3  |
                           +--------------------+
                           +-|;here it's an error,
                             |;multi-defined symbol
```

<text> Angle brackets cause Macro Assembler to treat the text between the angle brackets as a single literal. Placing parameters to a macro call inside angle brackets; or placing the list of parameters following the IRP directive inside angle brackets causes two results:

1. All text within the angle brackets is seen as a single parameter, even if commas are used.

2. Characters that have special functions are taken as literal characters. For example, the semicolon inside angle brackets <;> becomes a character, not the indicator that a comment follows.

One set of angle brackets is removed each time the parameter is used in a macro. When using nested macros, you will need to supply as many sets of angle brackets around parameters as there are levels of nesting.

;; In a macro or repeat block, a comment preceded by two semicolons is not saved as a part of the expansion.

The default listing condition for macros is .XALL (see Section 4.2.4, "Listing Directives," below). Under the influence of .XALL, comments in macro blocks are not listed because they do not generate code.

If you decide to place the .LALL listing directive in your program, then comments inside macro and repeat blocks are saved and listed. This can be the cause of an "out of memory error." To avoid this error, place double semicolons before comments inside macro and repeat blocks, unless you specifically want a comment to be retained.

! An exclamation point may be entered in an argument to indicate that the next character is to be taken literally. Therefore, !; is equivalent to <;>.

% The percent sign is used only in a macro argument to convert the expression that follows it (usually a symbol) to a number in the current radix. During macro expansion, the number derived from converting the expression is substituted for the dummy. Using the % special operator allows a macro call by value. (Usually, a macro call is a call by reference, with the text of the macro argument substituting exactly for the dummy.)

The expression following the % must evaluate to an absolute (non-relocatable) constant.

Example:

```
PRINTE  MACRO   MSG,N
        %OUT    * MSG,N *
        ENDM
SYM1    EQU     100
SYM2    EQU     200
        PRINTE  <SYM1 + SYM2 = >,%(SYM1 + SYM2)
```

Normally, the macro call statement would cause the string (SYM1 + SYM2) to be substituted for the dummy N. The result would be:

```
        %OUT    * SYM1 + SYM2 = (SYM1 + SYM2) *
```

When the % is placed in front of the parameter, the assembler generates:

```
        %OUT    * SYM1 + SYM2 = 300 *
```

4.2.4 Listing Directives

Listing directives perform two general functions: format control and listing control. Format control directives allow the programmer to insert page breaks and direct page headings. Listing directives turn on and off the listing of all or part of the assembled file.

<u>PAGE</u>

PAGE [<length>][,<width>]
PAGE [+]

PAGE with no arguments or with the optional [,+] argument causes the assembler to start a new output page. The assembler puts a form feed character in the listing file at the end of the page.

The PAGE directive with either the length or width arguments does not start a new listing page.

The value of <length>, if included, becomes the new page length (measured in lines per page) and must be in the range 10 to 255. The default page length is 50 lines per page.

The value of <width>, if included, becomes the new page width (measured in characters) and must be in the range 60 to 132. The default page width is 80 characters.

The plus sign (+) increments the major page number and resets the minor page number to one. Page numbers are in the form major-minor. The PAGE directive without the + increments only the minor portion of the page number.

Example:

```
  .
  .
  .
PAGE +    ;increment major,set minor to 1
  .
  .
  .
PAGE 58,60     ;page length=58 lines,
               ;width=60 characters
```

TITLE

TITLE <text>

TITLE specifies a title to be listed on the first line of each page. The <text> may be up to 60 characters long. If more than one TITLE is given, an error results. The first six characters of the title, if legal, are used as the module name, unless a NAME directive is used.

Example:

```
TITLE PROG1 -- 1st Program
  .
  .
  .
```

If the NAME directive is not used, the module name is now PROG1--1st Program. This title text will appear at the top of every page of the listing.

SUBTITLE

SUBTTL <text>

SUBTTL specifies a subtitle to be listed in each page heading on the line after the title. The <text> is truncated after 60 characters.

Any number of SUBTTLs may be given in a program. Each time the assembler encounters SUBTTL, it replaces the <text> from the previous SUBTTL with the <text> from the most recently encountered SUBTTL. To turn off SUBTTL for part of the output, enter a SUBTTL with a null string for <text>.

Example:

```
SUBTTL SPECIAL I/O ROUTINE
  .
  .
  .
SUBTTL
  .
  .
  .
```

The first SUBTTL causes the subtitle SPECIAL I/O ROUTINE to be printed at the top of every page. The second SUBTTL turns off subtitle (the subtitle line on the listing is left blank).

%OUT

%OUT <text>

. The text is listed on the terminal during assembly. %OUT is useful for displaying progress through a long assembly or for displaying the value of conditional assembly switches.

%OUT will output on both passes. If only one printout is desired, use the IF1 or IF2 directive, depending on which pass you want displayed. See Section 4.2.2, "Conditional Directives," for descriptions of the IF1 and IF2 directives.

Example:

```
%OUT *Assembly half done*
```

The assembler will send this message to the terminal screen when encountered.

```
IF1
%OUT *Pass 1 started*
ENDIF

IF2
%OUT *Pass 2 started*
ENDIF
```

.LIST
.XLIST

.LIST lists all lines with their code (the default condition).

.XLIST suppresses all listing.

If you specify a listing file following the Listing: prompt, a listing file with all the source statements included will be printed.

When .XLIST is encountered in the source file, source and object code will not be listed. .XLIST remains in effect until a .LIST is encountered.

.XLIST overrides all other listing directives. Nothing will be listed, even if another listing directive (other than .LIST) is encountered.

Example:

```
  .
  .
  .
.XLIST    ;listing suspended here
  .
  .
  .
.LIST     ;listing resumes here
```

.SFCOND

.SFCOND suppresses portions of the listing that contain conditional false expressions.

.LFCOND

.LFCOND assures the listing of conditional expressions that evaluate false. This is the default condition.

.TFCOND

.TFCOND toggles the current setting. .TFCOND operates independently from .LFCOND and .SFCOND. .TFCOND toggles the default setting, which is set by the presence or absence of the /X switch when the assembler is running. When /X is used, .TFCOND will cause false conditionals to list. When /X is not used, .TFCOND will suppress false conditionals.

.XALL

.XALL is the default.

.XALL lists source code and object code produced by a macro, but source lines which do not generate code are not listed.

.LALL

.LALL lists the complete macro text for all expansions, including lines that do not generate code. Comments preceded by two semicolons (;;) will not be listed.

.SALL

.SALL suppresses listing of all text and object code produced by macros.

.CREF
.XCREF

.CREF
.XCREF [<variable list>]

.CREF is the default condition. .CREF remains in effect until Macro Assembler encounters .XCREF.

.XCREF without arguments turns off the .CREF (default) directive. .XCREF remains in effect until Macro Assembler encounters .CREF. Use .XCREF to suppress the creation of cross-references in selected portions of the file. Use .CREF to restart the creation of a cross-reference file after using the .XCREF directive.

If you include one or more variables following .XCREF, these variables will not be placed in the listing or cross-reference file. All other cross-referencing, however, is not affected by an .XCREF directive with arguments. Separate the variables with commas.

Neither .CREF nor .XCREF without arguments takes effect unless you specify a cross-reference file when running the assembler. .XCREF <variable list> suppresses the variables from the symbol table listing regardless of the creation of a cross-reference file.

Example:

```
.XCREF CURSOR,FOO,GOO,BAZ,ZOO
       ;these variables will not be
       ;in the listing or cross-reference file
```

Contents

CHAPTER 5

ASSEMBLING A MACRO ASSEMBLER SOURCE FILE

Assembling a program with Macro Assembler requires two types of commands: a command to start Macro Assembler, and answers to command prompts. In addition, four switches control alternate Macro Assembler features. Usually, you will type all the commands to Macro Assembler on the terminal keyboard. As an option, answers to the command prompts and any switches may be contained in response (batch) file. Two command characters are provided to assist you while entering assembler commands. These command characters are described in Section 5.2, "Command Characters."

5.1 HOW TO START MACRO ASSEMBLER

Macro Assembler may be started in two ways. By the first method, you type the commands in response to individual prompts. By the second method, you type all commands on the line used to start Macro Assembler.

Summary of Methods to Start Macro Assembler

Method 1	MASM
Method 2	MASM <source>,<object>,<listing>, <cross-ref>[/switch...]

5.1.1 Method 1: Prompts

Type:

```
MASM
```

Macro Assembler will be loaded into memory. Then, Macro Assembler returns a series of four text prompts that appear one at a time. You answer the prompts as commands to Macro Assembler to perform specific tasks.

At the end of each line, you may specify one or more switches, each of which must be preceded by a forward slash (/).

The command prompts are summarized here and described in more detail in Section 5.3, "Macro Assembler Command Prompts."

Summary of Command Prompts

PROMPT	RESPONSES
Source filename [.ASM]:	List .ASM file to be assembled. (There is no default: a filename response is required.)
Object filename [source.OBJ	List filename for relocatable object code. (The default is source-filename.OBJ)
Source listing [NUL.LST]:	List filename for listing. (The default is no listing file.)
Cross reference [NUL.CRF]:	List filename for cross-reference file (used with MS-CREF to create a cross-reference listing). (The default is no cross-reference file.)

5.1.2 Method 2: Command Line

Type:

MASM <source>,<object>,<listing>,<cross-ref>[/switch...]

Macro Assembler will be loaded into memory. Then Macro Assembler immediately begins assembly. The entries following MASM are responses to the command prompts. The entry fields for the different prompts must be separated by commas.

where: source is the source filename

object is the name of the file to receive the relocatable output

listing is the name of the file to receive the listing

cross-ref is the name of the file to receive the cross-reference output

/switch are optional switches, which may be placed following any of the response entries (just before any of the commas or after the the <cross-ref>, as shown).

To select the default for a field, simply enter a second comma without space in between (see the example below).

Example:

```
MASM FUN,,FUN/D/X,FUN
```

This example causes Macro Assembler to be loaded, then causes the source file FUN.ASM to be assembled. Macro Assembler then outputs the relocatable object code to a file named FUN.OBJ (default caused by two commas in a row), creates a listing file named FUN.LST for both assembly passes but with false conditionals suppressed, and creates a cross-reference file named FUN.CRF. If names were not listed for listing and cross-reference, these files would not be created. If listing file switches are given but no filename, the switches are ignored.

5.2 MACRO ASSEMBLER COMMAND CHARACTERS

Macro Assembler provides two command characters.

Semicolon — Use a single semicolon (;), followed immediately by a carriage return, at any time after responding to the first prompt (from Source filename: on) to select default responses to the remaining prompts. This feature saves time and eliminates the need to enter a series of carriage returns.

NOTE

Once the semicolon has been entered, you can no longer respond to any of the prompts for that assembly. Therefore, do not use the semicolon to skip over some prompts. For this, use the <RETURN> key.

Example:

```
Source filename [.ASM]:  FUN
Object filename [FUN.OBJ]:  ;
```

The remaining prompts will not appear, and Macro Assembler will use the default values (including no listing file and no cross-reference file).

To achieve the same result, you could type:

```
Source filename [.ASM]:  FUN ;
```

This response produces the same files as the previous example.

CONTROL-C — Use <CONTROL-C> at any time to abort the assembly. If you enter an erroneous response, such as the wrong filename or an incorrectly spelled filename, you must press <CONTROL-C> to exit Macro Assembler. You can then restart Macro Assembler. If the error has been typed and not entered, you may delete the erroneous characters, but for that line only.

5.3 MACRO ASSEMBLER COMMAND PROMPTS

Macro Assembler is commanded by entering responses to four text prompts. When you have typed a response to the current prompt, the next appears. When the last prompt has been answered, Macro Assembler begins assembly automatically without further command. When assembly is finished, Macro Assembler exits to the operating system. When the operating system prompt is displayed, Macro Assembler has finished successfully. If the assembly is unsuccessful, Macro Assembler displays the appropriate error message.

Macro Assembler prompts you for the names of source, object, listing, and cross-reference files.

All command prompts accept a file specification as a response. You may type:

A filename only

A device designation only

A filename and an extension

A device designation and filename, or

A device designation, filename, and extension.

Do not type only a filename extension.

The following is a discussion of the command prompts that are displayed when you start Macro Assembler with Method 1:

<u>Source filename [.ASM]:</u>

Type the filename of your source program. Macro Assembler assumes by default that the filename extension is .ASM, as shown in square brackets in the prompt text. If your source program has any other filename extension, you must specify it along with the filename. Otherwise, the extension may be omitted.

<u>Object filename [source.OBJ]:</u>

Type the filename you want to receive the generated object code. If you simply press the carriage return key when this prompt appears, the object file will be given the same name as the source file, but with the filename extension .OBJ. If you want your object file to have a different name or a different filename extension, you must type your choice in response to this prompt. If you want to change only the filename but keep the .OBJ extension, type the filename only. To change the extension only, you must type both the filename and the extension.

Source listing [NUL.LST]:

Type the name of the file you want to receive the source listing. If you press the carriage return key, Macro Assembler does not produce this listing file. If you type a filename only, the listing is created and placed in a file with the name you type plus the filename extension .LST. You may also type your own extension.

The source listing file will contain a list of all the statements in your source program and will show the code and offsets generated for each statement. The listing will also show any error messages generated during the session.

Cross reference [NUL.CRF]:

Type the name of the file you want to receive the cross-reference file. If you press only the <RETURN> key, Macro Assembler does not produce this cross-reference file. If you type a filename only, the cross-reference file is created and placed in a file with the name you type plus the filename extension .CRF. You may also type your own extension.

The cross-reference file is used as the source file for the Microsoft CREF Cross-Reference Utility (MS-CREF). MS-CREF converts this cross-reference file into a cross-reference listing, which you can use to aid you during program debugging.

The cross-reference file contains a series of control symbols that identify records in the file. MS-CREF uses these control symbols to create a listing that shows all occurrences of every symbol in your program. The occurrence that defines the symbol is also identified.

5.4 MACRO ASSEMBLER COMMAND SWITCHES

The three Macro Assembler switches control assembler functions. Switches must be typed at the end of a prompt response, regardless of which method is used to start Macro Assembler. Switches may be grouped at the end of any one of the responses, or may be scattered at the end of several. If more than one switch is typed at the end of one response, each switch must be preceded by a forward slash (/). Do not specify only a switch as a response to a command prompt.

Switch	Function
/D	Produces a source listing on both assembler passes. The listings will, when compared, show where in the program phase errors occur and will, possibly, give you a clue to why the errors occur. The /D switch does not take effect unless you command Macro Assembler to create a source listing (type a filename in response to the Source listing: command prompt).
/O	Outputs the listing file in octal radix. The generated code and the offsets shown on the listing will all be given in octal. The actual code in the object file will be the same as if the /O switch were not given. The /O switch affects only the listing file.
/X	Suppresses the listing of false conditionals. If your program contains conditional blocks, the listing file will show the source statements, but no code if the condition evaluates false. To avoid the clutter of conditional blocks that do not generate code, use the /X switch to suppress the blocks that evaluate false from your listing. The /X switch does not affect any block of code in your file that is controlled by either the .SFCOND or .LFCOND directives.

If your source program contains the .TFCOND directive, the /X switch has the opposite effect. That is, normally the .TFCOND directive causes listing or suppressing of blocks of code that it controls. The first .TFCOND directive suppresses false conditionals, the second restores listing of false conditionals, and so on. When you use the /X switch, false conditionals are already suppressed. When Macro Assembler encounters the first .TFCOND directive, listing of false conditionals is restored. When the second .TFCOND is encountered (and the /X switch is used), false conditionals are again suppressed from the listing.

Of course, the /X switch has no effect if no listing is created. See additional discussion under the .TFCOND directive in Section 4.2.4, "Listing Directives."

The following chart illustrates the various effects of the conditional listing directives in combination with the /X switch.

Pseudo-op	No /X	/X
(none)	ON	OFF
.	.	.
.	.	.
.	.	.
.SFCOND	OFF	OFF
.	.	.
.	.	.
.	.	.
.LFCOND	ON	ON
.	.	.
.	.	.
.	.	.
.TFCOND	OFF	ON
.	.	.
.	.	.
.	.	.
.TFCOND	ON	OFF
.	.	.
.	.	.
.	.	.
.SFCOND	OFF	OFF
.	.	.
.	.	.
.	.	.
.TFCOND	OFF	ON
.TFCOND	ON	OFF
.	.	.
.	.	.
.	.	.
.TFCOND	OFF	ON

Summary of Command Switches

SWITCH	ACTION
/D	Produce a listing on both assembler passes.
/O	Show generated object code and offsets in octal radix on listing.
/X	Suppress the listing of false conditionals. Also used with the .TFCOND directive.

5.5 FORMATS OF LISTINGS AND SYMBOL TABLES

The source listing produced by Macro Assembler (created when you specify a filename in response to the Source listing: prompt) is divided into two parts.

The first part of the listing shows:

The line number for each line of the source file, if a cross-reference file is also being created.

The offset of each source line that generates code.

The code generated by each source line.

A plus sign (+), if the code came from a macro, or a letter C, if the code came from an INCLUDE file.

The source statement line.

The second part of the listing shows:

Macros--name and length in bytes

Structures and records--name, width and fields

Segments and groups--name, size, align, combine, and class

Symbols--name, type, value, and attributes

The number of warning errors and severe errors

5.5.1 Program Listing

The program portion of the listing is essentially your source program file with the line numbers, offsets, generated code, and (where applicable) a plus sign to indicate that the source statements are part of a macro block, or a letter C to indicate that the source statements are from a file input by the INCLUDE directive.

If any errors occur during assembly, the error message will be printed directly below the statement where the error occurred.

Part of a listing file follows this discussion, with notes explaining what the various entries represent.

The comments have been moved down one line because of format restrictions. If you print your listing on 132 column-paper, the comments shown here will easily fit on the same line as the rest of the statement.

Explanatory notes are spliced into the listing at points of special interest.

Summary of Listing Symbols

R = Linker resolves entry to left of R

E = External

---- = Segment name, group name, or segment variable used in MOV AX,<---->, DD <---->, JMP <---->, and so on.

= = Statement has an EQU or = directive

nn: = Statement contains a segment override

nn/ = REPxx or LOCK prefix instruction. Example:

```
003C  F3/ A5     REP  MOVSW ;move DS:SI to ES:DI
                            ;until CX=0
```

[xx] = DUP expression;xx is the value in parentheses following DUP; for example: DUP(?) places ?? where xx is shown here

\+ = Line comes from a macro expansion

C = Line comes from file named in INCLUDE directive statement

```
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EXTX  PASCAL entry for initializing programs


0000            STACK        SEGMENT WORD STACK  'STACK'
= 0000          HEAPbeg      EQU<-    THIS BYTE
^-----Indicates EQU or = directive
                                      ;Base of heap before init
0000      14 [               DB       20 DUP (?)<-
               ??<-Shows value in parentheses
               ]
                Indicates DUP expression
= 0014         SKTOP         EQU      THIS BYTE
0014           STACK         ENDS

0000           MAINSTARTUP SEGMENT  'MEMORY'
               DGROUP        GROUP  DATA,STACK<CONST,HEAP,MEMORY
                             ASSUME CS:MAINSTARTUP,DS:DGROUP,
                                    ES:DGROUP,SS:DGROUP

                             PUBLIC BEGXQQ ;Main entry


0000           BEGXQQ        PROC   FAR
0000    B8 ---- R            MOV    AX,DGROUP
                                    ;Get data segment value
0003    8E D8                MOV    DS,AX ;Set DS seg

0005    8C 06 0022 R         MOV    CESXQQ,ES

          Generated     Name       Action    Expression    Comment
Offset
                                                   .
                                                   .
                                                   .
000C    26: 8B 1E 0002       MOV      BX,ES:2   ;Highest
                                                   ;paragraph
        |_________________Segment override_|
```

```
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ENTX PASCAL entry for initializing programs

0011   2B D8              SUB     BX,AX    ;Get # paras for DS
0013   81 FB 1000         CMP     BX,4096 ;More than 64K?
0017   7E 03              JLE     SMLSTK   ;No, use what we have
0019   BB 1000            MOV     BX,4096 ;Can only address 64k

001C                SMLSTK: +> REPT     4
                          SHL     BX,1
                              ;Convert para to offset
                          ENDM

001C   D1 E3              SHL     BX,1
                              ;Convert para to offset
001E   D1 E3              SHL     BX,1
                              ;Convert para to offset
0020   D1 E3              SHL     BX,1
                              ;Convert para to offset
0022   D1 E3              SHL     BX,1
                              ;Convert para to offset

 macro     these lines    macro              number of
 block     from macro     directive          repetitions

0024   8B E3    MOV     SP,BX
                ;Set stack to top of memory
                 .
                 .
                               .
0069   EA 0000         R     JMP      FAR PTR STARTmain

                signal to linker      segment variable

        linker resolves: indicates segment name, group name,
        or segment variable used in MOV AX,<---->;
        DD <---->; JMP <---->,etc.  (See other
        examples in this listing.)

006E      BEGXQQ          ENDP

                           .
                           .
                           .
007E      MAIN_STARTUP    ENDS

0000      ENTXCM          SEGMENT WORD 'CODE'
                 ASSUME   CS:ENTXCM
                 PUBLIC   ENDXQQ,DOSXQQ
```

```
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ENTX    PASCAL entry for initializing programs

0000         STARTmain      PROC    FAR ;This code remains
0000   9A 0000 ---- E               CALL    ENTGQQ
                            ;call main program
             ;
0005         ENDXQQ         LABEL   FAR
                              ;termination entry point
0005   9A 0000 ---- E               CALL    ENDOQQ
                              ;user system termination
000A   9A 0000 ---- E               CALL    ENDYQQ
                              ;close all open files
000F   9A 0000 ---- E               CALL    ENDUQQ
                                            ;file system
                                            ;termination

0014  C7 06 0020 R 0000                        MOV     DOSOFF,0
```
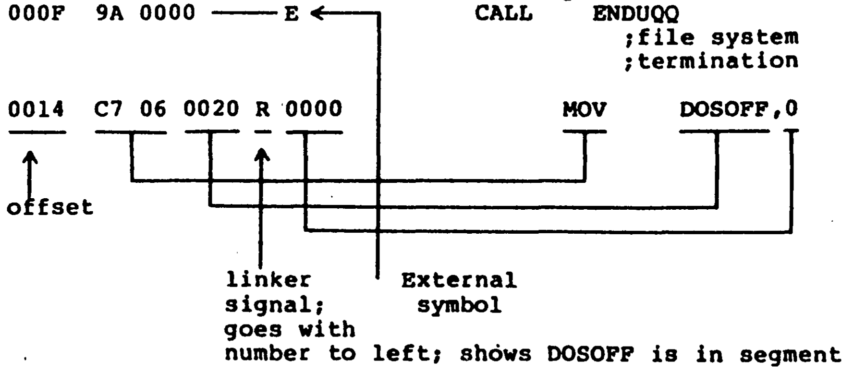




```
00 2E 0020 R             JMP     DWORD PTR DOSOFF
                                 ;return to DOS
001E       STARTmain     ENDP

                         .
                         .
                         .
0037       ENTXCM        ENDS

                 END     BEGXQQ
```

5.5.2 Differences Between Pass 1 And Pass 2 Listings

If you specify the /D switch when you run Macro Assembler to assemble your file, the assembler produces a listing for both passes. The option is especially helpful for finding the source of phase errors.

The following example was taken from a source file that assembled without reporting any errors. When the source file was reassembled using the /D switch, an error was produced on pass 1, but not on pass 2 (which is when errors are usually reported).

Example:

During Pass 1 a jump with a forward reference produces:

```
0017  7E 00              JLE     SMLSTK  ;No, use what we have
 E r r o r   ---         9:Symbol not defined
0019  BB 1000            MOV     BX,4096 ;Can only address 64k
001C     SMLSTK: REPT    4
```

During Pass 2 this same instruction is fixed up and does not return an error.

```
0017  7E 03              JLE     SMLSTK  ;No, use what we have
0019  BB 1000            MOV     BX,4096 ;Can only address 64k
001C     SMLSTK: REPT    4
```

Notice that the JLE instruction's code now contains 03 instead of 00; this is a jump of 3 bytes.

The same amount of code was produced during both passes, so there was no phase error. The only difference in this case is one of content instead of size,

5.5.3 Symbol Table Format

The symbol table portion of a listing separates all "symbols" into their respective categories, showing appropriate descriptive data. This data gives you an idea how your program is using various symbolic values. and is useful when you debug.

Also, you can use a cross-reference listing, produced by MS-CREF, to help you locate uses of the various "symbols" in your program.

On the next page is a complete symbol table listing. Following the complete listing, sections from different symbol tables are shown with explanatory notes.

For all sections of symbol tables, this rule applies: if there are no symbolic values in your program for a particular category, the heading for the category will be omitted from the symbol table listing. For example, if you use no macros in your program, you will not see a macro section in the symbol table.

```
Microsoft Macro Assembler MACRO
Assembler     date      PAGE   Symbols-1
CALLER - SAMPLE ASSEMBLER ROUTINE (EXMP1M.ASM)


Macros:

        Name                Length

BIOSCALL . . . . . . .      0002
DISPLAY. . . . . . . .      0005
DOSCALL. . . . . . . .      0002
KEYBOARD . . . . . . .      0003
LOCATE . . . . . . . .      0003
SCROLL . . . . . . . .      0004


Structures and records:

        Name                Width   # fields
                            Shift   Width   Mask    Initial

PARMLIST . . . . . . .      001C    0004
  BUFSIZE. . . . . . .      0000
  NAMESIZE . . . . . .      0001
  NAMETEXT . . . . . .      0002
  TERMINATOR . . . . .      001B


Segments and groups:

        Name                Size    align   combine class

CSEG . . . . . . . . .      0044    PARA    PUBLIC  'CODE'
STACK. . . . . . . . .      0200    PARA    STACK   'STACK'
WORKAREA . . . . . . .      0031    PARA    PUBLIC  'DATA'


Symbols:

        Name                Type    Value   Attr

CLS. . . . . . . . . .      N PROC  0036    CSEG    Length =000E
MAXCHAR. . . . . . . .      Number  0019
MESSG. . . . . . . . .      L BYTE  001C    WORKAREA
PARMS. . . . . . . . .      L 001C  0000    WORKAREA
RECEIVR. . . . . . . .      L FAR   0000            External
START. . . . . . . . .      F PROC  0000    CSEG    Length =0036


Warning Severe
Errors  Errors
0       0
```

Macros:

```
        Name              Length  <---number of 32-byte blocks
                                      macro occupies in memory
BIOSCALL . . . . . .      0002
DISPLAY. . . . . . .      0005
DOSCALL. . . . . . .      0002
KEYBOARD . . . . . .      0003
LOCATE . . . . . . .      0003
SCROLL . . . . . . .      0004

   ^
   |
names of macros
```

This section of the symbol table tells you the names of your macros and how big they are in 32-byte block units. In this listing, the macro DISPLAY is 5 blocks long or (5 X 32 bytes =) 160 bytes long.

Structures and records:

Example for Structures

```
                 Name         Width  # fields <-- *
                              Shift  Width  Mask  Initial <--**

PARMLIST . . . . . .          001C|-\0004
  |BUFSIZE. . . . . .         0000|
 -|NAMESIZE . . . . .         0001|
| |NAMETEXT . . . . .         0002|
| |TERMINATOR . . . .         001B|                          ***
|
 --field names of            Offset of field
   PARMLIST Structure         into structure
                                            The number of bytes
                                              wide of Structure
```

Example for Records

```
        Name                  Width    # fields
                              Shift    Width  Mask Initial  <-- *


BAZ. . . . . . . . . .      ->0008     0003<--number of fields
                                              in Record
  FLD1 . . . . . . . .        0006|    0002|  00C0   0040
  FLD2 . . . . . . . .        0003|    0003|  0038   0000<--initial
                                                            value
  FLD3 . . . . . . . .        0000|    0003|  0007   0003
BAZ1 . . . . . . . . .      ->000B|    0002          \--MASK of field
  BZ1. . . . . . . . .        0003|    0008   07F8   0400 maximum
                                                          value
  BZ2. . . . . . . . .        0000|    0003   0007   0002

            number of        shift     number of
         bits in Record      count     bits in field
                           to right
```

* This line applies to Structure Names (begin in column 1).
** This line for fields of Records (indented).
***Number of fields in Structure.

This section lists your Structures and/or Records and their fields. The upper line of column headings applies to Structure names, Record names, and field names of Structures. The lower line of column headings applies to field names of Records.

For Structures:

Width (upper line) shows the number of bytes your Structure occupies in memory.

fields shows how many fields comprise your Structure.

For Records:

Width (upper line) shows the number of bits the Record occupies.

fields shows how many fields comprise your Record.

For Fields of Structures:

Shift shows the number of bytes the fields are offset into the Structure.

The other columns are not used for fields of Structures.

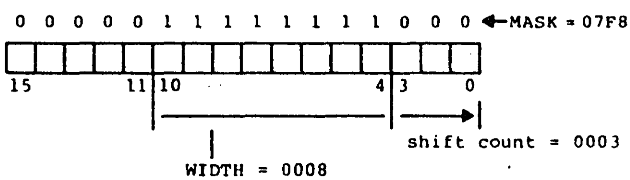
For Fields of Records:

Shift is the shift count to the right.

Width (lower line) shows the number of bits this field occupies.

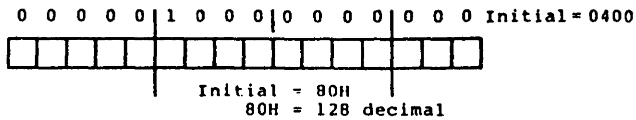
Mask shows the maximum value of the record, expressed in hexadecimal, if one field is masked and ANDed (the field is set to all 1's and all other fields are set to all 0's).

Using field BZ1 of the Record BAZ1 above to illustrate:



Initial shows the value specified as the initial value for the field, if any.

> When naming the field, you specified:
>
> fieldname:# = value
>
> Fieldname is the name of the field
>
> # is the width of the field in bits
>
> Value is the initial value you want this field to hold. The symbol table shows this value as if it is placed in the field and all other fields are masked (equal 0). Using the example and diagram from above:



Segments and groups:

```
        Name                Size    align   combine class
                                          /---called Private
                                         / in MS-LINK manual
AAAXQQ . . . .        0000    WORD    NONE    'CODE'<--segment
DGROUP. . . . .       GROUP <-------------------------group
  DATA . . . .        0024    WORD    PUBLIC  'DATA'    |
  STACK. . . .        0014    WORD    STACK   'STACK'   |segments
  CONST. . . .        0000    WORD    PUBLIC  'CONST'   | of
  HEAP . . . .        0000    WORD    PUBLIC  'MEMORY'  |  DGROUP
  MEMORY . . .        0000    WORD    PUBLIC  'MEMORY'  |
ENTXCM . . . .        0037    WORD    NONE    'CODE'
MAIN_STARTUP .        007E    PARA    NONE    'MEMORY'
          ----        -----------------------
                      length   statement line entries
                        of
                      segment
```

For Groups:

The name of the group will appear under the Name column, beginning in column 1 with the applicable Segment names indented 2 spaces. The word Group will appear under the Size column.

For Segments:

The segment names may appear in column 1 (as here) if you do not declare them part of a group. If you declare a group, the segment names will appear indented under their group name.

For all Segments, whether a part of a group or not:

Size is the number of bytes the Segment occupies.

Align is the type of boundary where the segment begins:

```
    PAGE = page - address is xxx00H (low byte = 0);
    begins on a 256-byte boundary
        PARA = paragraph - address is xxxx0H
                (low nibble = 0);  default

        WORD = word - address is xxxxeH
                (e = even number;
                low bit of low byte = 0)
            bit map - |x|x|x|x|x|x|x|0|

        BYTE = byte - address is xxxxxH (anywhere)
```

Combine describes how the Microsoft LINK Linker Utility will combine the various segments. (See the Microsoft LINK Linker Utility Manual for a full description.)

Class is the class name under which MS-LINK will combine segments in memory. (See MS-LINK Linker Utility Manual and Chapter 9 of the MS-DOS User's Guide for a full description.)

Symbols:

```
            Name      Type      Value     Attr

FOO. . . . . .        Number    0005         |
FOO1 . . . . .        Text      1.234        |
FOO2 . . . . .        Number    0008         |  all formed by
FOO3 . . . . .        Alias     FOO          |  EQU or =
FOO4 . . . . .        Text      5[BP][DI]    |  directive
FOO5 . . . . .        Opcode                 |
```

Symbols:

```
            Name Type      Value Attr

BEGHQQ . . . . L WORD   0012  DATA       Global
BEGOQQ . . . . L FAR    0000       External
BEGXQQ . . . . F PROC   0000  MAIN_STARTUP Global Length=006E
CESXQQ . . . . L WORD   0022  DATA       Global          ┌──────────
CLNEQQ . . . . L WORD   0002  DATA       Global          └length
CRCXQQ . . . . L WORD   001C  DATA       Global            of PROC
CRDXQQ . . . . L WORD   001E  DATA       Global
CSXFQQ . . . . L WORD   0000  DATA       Global
CURHQQ . . . . L WORD   0014  DATA       Global
DOSOFF . . . . L WORD   0020  DATA
DOSXQQ . . . . F PROC   001E  ENTXCM     Global Length =0019
ENDHQQ . . . . L WORD   0016  DATA       Global
ENDOQQ . . . . L FAR    0000             External
ENDUQQ . . . . L FAR    0000             External
ENDXQQ . . . . L FAR    0005  ENTXCM     Global
ENDYQQ . . . . L FAR    0000             External
ENTGQQ . . . . L FAR    0000             External
FREXQQ . . . . F PROC   006E  MAIN_STARTUP Global Length=0010
HDRFQQ . . . . L WORD   0006  DATA       Global
HDRVQQ . . . . L WORD   0008  DATA       Global
HEAPBEG. . . . BYTE     0000  STACK  <───┬EQU statements
HEAPLOW. . . . BYTE     0000  HEAP  <────┘showing segment
INIUQQ . . . . L FAR    0000             External |
PNUXQQ . . . . L WORD   0004  DATA       Global   |
RECEQQ . . . . L WORD   0010  DATA       Global   |
REFEQQ . . . . L WORD   000C  DATA       Global   |
REPEQQ . . . . L WORD   000E  DATA       Global  /
RESEQQ . . . . L WORD   000A  DATA       Global /
SKTOP. . . . . BYTE     0014  STACK  <─────────┘
SMLSTK . . . . L NEAR   001C  MAIN_STARTUP
STARTMAIN. . . F PROC   0000  ENTXCM Length=001E
STKBQQ . . . . L WORD   0018  DATA      Global
STKHQQ . . . . L WORD   001A  DATA       Global
       ┌──────────────
       └If Macro Assembler knows this length as one of the
        type lengths (BYTE, WORD, DWORD, QWORD,
        TBYTE), it shows that type name here.
```

This section lists all other symbolic values in your program that do not fit under the other categories.

Type shows the symbol's type:

```
L = Label
F = Far
N = Near
PROC = Procedure
Number |
Alias  |-----all defined by EQU or = directive
Text   |
Opcode |
```

These entries may be combined to form the various types shown in the example.

For all procedures, the length of the procedure is given after its attribute (segment).

You may also see an entry under Type like:

L 0031

This entry results from code such as the following:

BAZ LABEL FOO

where FOO is a STRUC that is 31 bytes long.

BAZ will be shown in the symbol table with the L 0031 entry. Basically, Number (and some other similar entries) indicates that the symbol was defined by an EQU or = directive.

Value (usually) shows the numeric value the symbol represents. (In some cases, the Value column will show some text -- when the symbol was defined by EQU or = directive.)

Attr always shows the segment of the symbol, if known. Otherwise, the Attr column is blank. Following the segment name, the table will show either External, Global, or a blank (which means not declared with either the EXTRN or PUBLIC directive). The last entry applies to PROC types only. This is a length = entry, which is the length of the procedure.

If Type is Number, Opcode, Alias, or Text, the Symbols section of the listing will be structured differently. Whenever you see one of these four entries under Type, the symbol was created by an EQU directive or an = directive. All information that follows one of these entries is considered its "value," even if the "value" is simple text.

Each of the four types shows a value as follows:

Number shows a constant numeric value.

Opcode shows a blank. The symbol is an alias for an instruction mnemonic.

Sample directive statement: FOO EQU ADD

Alias shows a symbol name which the named symbol equals.

Sample directive statement: FOO EQU BAX

Text shows the "text" the symbol represents. "Text" is any other operand to an EQU directive that does not fit one of the other three categories above.

Sample directive statements:

```
GOO EQU 'WOW'
BAZ EQU DS:8[BX]
ZOO EQU 1.234
```

Contents

CHAPTER 6

8087 SUPPORT

Macro Assembler supports standard Intel 8087 instructions and operands. A list of the instructions and opcodes can be found in Appendix C of this manual.

6.1 SWITCHES

There are two switches that are used when running Macro Assembler with an 8087. These switches are /R (for Real) and /E (for Emulate). The /R and /E switches are described below.

Switch	Function
/R	Use the /R switch when the code being produced by Macro Assembler is going to be run on a real 8087 machine (not an emulated machine). Code produced with the /R switch will only run on real 8087 machines.
/E	Use the /E switch when the code being produced by Macro Assembler is going to be run on an emulated 8087 machine. Code produced with the /E switch will also run on real 8087 machines with the appropriate emulator library.

The emulator library is provided with some MS-DOS language products. It contains specific 8087 emulation routines. Refer to your language compiler user's guide for information on the emulator library that has been provided. If your code is going to run on an emulated 8087 machine, you must specify the appropriate emulator library when you link your code with MS-LINK. If the library is not specified, MS-LINK will return errors for those unresolved symbols that are defined in the emulator library.

Contents

CHAPTER 7

MACRO ASSEMBLER MESSAGES

Most of the messages output by Macro Assembler are error messages. The nonerror messages output by Macro Assembler are the banner Macro Assembler displays when first started, the command prompt messages, and the end of (successful) assembly message. These nonerror messages are classified here as operating messages. The error messages are classified as assembler errors, I/O handler errors, and runtime errors.

7.1 OPERATING MESSAGES

Banner Message and Command Prompts:

```
Macro Assembler v2.0 Copyright (C) Microsoft, Inc.

Source filename [.ASM]:
Object filename [source.OBJ]:
Source listing [NUL.LST]:
Cross reference [NUL.CRF]:
```

End of Assembly Message:

```
Warning   Fatal
Errors    Errors
n         n         (n=number of errors)
```

(your disk operating system's prompt)

7.2 ERROR MESSAGES

If the assembler encounters errors, error messages are output, along with the numbers of warning and fatal errors, and control is returned to your disk operating system. The message is output either to your terminal screen or to the listing file if you command one be created.

Error messages are divided into three categories: assembler errors, I/O handler errors, and runtime errors. In each category, messages are listed in alphabetical order with a short explanation where necessary. At the end of this chapter, the error messages are listed in a single numerical order list but without explanations.

Assembler Errors

Already defined locally (Code 23)

> Tried to define a symbol as EXTERNAL that had already been defined locally.

Already had ELSE clause (Code 7)

> Attempt to define an ELSE clause within an existing ELSE clause (you cannot nest ELSE without nesting IF...ENDIF).

Already have base register (Code 46)

> Trying to double base register.

Already have index register (Code 47)

> Trying to double index address

Block nesting error (Code 0)

> Nested procedures, segments, structures, macros, IRC, IRP, or REPT are not properly terminated. An example of this error is close of an outer level of nesting with inner level(s) still open.

Byte register is illegal (Code 58)

Use of one of the byte registers in context where it is illegal. For example, PUSH AL.

Can't override ES segment (Code 67)

Trying to override the ES segment in an instruction where this override is not legal. For example, store string.

Can't reach with segment reg (Code 68)

There is no ASSUME that makes the variable reachable.

Can't use EVEN on BYTE segment (Code 70)

Segment was declared to be byte segment and attempt to use EVEN was made.

Circular chain of EQU aliases (Code 83)

An alias EQU eventually points to itself.

Constant was expected (Code 42)

Expecting a constant and received something else.

CS register illegal usage (Code 59)

Trying to use the CS register illegally. For example, XCHG CS,AX.

Directive illegal in STRUC (Code 78)

All statements within STRUC blocks must either be comments preceded by a semicolon (;), or one of the Define directives.

Division by 0 or overflow (Code 29)

An expression is given that results in a divide by 0.

DUP is too large for linker (Code 74)

Nesting of DUP's was such that too large a record was created for the linker.

8087 opcode can't be emulated (Code 84)

Either the 8087 opcode or the operands you used with it produce an instruction that the emulator cannot support.

Extra characters on line (Code 1)

This occurs when sufficient information to define the instruction directive has been received on a line and superfluous characters beyond are received.

Field cannot be overridden (Code 80)

In a STRUC initialization statement, you tried to give a value to a field that cannot be overridden.

Forward needs override (Code 71)

This message is not currently used.

Forward reference is illegal (Code 17)

Attempt to forward reference something that must be defined in pass 1.

Illegal register value (Code 55)

The register value specified does not fit into the "reg" field (the reg field is greater than 7).

Illegal size for item (Code 57)

Size of referenced item is illegal. For example, shift of a double word.

Illegal use of external (Code 32)

Use of an external in some illegal manner. For example, DB M DUP(?) where M is declared external.

Illegal use of register (Code 49)

Use of a register with an instruction where there is no 8086 or 8088 instruction possible.

Illegal value for DUP count (Code 72)

DUP counts must be a constant that is not 0 or negative.

Improper operand type (Code 52)

Use of an operand such that the opcode cannot be generated.

Improper use of segment reg (Code 61)

Specification of a segment register where this is illegal. For example, an immediate move to a segment register.

Index displ. must be constant (Code 54)

Illegal use of index display.

Label can't have seg. override (Code 65)

Illegal use of segment override.

Left operand must have segment (Code 38)

Used something in right operand that required a segment in the left operand. (For example, ":.")

More values than defined with (Code 76)

Too many fields given in REC or STRUC allocation.

Must be associated with code (Code 45)

Use of data related item where code item was expected.

Must be associated with data (Code 44)

Use of code related item where data related item was exected. For example, MOV AX,<code-label>.

Must be AX or AL (Code 60)

Specification of some register other than AX or AL where only these are acceptable. For example, the IN instruction.

Must be index or base register (Code 48)

Instruction requires a base or index register and some other register was specified in square brackets, [ ].

Must be declared in pass 1 (Code 13)

Assembler expecting a constant value but got something else. An example of this might be a vector size being a forward reference.

Must be in segment block (Code 69)

Attempt to generate code when not in a segment.

Must be record field name (Code 33)

Expecting a record field name but got something else.

Must be record or field name (Code 34)

Expecting a record name or field name and received something else.

Must be register (Code 18)

Register unexpected as operand but you furnished a symbol -- was not a register.

Must be segment or group (Code 20)

Expecting segment or group and something else was specified.

Must be structure field name (Code 37)

Expecting a structure field name but received something else.

Must be symbol type (Code 22)

Must be WORD, DW, QW, BYTE, or TB but received something else.

Must be var, label or constant (Code 36)

Expecting a variable, label, or constant but received something else.

Must have opcode after prefix (Code 66)

Use of one of the prefix instructions without specifying any opcode after it.

Near JMP/CALL to different CS (Code 64)

Attempt to do a NEAR jump or call to a location in a different CS ASSUME.

No immediate mode (Code 56)

Immediate mode specified or an opcode that cannot accept the immediate. For example, PUSH.

No or unreachable CS (Code 62)

Trying to jump to a label that is unreachable.

Normal type operand expected (Code 41)

Received STRUCT, FIELDS, NAMES, BYTE, WORD, or DW when expecting a variable label.

Not in conditional block (Code 8)

An ENDIF or ELSE is specified without a previous conditional assembly directive active.

Not proper align/combine type (Code 25)

SEGMENT parameters are incorrect.

One operand must be const (Code 39)

This is an illegal use of the addition operator.

Only initialize list legal (Code 77)

Attempt to use STRUC name without angle brackets, < >.

Operand combination illegal (Code 63)

Specification of a two-operand instrucion where the combination specified is illegal.

Operands must be same or 1 abs (Code 40)

Illegal use of the subtraction operator.

Operand must have segment (Code 43)

Illegal use of SEG directive.

Operand must have size (Code 35)

Expected operand to have a size, but it did not.

Operand not in IP segment (Code 51)

Access of operand is impossible because it is not in the current IP segment.

Operand types must match (Code 31)

Assembler gets different kinds or sizes of arguments in a case where they must match. For example, MOV.

Operand was expected (Code 27)

Assembler is expecting an operand but an operator was received.

Operator was expected (Code 28)

Assembler was expecting an operator but an operand was received.

Override is of wrong type (Code 81)

In a STRUC initialization statement, you tried to use the wrong size on override. For example, 'HELLO' for DW field.

Override with DUP is illegal (Code 79)

In a STRUC initialization statement, you tried to use DUP in an override.

Phase error between passes (Code 6)

The program has ambiguous instruction directives such that the location of a label in the program changed in value between pass 1 and pass 2 of the assembler. An example of this is a forward reference coded without a segment override where one is required. There would be an additional byte (the code segment override) generated in pass 2 causing the next label to change. You can use the /D switch to produce a listing to aid in resolving phase errors between passes (see Section 5.4, "Macro Assembler Command Switches").

Redefinition of symbol (Code 4)

This error occurs on pass 2 and succeeding definitions of a symbol.

Reference to mult defined (Code 26)

The instruction references something that has been multi-defined.

Register already defined (Code 2)

This will only occur if the assembler has internal logic errors.

Register can't be forward ref (Code 82)

Relative jump out of range (Code 53)

Relative jumps must be within the range -128 +127 of the current instruction, and the specific jump is beyond this range.

Segment parameters are changed (Code 24)

List of arguments to SEGMENT were not identical to the first time this segment was used.

Shift count is negative (Code 30)

A shift expression is generated that results in a negative shift count.

Should have been group name (Code 12)

Expecting a group name but something other than this was given.

Symbol already different kind (Code 15)

Attempt to define a symbol differently from a previous definition.

Symbol already external (Code 73)

Attempt to define a symbol as local that is already external.

Symbol has no segment (Code 21)

Trying to use a variable with SEG, and the variable has no known segment.

Symbol is multi-defined (Code 5)

This error occurs on a symbol that is later redefined.

Symbol is reserved word (Code 16)

Attempt to use an assembler reserved word illegally. (For example, to declare MOV as a variable.)

Symbol not defined (Code 9)

A symbol is used that has no definition.

Symbol type usage illegal (Code 14)

Illegal use of a PUBLIC symbol.

Syntax error (Code 10)

The syntax of the statement does not match any recognizable syntax.

Type illegal in context (Code 11)

The type specified is of an unacceptable size.

Unknown symbol type (Code 3)

Symbol statement has something in the type field that is unrecognizable.

Usage of ? (indeterminate) bad (Code 75)

Improper use of the "?". For example, ?+5.

Value is out of range (Code 50)

Value is too large for expected use. For example, MOV AL,5000.

Wrong type of register (Code 19)

Directive or instruction expected one type of register, but another was specified. For example, INC CS.

I/O Handler Errors

These error messages are generated by the I/O handlers. These messages appear in a different format from the Assembler Errors:

```
MASM Error -- error-message-text
  in:  filename
```

The _filename_ is the name of the file being handled when the error occurred.

The _error-message-text_ is one of the following messages:

Data format (Code 114)

Device full (Code 108)

Device name (Code 102)

Device offline (Code 105)

File in use (Code 112)

File name (Code 107)

File not found (Code 110)

File not open (Code 113)

File system (Code 104)

Hard data (Code 101)

Line too long (Code 115)

Lost file (Code 106)

Operation (Code 103)

Protected file (Code 111)

Unknown device (Code 109)

Runtime Errors

These messages may be displayed as your assembled program is being executed.

Internal Error

Usually caused by an arithmetic check. If it occurs, notify Microsoft Corporation.

Out of Memory

This message has no corresponding number. Either the source was too big or too many labels are in the symbol table.

Numerical Order List of Error Messages

Code	Message
0	Block nesting error
1	Extra characters on line
2	Register already defined
3	Unknown symbol type
4	Redefinition of symbol
5	Symbol is multi-defined
6	Phase error between passes
7	Already had ELSE clause
8	Not in conditional block
9	Symbol not defined
10	Syntax error
11	Type illegal in context
12	Should have been group name
13	Must be declared in pass 1
14	Symbol type usage illegal
15	Symbol already different kind
16	Symbol is reserved word
17	Forward reference is illegal
18	Must be register
19	Wrong type of register
20	Must be segment or group
21	Symbol has no segment
22	Must be symbol type
23	Already defined locally
24	Segment parameters are changed
25	Not proper align/combine type
26	Reference to mult defined
27	Operand was expected
28	Operator was expected
29	Division by 0 or overflow
30	Shift count is negative
31	Operand types must match
32	Illegal use of external
33	Must be record field name
34	Must be record or field name
35	Operand must have size
36	Must be var, label or constant
37	Must be structure field name
38	Left operand must have segment
39	One operand must be const
40	Operands must be same or 1 abs
41	Normal type operand expected
42	Constant was expected
43	Operand must have segment
44	Must be associated with data
45	Must be associated with code
46	Already have base register
47	Already have index register
48	Must be index or base register
49	Illegal use of register
50	Value is out of range

51 Operand not in IP segment
52 Improper operand type
53 Relative jump out of range
54 Index displ. must be constant
55 Illegal register value
56 No immediate mode
57 Illegal size for item
58 Byte register is illegal
59 CS register illegal usage
60 Must be AX or AL
61 Improper use of segment reg
62 No or unreachable CS
63 Operand combination illegal
64 Near JMP/CALL to different CS
65 Label can't have seg. override
66 Must have opcode after prefix
67 Can't override ES segment
68 Can't reach with segment reg
69 Must be in segment block
70 Can't use EVEN on BYTE segment
71 Forward needs override
72 Illegal value for DUP count
73 Symbol already external
74 DUP is too large for linker
75 Usage of ? (indeterminate) bad (Code 75)
76 More values than defined with
77 Only initialize list legal
78 Directive illegal in STRUC
79 Override with DUP is illegal
80 Field cannot be overridden
81 Override is of wrong type
82 Register can't be forward ref
83 Circular chain of EQU aliases
84 8087 opcode can't be emulated

101 Hard data
102 Device name
103 Operation
104 File system
105 Device offline
106 Lost file
107 File name
108 Device full
109 Unknown device
110 File not found
111 Protected file
112 File in use
113 File not open
114 Data format
115 Line too long

Contents

APPENDIX A

ASCII CHARACTER CODES

Dec	Hex	CHR	Dec	Hex	CHR
000	00H	NUL	033	21H	!
001	01H	SOH	034	22H	"
002	02H	STX	035	23H	#
003	03H	ETX	036	24H	$
004	04H	EOT	037	25H	%
005	05H	ENQ	038	26H	&
006	06H	ACK	039	27H	'
007	07H	BEL	040	28H	(
008	08H	BS	041	29H	)
009	09H	HT	042	2AH	*
010	0AH	LF	043	2BH	+
011	0BH	VT	044	2CH	,
012	0CH	FF	045	2DH	-
013	0DH	CR	046	2EH	.
014	0EH	SO	047	2FH	/
015	0FH	SI	048	30H	0
016	10H	DLE	049	31H	1
017	11H	DC1	050	32H	2
018	12H	DC2	051	33H	3
019	13H	DC3	052	34H	4
020	14H	DC4	053	35H	5
021	15H	NAK	054	36H	6
022	16H	SYN	055	37H	7
023	17H	ETB	056	38H	8
024	18H	CAN	057	39H	9
025	19H	EM	058	3AH	:
026	1AH	SUB	059	3BH	;
027	1BH	ESCAPE	060	3CH	<
028	1CH	FS	061	3DH	=
029	1DH	GS	062	3EH	>
030	1EH	RS	063	3FH	?
031	1FH	US	064	40H	@
032	20H	SPACE			

Dec=decimal, Hex=hexadecimal (H), CHR=character.
LF=Line Feed, FF=Form Feed, CR=Carriage Return, DEL=Rubout

ASCII CHARACTER CODES

Dec	Hex	CHR	Dec	Hex	CHR
065	41H	A	097	61H	a
066	42H	B	098	62H	b
067	43H	C	099	63H	c
068	44H	D	100	64H	d
069	45H	E	101	65H	e
070	46H	F	102	66H	f
071	47H	G	103	67H	g
072	48H	H	104	68H	h
073	49H	I	105	69H	i
074	4AH	J	106	6AH	j
075	4BH	K	107	6BH	k
076	4CH	L	108	6CH	l
077	4DH	M	109	6DH	m
078	4EH	N	110	6EH	n
079	4FH	O	111	6FH	o
080	50H	P	112	70H	p
081	51H	Q	113	71H	q
082	52H	R	114	72H	r
083	53H	S	115	73H	s
084	54H	T	116	74H	t
085	55H	U	117	75H	u
086	56H	V	118	76H	v
087	57H	W	119	77H	w
088	58H	X	120	78H	x
089	59H	Y	121	79H	y
090	5AH	Z	122	7AH	z
091	5BH	[	123	7BH	{
092	5CH	\	124	7CH	|
093	5DH	]	125	7DH	}
094	5EH	^	126	7EH	~
095	5FH	_	128	7FH	DEL
096	60H	`			

Dec=decimal, Hex=hexadecimal (H), CHR=character.
LF=Line Feed, FF=Form Feed, CR=Carriage Return, DEL=Rubout

APPENDIX B

TABLE OF MACRO ASSEMBLER DIRECTIVES

B.1 MEMORY DIRECTIVES

```
                  ASSUME <seg-reg>:<seg-name>[,<seg-reg>:
                          <seg-name>...]
                  ASSUME NOTHING
                  COMMENT <delim><text><delim>

           <name> DB <exp>
           <name> DD <exp>
           <name> DQ <exp>
           <name> DT <exp>
           <name> DW <exp>

                  END [<exp>]
           <name> EQU <exp>
           <name> = <exp>
                  EXTRN <name>:<type>[,<name>:<type>...]
                  PUBLIC <name>[,<name>...]
           <name> LABEL <type>
                  NAME <module-name>

           <name> PROC [NEAR]
           <name> PROC [FAR]
                    |
      <proc-name> ENDP

                  .RADIX <exp>
           <name> RECORD <field>:<width>[=<exp>][,...]

           <name> GROUP <segment-name>[,...]
           <name> SEGMENT [<align>][<combine>][<class>]
                    |
       <seg-name> ENDS
                  EVEN
                  ORG <exp>

           <name> STRUC
                    |
     <struc-name> ENDS
```

B.2 MACRO DIRECTIVES

```
         ENDM
         EXITM
         IRP <dummy>,<parameters in angle brackets>
         IRPC <dummy>,string
         LOCAL <parameter>[,<parameter>...]
  <name> MACRO <parameter>[,<parameter>...]
         PURGE <macro-name>[,...]
         REPT <exp>

         Special Macro Operators
         & (ampersand) - concantenation
         <text> (angle brackets - single literal)
         ;; (double semicolons) - suppress comment
         ! (exclamation point) - next character literal
         % (percent sign) - convert expression to number
```

B.3 CONDITIONAL DIRECTIVES

```
ELSE
IF <exp>
IFB <arg>
IFDEF <symbol>
IFDIF <arg1>,<arg2>
IFE <exp>
IFIDN <arg1>,<arg2>
IFNB <arg>
IFNDEF <symbol>
IF1
IF2
```

B.4 LISTING DIRECTIVES

```
.CREF
.LALL
.LFCOND
.LIST
%OUT <text>
PAGE <exp>
.SALL
.SFCOND
SUBTTL <text>
.TFCOND
TITLE <text>
.XALL
.XCREF
.XLIST
```

B.5 ATTRIBUTE OPERATORS

Override operators

```
Pointer (PTR)
    <attribute>   PTR   <expression>
Segment Override (:) (colon)
    <segment-register>:<address-expression>
    <segment-name>:<address-expression>
    <group-name>:<address-expression>
SHORT
    SHORT <label>
THIS
    THIS <distance>
    THIS <type>
```

Value Returning Operators

```
SEG
    SEG <label>
    SEG <variable>
OFFSET
    OFFSET <label>
    OFFSET <variable>
TYPE
    TYPE <label>
    TYPE <variable>
.TYPE
    .TYPE <variable>
LENGTH
    LENGTH <variable>
SIZE
    SIZE <variable>
```

Record Specific operators

```
Shift-count  - (Record fieldname)
    <record-fieldname>
MASK
    MASK <record-fieldname>
WIDTH
    WIDTH <record-fieldname>
    WIDTH <record>
```

B.6 PRECEDENCE OF OPERATORS

All operators in a single item have the same precedence, regardless of the order listed within the item. Spacing and line breaks are used for visual clarity, not to indicate functional relations.

1. LENGTH, SIZE, WIDTH, MASK
   Entries inside: parenthesis ( )
   angle brackets < >
   square brackets [ ]
   structure variable operand: <variable>.<field>

2. segment override operator: colon (:)

3. PTR, OFFSET, SEG, TYPE, THIS

4. HIGH, LOW

5. *, /, MOD, SHL, SHR

6. +, - (both unary and binary)

7. EQ, NE, LT, LE, GT, GE

8. Logical NOT

9. Logical AND

10. Logical OR, XOR

11. SHORT,.TYPE

APPENDIX C

TABLE OF 8086 AND 8087 INSTRUCTIONS

Macro Assembler supports both the 8086 and 8087 mnemonics. The mnemonics are listed alphabetically with their full names. The 8086 instructions are also listed in groups based on the type of arguments the instruction takes.

C.1 8086 INSTRUCTION MNEMONICS, ALPHABETICAL

Mnemonic	Full Name
AAA	ASCII adjust for addition
AAD	ASCII adjust for division
AAM	ASCII adjust for multiplication
AAS	ASCII adjust for subtraction
ADC	Add with carry
ADD	Add
AND	AND
CALL	CALL
CBW	Convert byte to word
CLC	Clear carry flag
CLD	Clear direction flag
CLI	Clear interrupt flag
CMC	Complement carry flag
CMP	Compare
CMPS	Compare byte or word (of string)
CMPSB	Compare byte string
CMPSW	Compare word string
CWD	Convert word to double word
DAA	Decimal adjust for addition
DAS	Decimal adjust for subtraction
DEC	Decrement
DIV	Divide
ESC	Escape
HLT	Halt
IDIV	Integer divide
IMUL	Integer multiply
IN	Input byte or word
INC	Increment
INT	Interrupt
INTO	Interrupt on overflow

IRET	Interrupt return
JA	Jump on above
JAE	Jump on above or equal
JB	Jump on below
JBE	Jump on below or equal
JC	Jump on carry
JCXZ	Jump on CX zero
JE	Jump on equal
JG	Jump on greater
JGE	Jump on greater or equal
JL	Jump on less than
JLE	Jump on less than or equal
JMP	Jump
JNA	Jump on not above
JNAE	Jump on not above or equal
JNB	Jump on not below
JNBE	Jump on not below or equal
JNC	Jump on no carry
JNE	Jump on not equal
JNG	Jump on not greater
JNGE	Jump on not greater or equal
JNL	Jump on not less than
JNLE	Jump on not less than or equal
JNO	Jump on not overflow
JNP	Jump on not parity
JNS	Jump on not sign
JNZ	Jump on not zero
JO	Jump on overflow
JP	Jump on parity
JPE	Jump on parity even
JPO	Jump on parity odd
JS	Jump on sign
JZ	Jump on zero
LAHF	Load AH with flags
LDS	Load pointer into DS
LEA	Load effective address
LES	Load pointer into ES
LOCK	LOCK bus
LODS	Load byte or word (of string)
LODSB	Load byte (string)
LODSW	Load word (string)
LOOP	LOOP
LOOPE	LOOP while equal
LOOPNE	LOOP while not equal
LOOPNZ	LOOP while not zero
LOOPZ	LOOP while zero
MOV	Move
MOVS	Move byte or word (of string)
MOVBS	Move byte (string)
MOVSW	Move word (string)
MUL	Multiply
NEG	Negate
NOP	No operation
NOT	NOT
OR	OR

OUT	Output byte or word
POP	POP
POPF	POP flags
PUSH	PUSH
PUSHF	PUSH flags
RCL	Rotate through carry left
RCR	Rotate through carry right
REP	Repeat
RET	Return
ROL	Rotate left
ROR	Rotate right
SAHF	Store AH into flags
SAL	Shift arithmetic left
SAR	Shift arithmetic right
SBB	Subtract with borrow
SCAS	Scan byte or word (of string)
SCASB	Scan byte (string)
SCASW	Scan word (string)
SHL	Shift left
SHR	Shift right
STC	Set carry flag
STD	Set direction flag
STI	Set interrupt flag
STOS	Store byte or word (of string)
STOSB	Store byte (string)
STOSW	Store word (string)
SUB	Subtract
TEST	TEST
WAIT	WAIT
XCHG	Exchange
XLAT	Translate
XOR	Exclusive OR

C.2 8087 INSTRUCTION MNEMONICS, ALPHABETICAL

Mnemonic	Full Name
F2XM1	Calculate 2X-1
FABS	Take absolute value of top of stack
FADD	Add real
FADDP	Add real and pop stack
FBLD	Load packed decimal onto top of stack
FBSTP	Store packed decimal and pop stack
FCHS	Change sign on the top stack element
FCLEX	Clear exceptions after WAIT
FCOM	Compare real
FCOMP	Compare real and pop stack
FCOMPP	Compare real and pop stack twice
FDECSTP	Decrement stack pointer
FDISI	Disable interrupts after WAIT
FDIV	Divide real
FDIVP	Divide real and Pop stack
FDIVR	Reversed real divide
FDIVRP	Reversed real divide and pop stack twice
FENI	Enable interrupts after WAIT
FFREE	Free stack element
FIADD	Add integer
FICOM	Integer compare
FICOMP	Integer compare and pop stack
FIDIV	Integer divide
FIDIVR	Reversed integer divide
FILD	Load integer onto top of stack
FIMUL	Integer multiply
FINCSTP	Increment stack pointer
FINIT	Initialize processor after WAIT
FIST	Store integer
FISTP	Store integer and pop stack
FISUB	Integer subtract
FISUBR	Reversed integer subtract
FLD	Load real onto top of stack
FLD1	Load +1.0 onto top of stack
FLDCW	Load control word
FLDENV	Load 8087 environment
FLDL2E	Load log 2 e onto top of stack
FLDL2T	Load log 2 10 onto top of stack
FLDLG2	Load log 10 2 onto top of stack
FLDLN2	Load log e 2 onto top of stack
FLDPI	Load pi onto top of stack
FLDZ	Load +0.0 onto top of stack

FMUL	Multiply real
FMULP	Multiply real and pop stack
FNCLEX	Clear exceptions with no WAIT
FNDISI	Disable interrupts with no WAIT
FNENI	Enable interrupts with no WAIT
FNINIT	Initialize processor, with no WAIT
FNOP	No operation
FNSAVE	Save 8087 state with no WAIT
FNSTCW	Store control word without WAIT
FNSTENV	Store 8087 environment with no WAIT
FNSTSW	Store 8087 status word with on WAIT
FPATAN	Partial arctangent function
FPREM	Partial remainder
FPTAN	Partial tangent function
FRNDINT	Round to integer
FRSTOR	Restore state
FSAVE	Save 8087 state after WAIT
FSCALE	Scale
FSQRT	Square root
FST	Store real
FSTCW	Store control word with WAIT
FSTENV	Store 8087 environment after WAIT
FSTP	Store real and pop stack
FSTSW	Store 8087 status word after WAIT
FSUB	Subtract real
FSUBP	Subtract real and pop stack
FSUBR	Reversed real subtract
FSUBRP	Reversed real subtract and pop stack
FTST	Test top of stack
FWAIT	Wait for last 8087 operation to complete
FXAM	Examine top of stack element
FXCH	Exchange contents of stack element and stack top
FXTRACT	Extract exponent and significand from number in top of stack
FYL2X	Calculate Y:log 2 X
FYL2PI	Calculate Y:log 2 (x+1)

C.3 8086 INSTRUCTION MNEMONICS BY ARGUMENT TYPE

In this section, the instructions are grouped according to the type of argument(s) they take. In each group the instructions are listed alphabetically in the first column. The formats of the instructions with the valid argument types are shown in the second column. If a format shows OP, that format is legal for all the instructions shown in that group. If a format is specific to one mnemonic, the mnemonic is shown in the format instead of OP.

The following abbreviations are used in these lists:

OP = opcode; instruction mnemonic

reg = byte register (AL,AH,BL,BH,CL,CH,DL,DH)
or word register (AX,BX,CX,DX,SI,DI,BP,SP)

r/m = register or memory address or indexed and/or based

accum = AX or AL register

immed = immediate

mem = memory operand

segreg = segment register (CS,DS,SS,ES)

<u>General 2 operand instructions</u>

Mnemonics	Argument Types
ADC	OP reg,r/m
ADD	OP r/m,reg
AND	OP accum,immed
CMP	OP r/m,immed
OR	
SBB	
SUB	
TEST	
XOR	

In addition, add to the arguments a sign extent for word immediate.

<u>CALL and JUMP type instructions</u>

Mnemonics	Argument Types
CALL	OP mem {NEAR}{FAR} direction
JMP	OP r/m (indirect data -- DWORD, WORD)

Relative jumps

Argument Type

OP addr (+129 or -126 of IP at start, or ±127 at end of jump instruction)

Mnemonics

JA	JC	JZ	JNGE	JNP
JNBE	JNAE	JG	JLE	JPO
JAE	JBE	JNLE	JNG	JNS
JNB	JNA	JGE	JNE	JO
JNC	JCXZ	JNL	JNZ	JP
JB	JE	JL	JNO	JPE
				JS

Loop instructions : same as Relative jumps

LOOP LOOPE LOOPZ LOOPNE LOOPNZ

Return instruction

Mnemonic Argument Type

RET [immed] (optional, number of words to POP)

No operand instructions

Mnemonics

AAA	CLD	DAA	LODSB	PUSHF	STI
AAD	CLI	DAS	LODSW	SAHF	STOSB
AAM	CMC	HLT	MOVSB	SCASB	STOSW
AAS	CMPSB	INTO	MOVSW	SCASW	WAIT
CBW	CMPSW	IRET	NOP	STC	XLATB
CLC	CWD	LAHF	POPF	STD	

Load instructions

Mnemonics Argument Type

LDS OP r/m (except that OP reg is illegal)
LEA
LES

Move instructions

Mnemonic	Argument Types
MOV	OP mem,accum
	OP accum,mem
	OP segreg,r/m
	(except CS is illegal)
	OP r/m,segreg
	OP r/m,reg
	OP reg,r/m
	OP reg,immed
	OP r/m,immed

Push and pop instructions

Mnemonics	Argument Types
PUSH	OP word-reg
POP	OP segreg
	(POP CS is illegal)
	OP r/m

Shift/rotate type instructions

Mnemonics	Argument Types
RCL	OP r/m,1
RCR	OP r/m,CL
ROL	
ROR	
SAL	
SHL	
SAR	
SHR	

Input/output instructions

Mnemonics	Argument Types
IN	IN accum,byte-immed
	(immed = port 0-255)
	IN accum,DX
OUT	OUT immed,accum
	OUT DX,accum

<u>Increment/decrement instructions</u>

Mnemonics	Argument Types
INC	OP word-reg
DEC	OP r/m

<u>Arith. multiply/division/negate/not</u>

Mnemonics	Argument Type
DIV	OP r/m (implies AX OP
IDIV	r/m, except NEG)
MUL	
IMUL	
NEG	(NEG implies AX OP NOP)
NOT	

<u>Interrupt instruction</u>

Mnemonic	Argument Types
INT	INT 3 (value 3 is one-byte instruction) INT byte-immed

<u>Exchange instruction</u>

Mnemonic	Argument Types
XCHG	XCHG accum,reg XCHG reg,accum XCHG reg,r/m XCHG r/m,reg

Miscellaneous instructions

Mnemonics	Argument Types
XLAT	XLAT byte-mem (only checks argument, not in opcode)
ESC	ESC 6-bit-number,r/m

String primitives

These instructions have bits to record only their operand(s), if they are byte or word, and if a segment override is involved.

Mnemonics	Argument Types
CMPS	CMPS byte-word,byte-word (CMPS right operand is ES)
LODS	LODS byte/word,byte/word (LODS one argument = no ES)
MOVS	MOVS byte/word,byte/word (MOVS left operand is ES)
SCAS	SCAS byte/word,byte/word (SCAS one argument = ES)
STOS	STOS byte/word,byte/word (STOS one argument = ES)

Repeat prefix to string instructions

Mnemonics

LOCK
REP
REPE
REPZ
REPNE
REPNZ

C.4 8087 INSTRUCTION MNEMONICS BY ARGUMENT TYPE

No operands

F2XM1	FABS	FCHS	FCLEX	FCOMPP	FDECSTP
FDISI	FENI	FINCSTP	FINIT	FLD1	FLD2E
FLD2T	FLDLG2	FLDLN2	FLDPI	FLDZ	FNCLEX
FNDISI	FNENI	FNINIT	FNOP	FPATAN	FPREM
FPTAN	FRNDINT	FSCALE	FSQRT	FTST	FXAM
FXTRACT	FYL2X	FYL2XP1	FWAIT		

2-Argument Floating Arithmatic

Mnemonics	Argument Types
FADD	Blank
FDIV	mem 4,8 bytes
FDIVR	ST,ST(i)
FMUL	ST(i),ST
FSUB	
FSUBR	

Stack only floating point arithmatic

Mnemonics	Argument Types
FADDP	ST(i)
FDIVP	ST
FDIVRP	
FMULP	
FSUBP	
FSUBRP	

Compare and store using stack

Mnemonics	Argument Types
FCOM	ST
FCOMP	ST(i)
FST	blank

Stack

Mnemonics	Argument Types
FFREE	ST(i)
FXCH	blank

Integer arithmatic

Mnemonics	Argument Types
FIADD	mem 2,4 bytes
FICOM	
FICOMP	
FIDIV	
FIDIVR	
FIMUL	
FIST	
FISUB	
FISUBR	

Floating point load/store memory

Mnemonics	Argument Types
FLD FSTP	mem 4,8, or 10 bytes

Integer load/store memory

Mnemonics	Argument Types
FILD FISTP	mem 2,4, or 8 bytes

Load/store control or status

Mnemonics	Argument Types
FLDCW FNSTCW FNSTSW FSTCW FSTSW	mem 2 bytes

Save/Restore 8087 environment

Mnemonics	Argument Types
FLDENV FNSTENV FSTENV	mem 14 bytes

94-byte memory (8087 Save/Restore entire state)

Mnemonics	Argument Types
FNSAVE FRSTOR FSAVE	mem 94 bytes

BCD load/store

Mnemonics	Argument Types
FBLD FBSTP	mem 10 bytes

INDEX

Microsoft® Link

Linker Utility

for 8086 and 8088 Microprocessors

Microsoft Corporation

System Requirements

The Microsoft LIB Library Manager requires:

38K bytes of memory minimum:
28K bytes for code
10K bytes for run space

Disk drive(s):
One disk drive if and only if output is sent to the same physical disk from which the input was taken. The Microsoft LIB Library Manager does not allow time to swap disks during operation on a one-drive configuration. Therefore, two disk drives is a more practical configuration.

Contents

CHAPTER 1

INTRODUCTION

The Microsoft Linker Utility (MS-LINK) is a relocatable linker designed to link separately produced modules of 8086 object code. The input to MS-LINK is a subset of the Intel object module format standard.

MS-LINK prompts you for all MS-LINK commands. Your answers to these prompts are the commands for MS-LINK.

The output file from MS-LINK (a Run file) is not bound to specific memory addresses and, therefore, can be loaded and executed at any convenient address by the operating system.

MS-LINK uses a dictionary-indexed library search method, which substantially reduces link time for sessions involving library searches.

MS-LINK is able to link files totaling 1 megabyte.

NOTE

This manual describes some of the technical information about MS-LINK. It is recommended that this manual be read in conjunction with Chapter 9, "The Linker Program (MS-LINK)," in the MS-DOS User's Guide.

1.1 OVERVIEW OF MS-LINK OPERATION

MS-LINK performs the following steps to combine object modules and produce a Run file:

1. Reads segments in object modules
2. Assigns addresses to segments
3. Assigns public symbol addresses
4. Reads data in segments
5. Reads all relocation references in object modules
6. Resolves references and determines relocation information
7. Outputs a Run file (executable image) and relocation information

As it combines modules, MS-LINK can search multiple library files for definitions of any external references left unresolved.

MS-LINK also produces a List file that shows external references resolved and any error messages.

MS-LINK uses available memory as much as possible. When available memory is exhausted, MS-LINK then creates a disk file (VM.TMP) to use as temporary memory.

The following figure illustrates the MS-LINK operation.

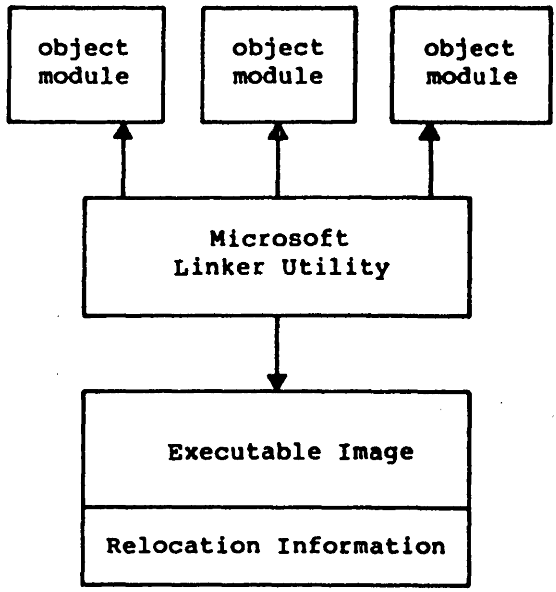


Figure 1. MS-LINK Operation

The executable image contains the concatenated object modules that make the Run file. The relocation information is a list of long addresses that must change when the executable image is relocated in memory. Refer to Section 1.7.4, "Long References," for an explanation of long addresses.

1.2 DEFINITIONS

The following terms describe the functioning of MS-LINK. An understanding of the concepts that define these terms will provide a basic understanding of the way MS-LINK works. Refer to the MS-DOS User's Guide for more information on these definitions.

1. Segment

   A segment is a contiguous area of memory up to 64K bytes in length. A segment may be located anywhere in 8086 memory. The contents of a segment are addressed by a canonical frame address and offset within that frame. Refer to Section 1.5, "Segment Addresses," for further discussion of canonical frames.

2. Group

   A group is a collection of segments that fit within 64K bytes of memory. The segments are named to the group by the assembler, by the compiler, or by you. You give the group name in the assembly language program. For the high-level languages (BASIC, FORTRAN, COBOL, Pascal), the naming is carried out by the compiler.

   The group is used for addressing segments in memory. Each group is addressed by a common canonical frame. This frame is the lowest canonical frame of the segments that belong to the group. It is a usual practice in assembler and higher languages for the canonical frame address to be contained in a segment register. MS-LINK checks to see that the object modules of a group meet the 64K-byte constraint.

3. Class

   A class is a collection of segments. The naming of segments to a class controls the order and relative placement of segments in memory. You give the class name in the assembly language program. For the high-level languages (BASIC, FORTRAN, COBOL, Pascal), the naming is carried out by the compiler. The segments are named to a class at compile time or assembly time.

   The segments of a class are loaded into memory contiguously. The segments are ordered within a class in the order the Linker encounters the segments in the object files. One class precedes another in memory only if a segment for the first class precedes all segments for the second class in the input to MS-LINK. Classes may be loaded across 64K-byte boundaries. Groups may span classes.

4. Alignment

Alignment refers to certain segment boundaries. These can be byte, word, or paragraph boundaries.

Byte Alignment: A segment can begin on any byte boundary.

Word Alignment: The beginning address of a segment must occur on an even address.

Paragraph Alignment: The beginning address of a segment must occur on a segment (16-byte) boundary.

5. Combine Type

A combine type is an attribute of a segment; it tells the Linker how to combine segments of a like name or it relays other information about the properties of a segment. Combine types are: stack, public, private, and common. The way MS-LINK arranges these combine types is discussed in the next section.

CHAPTER 2

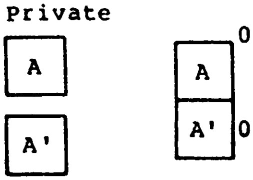
MS-LINK TECHNICAL INFORMATION

2.1 HOW MS-LINK COMBINES AND ARRANGES SEGMENTS

MS-LINK works with four combine types, which are declared in the source module for the assembler or compiler: private, public, stack, and common. The memory combine type available in Microsoft's Macro Assembler is processed the same as public combine type. MS-LINK does not automatically place memory combine type as the highest segments (as defined in the Intel standard).

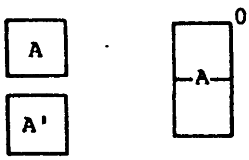
MS-LINK arranges these combine types as follows:

Private



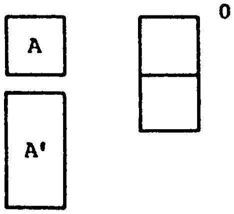
Private segments are loaded separately and remain separate. They may be physically (but not logically) contiguous even if the segments have the same name. Each private segment has its own canonical frame.

Public and Stack



Public and stack segments of the same name and class name are loaded contiguously. Offset is from the beginning of the first segment loaded through the last segment loaded. There is only one canonical frame for all public segments of the same name and class name. Stack and memory combine types are treated the same as public. However, the Stack Pointer is set to the last address of the first stack segment.

Common

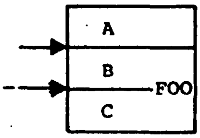


Common segments of the same name and class name are loaded overlapping one another. There is only one canonical frame for all common segments of the same name. The length of the common area is the length of the longest segment.

Placing segments in a group in the assembler provides offset addressing of items from a single canonical frame for all segments in that group.

DS:DGROUP--->XXXX0H..........0 -- relative offset

Any number of other segments may intervene between segments of a group. Thus, the offset of FOO may be greater than the size of segments in the group combined, but no larger than 64K.



An operand of DGROUP:FOO in assembly language returns the offset of FOO from the beginning of the first segment (segment A here).

Segments are partitioned by declared class names. The Linker loads all the segments belonging to the first class name encountered, then loads all the segments of the next class name encountered, and so on until all classes have been loaded.

If your program contains:	They will be loaded as:
A SEGMENT 'FOO'	'FOO'
B SEGMENT 'BAZ'	A
C SEGMENT 'BAZ'	E
D SEGMENT 'ZOO'	'BAZ'
E SEGMENT 'FOO'	B
	C
	'ZOO'
	D

If you are writing assembly language programs, you can control the order of classes in memory by writing a dummy module and listing it first after the MS-LINK Object Modules: prompt. The dummy module declares segments into classes in the order you want the classes loaded.

WARNING

Do not use this method with BASIC, COBOL, FORTRAN, or Pascal programs. Allow the compiler and the Linker to perform their tasks in the normal way.

Example:

```
A        SEGMENT 'CODE'
A        ENDS
B        SEGMENT 'CONST'
B        ENDS
C        SEGMENT 'DATA'
C        ENDS
D        SEGMENT STACK   'STACK'
D        ENDS
E        SEGMENT 'MEMORY'
E        ENDS
```

Make sure you declare all classes to be used in your program in this module. If you do not, you lose absolute control over the ordering of classes.

Also, if you want memory combine type to be loaded as the last segments of your program, you can use this method. Simply add MEMORY between SEGMENT and 'MEMORY' in the E segment line above. Note, however, that these segments are loaded last only because you imposed this control on them, not because of any inherent capability in the Linker or assembler operations.

2.2 SEGMENT ADDRESSES

The 8086 must be able to address all segments in memory. Any 20-bit number can be addressed. The 8086 represents these numbers as two 16-bit numbers; for example, HEX F:12. The F represents a canonical frame address and the 12 is the offset. The canonical frame address is the largest frame address or segment address that can contain the segment. An offset is the segment's location, offset from the beginning of the canonical frame.

The Linker recognizes a segment by its canonical frame address and its offset within the frame.

To convert the segmented address F:12 to a 20-bit number, shift the frame address left 4 bits, and add the offset. Using the above example:

```
          F0
    +     12
         ----
 F:12 =  102   (20-bit address)
```

2.3 HOW MS-LINK ASSIGNS ADDRESSES

To assign addresses to segments, MS-LINK:

1. Orders each segment by segment and class name.

2. On the basis of the alignment and size of each segment (assuming they are contiguous), the Linker assigns a frame address and an offset to each segment. This information is used for resolving relocatable references. The addresses start at 0:0.

2.4 RELOCATION FIXUPS

MS-LINK performs relocation fixups (i.e., resolves) on four types of references in object modules:

Short

Near Self-Relative

Near Segment-Relative

Long

These references and the Linker's fixups are described in the next sections.

2.4.1 Short References

Short references are all self-relative. The implication is that the frame address of the target and source frames are the same. MS-LINK will generate the fixup error message

```
Fixup offset exceeds field width
```

under the following conditions:

1. The target and source frame addresses are different.
2. The target is more than 128 bytes before or after the source frame address.

The resulting value of the short reference must fit into one signed byte.

2.4.2 Near Self-Relative References

When near self-relative references are used, the frame address of the target and source frames are the same. MS-LINK will generate the fixup error message under the following conditions:

1. The target and source frame addresses are different.

2. The target is more than 32K before or after the source frame address.

The resulting value of the near self-relative reference must fit into one signed word (16 bits).

2.4.3 Near Segment-Relative References

Given the target's canonical frame, another frame is specified (via an ASSUME directive or the : operator in assembly language; or via a high-level language convention). The target must be addressable through the canonical frame specified. MS-LINK will generate the fixup error message under the following conditions:

1. The offset of the target within the specified frame is greater than 64K or less than zero.

2. The beginning of the canonical frame of the target is not addressable by the specified frame.

The resulting value of a near segment-relative reference must be an unsigned 16-bit quantity.

2.4.4 Long References

Long references have a target and another frame (specified by an ASSUME or by a high-level language). The target must be addressable through the canonical frame specified. MS-LINK will generate the fixup error message under the following conditions:

1. The offset of the target within the specified frame is greater than 64K or less than zero.

2. The beginning of the canonical frame of the target is not addressable by the specified frame.

The resulting value of a long reference must be a frame address and an offset.

2.5 SAMPLE MS-LINK SESSION

The following example illustrates the type of information that is displayed during an MS-LINK session.

In response to the MS-DOS prompt (>), the system responds with the following messages and prompts. Answers to the prompts are underlined. Note that pathnames are supported under MS-DOS 2.0. Therefore, your answers to MS-LINK prompts can be full pathnames instead of filenames.

```
Microsoft Object Linker V.2.00
(C) Copyright 1982 by Microsoft Inc.

Object Modules [.OBJ]: IO SYSINIT
Run File [IO.EXE]:
List File [NUL.MAP]: IO /MAP
Libraries [.LIB]: ;
```

Notes:

1. By specifying /MAP, you can get both a sorted alphabetic listing and a sorted address listing of public symbols.

2. By responding PRN to the List File: prompt, you can redirect your output to the printer.

3. By specifying the /LINE switch, MS-LINK gives you a listing of all line numbers for all modules. (Note that the /LINE switch can generate a large volume of output.)

4. By pressing <RETURN> in response to the Libraries: prompt, an automatic library search is performed.

Once MS-LINK locates all libraries, the linker map displays a list of segments in the order of their appearance within the load module. The list might look like this:

Start	Stop	Length	Name
00000H	009ECH	09EDH	CODE
009F0H	01166H	0777H	SYSINITSEG

The information in the Start and Stop columns shows the 20-bit hex address of each segment relative to location zero. Location zero is the beginning of the load module.

Because the /MAP switch was used, MS-LINK displays the public symbols by name and value. For example:

```
ADDRESS          PUBLICS BY NAME
009F:0012        BUFFERS
009F:0005        CURRENT_DOS_LOCATION
009F:0011        DEFAULT_DRIVE
009F:000B        DEVICE_LIST
009F:0013        FILES
009F:0009        FINAL_DOS_LOCATION
009F:000F        MEMORY_SIZE
009F:0000        SYSINIT

ADDRESS          PUBLICS BY VALUE
009F:0000        SYSINIT
009F:0005        CURRENT_DOS_LOCATION
009F:0009        FINAL_DOS_LOCATION
009F:000B        DEVICE_LIST
009F:000F        MEMORY_SIZE
009F:0011        DEFAULT_DRIVE
009F:0012        BUFFERS
009F:0013        FILES
```

The addresses of the public symbols are in the frame:offset format, showing the location relative to zero as the beginning of the load module. In some cases, an entry may look like this:

```
780:A2
```

This entry appears to be the address of a load module that is almost one megabyte in size. Actually, the area being referenced is relative to a segment base that is pointing to a segment below the relative zero beginning of the load module. This condition produces a pointer that has effectively gone negative.

When MS-LINK has completed processing, the following message is displayed:

```
Program entry point at 0009F:0000
```

2.6 ERROR MESSAGES

All messages, except for the warning messages, cause the MS-LINK session to end. After you locate and correct a problem, you must rerun MS-LINK.

Messages appear in the List file and are displayed on the screen. If you direct the List file to CON, the error messages will not be displayed on the screen.

MS-LINK error messages are described in Chapter 9 of the MS-DOS User's Guide.

ADDENDUM to the Microsoft MS-DOS Macro Assembler Manual

MS-LINK

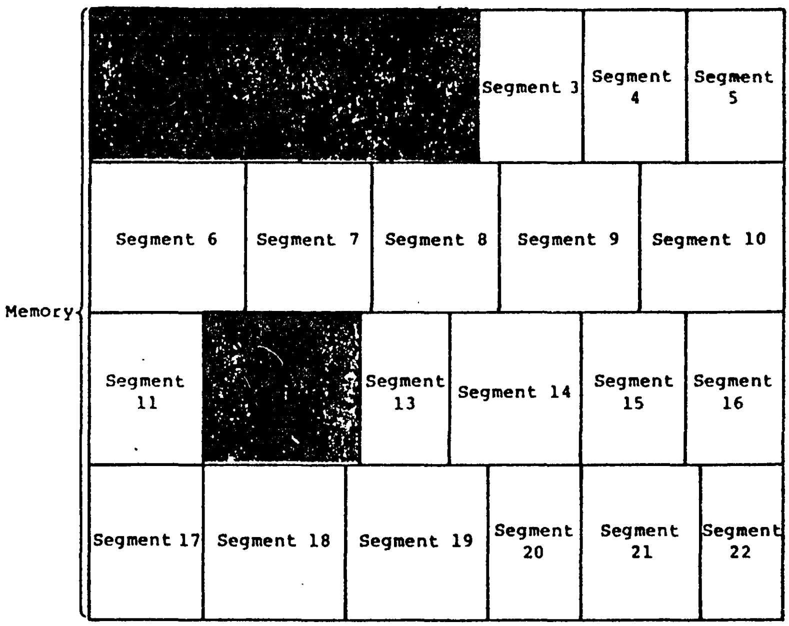
NOTE

References in the Macro Assembler Manual to the MS-DOS User's Guide refer to this addendum. You may want to place this addendum before the MS-LINK section in this manual.

1.0 DEFINITIONS

Some of the terms used in the MS-LINK section of this manual are explained below to help you understand how MS-LINK works. Generally, if you are linking object modules compiled from BASIC, Pascal, or a high-level language, you will not need to know these terms. If you are writing and compiling programs in assembly language, however, you will need to understand MS-LINK and the definitions described below.

In MS-DOS, memory can be divided into segments, classes, and groups. Figure 1 illustrates these concepts.



shaded area = a group (64K bytes addressable)

Figure 1. How Memory Is Divided

Example:

	Segment Name	Segment Class Name
Segment 1	PROG.1	CODE
Segment 2	PROG.2	CODE
Segment 12	PROG.3	DATA

Note that segments 1, 2, and 12 have different segment names but may or may not have the same segment class name. Segments 1, 2, and 12 form a group, with a group address of the lowest address of segment 1 (i.e., the lowest address in memory).

Each segment has a segment name and a class name. MS-LINK loads all segments into memory by class name, from the first segment encountered to the last. All segments assigned to the same class are loaded into memory contiguously.

During processing, MS-LINK references segments by their addresses in memory (where they are located). MS-LINK does this by finding groups of segments.

A group is a collection of segments that fit within a 64K byte area of memory. The segments do not need to be contiguous to form a group (see Figure 1). The address of any group is the lowest address of the segments in that group. At link time, MS-LINK analyzes the groups, then references the segments by the address in memory of that group. A program may consist of one or more groups.

If you are writing in assembly language, you may assign the group and class names in your program. In high-level languages (BASIC, COBOL, FORTRAN, Pascal), the naming is done automatically by the compiler.

2.0 FILES THAT MS-LINK USES

MS-LINK performs the following functions:

Works with one or more input files

Produces two output files

May create a temporary disk file

May be directed to search up to eight library files

For each type of file, you can give a three-part file specification. The format of MS-LINK file specifications is the same as that of a disk file:

[d:]<filename>[<.ext>]

where: d: is the drive designation. Permissible drive designations for MS-LINK are A: through O:. The colon is always required as part of the drive designation.

filename is any legal filename of one to eight characters.

.ext is a one- to three-character extension to the filename. The period is always required as part of the extension.

2.1 Input File Extensions

If no filename extensions are given in the input (object) file specifications, MS-LINK will recognize the following extensions by default:

.OBJ	Object
.LIB	Library

2.2 Output File Extensions

MS-LINK appends the following default extensions to the output (run and list) files:

.EXE	Run (may not be overridden)
.MAP	List (may be overridden)

2.3 VM.TMP (Temporary) File

MS-LINK uses available memory for the link session. If the files to be linked create an output file that exceeds available memory, MS-LINK will create a temporary file, name it VM.TMP, and put it on the disk in the default drive. If MS-LINK creates VM.TMP, it will display the message:

```
VM.TMP has been created.
Do not change diskette in drive, <d:>
```

Once this message has been displayed, you must not remove the disk from the default drive until the link session ends. If the disk is removed, the operation of MS-LINK will be unpredictable, and MS-LINK might display the error message:

```
Unexpected end of file on VM.TMP
```

The contents of VM.TMP are written to the file named following the Run File: prompt. VM.TMP is a working file only and is deleted at the end of the linking session.

WARNING

Do not use VM.TMP as a filename for any file. If you have a file named VM.TMP on the default drive and MS-LINK needs to create a VM.TMP file, MS-LINK will delete the VM.TMP already on disk and create a new VM.TMP. Thus, the contents of the previous VM.TMP file will be lost.

3.0 HOW TO START MS-LINK

MS-LINK requires two types of input: a command to start MS-LINK and responses to command prompts. In addition, seven switches control MS-LINK features. Usually, you will type all the commands to MS-LINK on the terminal keyboard. As an option, answers to the command prompts and any switches may be contained in a response file. Command characters can be used to assist you while giving commands to MS-LINK.

MS-LINK can be started in any of three ways. The first method is to type the commands in response to individual prompts. In the second method, you type all commands and switches on the line used to start MS-LINK. To start MS-LINK by the third method, you must create a response file that contains all the necessary commands, and then tell MS-LINK where that file is when you start MS-LINK.

Summary of Methods to Start MS-LINK

Method 1	LINK
Method 2	LINK <filenames>[/switches]
Method 3	LINK @<filespec>

3.1 Method 1: Prompts

To start MS-LINK with Method 1, type:

```
LINK
```

MS-LINK will be loaded into memory. MS-LINK will then display four text prompts that appear one at a time. You answer the prompts to command MS-LINK to perform specific tasks.

At the end of each line, you may type one or more switches, preceded by the switch character, a forward slash (/).

The command prompts are summarized below.

PROMPT	RESPONSES
Object Modules [.OBJ]:	List .OBJ files to be linked. They must be separated by blank spaces or plus signs (+). If a plus sign is the last character typed, the prompt will reappear. There is no default; a response is required.
Run File [.EXE]:	Give filename for executable object code. The default is first-object-filename.EXE. (You cannot change the output extension.)
List File [NUL.MAP]:	Give filename for listing. The default is NUL.MAP.
Libraries [.LIB]:	List filenames to be searched, separated by blank spaces or plus signs (+). If a plus sign is the last character typed, the prompt will reappear. The default is to search for default libraries in the object modules. (Extensions will be changed to .LIB.)

3.2 Method 2: Command Line

To start MS-LINK using Method 2, type all commands on one line. The entries following LINK are responses to the command prompts. The entry fields for the different prompts must be separated by commas. Use the following syntax:

```
LINK <object-list>,<runfile>,<listfile>,<lib-list>[/switch]
```

where: object-list is a list of object modules, separated by plus signs.

runfile is the name of the file that receives the executable output.

listfile is the name of the file that receives the listing.

lib-list is a list of library modules to be searched.

/switch refers to optional switches, which may be placed following any of the response entries (just before any of the commas or after the <lib-list>, as shown).

To select the default for a field, simply type a second comma with no spaces between the two commas.

Example:

```
LINK
FUN+TEXT+TABLE+CARE/P/M,,FUNLIST,COBLIB.LIB
```

This command causes MS-LINK to be loaded; then the object modules FUN.OBJ, TEXT.OBJ, TABLE.OBJ, and CARE.OBJ are loaded. MS-LINK then pauses (as a result of using the /P switch). MS-LINK links the object modules when you press any key, and produces a global symbol map (the /M switch). MS-LINK then defaults to the FUN.EXE run file; creates a list file named FUNLIST.MAP; and searches the library file COBLIB.LIB.

3.3 Method 3: Response File

To start MS-LINK with Method 3, type:

```
LINK @<filespec>
```

where: filespec is the name of a response file. A response file contains answers to the MS-LINK prompts (shown in Method 1) and may also contain any of the switches. When naming a response file, use of the filename extension is optional. Method 3 permits the command that starts MS-LINK to be entered from the keyboard or within a batch file, without requiring you to make any further responses.

To use this option, you must create a response file containing several lines of text, each of which is the response to an MS-LINK prompt. The responses must be in the same order as the MS-LINK prompts discussed in Method 1. If desired, a long response to the Object Modules: or Libraries: prompt may be typed on several lines by using a plus sign (+) to continue the same response onto the next line.

Switches and command characters can be used in the response file the same way as they are used for responses typed on the terminal keyboard.

When the MS-LINK session begins, each prompt will be displayed in order with the responses from the response file. If the response file does not contain answers for all the prompts (in the form of filenames, the semicolon command character, or carriage returns), MS-LINK will display the prompt which does not have a response, then wait for you to type a legal response. When a legal response has been typed, MS-LINK continues the link session.

Example:

```
FUN TEXT TABLE CARE
/PAUSE/MAP
FUNLIST
COBLIB.LIB
```

This response file tells MS-LINK to load the four object modules named FUN, TEXT, TABLE, and CARE. MS-LINK pauses to permit you to swap disks before producing a public symbol map (see discussion under /PAUSE in the "Switches" section before using this feature). When you press any key, the output files will be named FUN.EXE and FUNLIST.MAP. MS-LINK will then search the library file COBLIB.LIB, and will use default settings for the switches.

4.0 COMMAND CHARACTERS

MS-LINK recognizes three command characters.

Plus sign

Use the plus sign (+) to separate entries and to extend the current line in response to the Object Modules: and Libraries: prompts. (A blank space may be used to separate object modules.) To type a large number of responses (each may be very long), type a plus sign/<RETURN> at the end of the line to extend it. If the plus sign/<RETURN> is the last entry following these two prompts, MS-LINK will prompt you for more module names. When the Object Modules: or Libraries: prompt appears again, continue to type responses. When all the modules to be linked and libraries to be searched have been listed, be sure the response line ends with a module name and a <RETURN> and not a plus sign/<RETURN>.

Example:

```
Object Modules [.OBJ]: FUN TEXT TABLE
CARE+<RETURN>
Object Modules [.OBJ]:
FOO+FLIPFLOP+JUNQUE+<RETURN>
Object Modules [.OBJ]: CORSAIR<RETURN>
```

Semicolon — To select default responses to the remaining prompts, use a single semicolon (;) followed immediately by a carriage return at any time after the first prompt (Run File:). This feature saves time and overrides the need to press a series of <RETURN> keys.

NOTE

Once the semicolon has been entered (by pressing the <RETURN> key), you can no longer respond to any of the prompts for that link session. Therefore, do not use the semicolon to skip some prompts. To skip prompts, use the <RETURN> key.

Example:

```
Object Modules [.OBJ]: FUN TEXT TABLE
CARE<RETURN>
Run Module [FUN.EXE]: ;<RETURN>
```

No other prompts will appear, and MS-LINK will use the default values (including FUN.MAP for the list file).

<CONTROL-C> — Use the <CONTROL-C> key to abort the link session at any time. If you type an erroneous response, such as the wrong filename or an incorrectly spelled filename, you must press <CONTROL-C> to exit MS-LINK, then you must restart MS-LINK. If the error has been typed but you have not pressed the <RETURN> key, you may delete the erroneous characters with the backspace key, but for that line only.

5.0 MS-LINK SWITCHES

The seven MS-LINK switches control various MS-LINK functions. Switches must be typed at the end of a prompt response, regardless of which method is used to start MS-LINK. Switches may be grouped at the end of any response, or may be scattered at the end of several. If more than one switch is typed at the end of a response, each switch must be preceded by a forward slash (/).

All switches may be abbreviated. The only restriction is that an abbreviation must be sequential from the first letter through the last typed; no gaps or transpositions are allowed. For example:

Legal	Illegal
/D	/DSL
/DS	/DAL
/DSA	/DLC
/DSALLOCA	/DSALLOCT

/DSALLOCATE

Using the /DSALLOCATE switch tells MS-LINK to load all data at the high end of the Data Segment. Otherwise, MS-LINK loads all data at the low end of the Data Segment. At runtime, the DS pointer is set to the lowest possible address to allow the entire DS segment to be used. Use of the /DSALLOCATE switch in combination with the default load low (that is, the /HIGH switch is not used) permits the user application to dynamically allocate any available memory below the area specifically allocated within DGroup, yet to remain addressable by the same DS pointer. This dynamic allocation is needed for Pascal and FORTRAN programs.

NOTE

Your application program may dynamically allocate up to 64K bytes (or the actual amount of memory available) less the amount allocated within DGroup.

/HIGH

Use of the /HIGH switch causes MS-LINK to place the run file as high as possible in memory. Otherwise, MS-LINK places the run file as low as possible.

IMPORTANT

Do not use the /HIGH switch with Pascal or FORTRAN programs.

/LINENUMBERS

The /LINENUMBERS switch tells MS-LINK to include in the list file the line numbers and addresses of the source statements in the input modules. Otherwise, line numbers are not included in the list file.

NOTE

Some compilers produce object modules that do not contain line number information. In these cases, of course, MS-LINK cannot include line numbers.

/MAP

/MAP directs MS-LINK to list all public (global) symbols defined in the input modules. If /MAP is not given, MS-LINK will list only errors (including undefined globals).

The symbols are listed alphabetically at the end of the list file. For each symbol, MS-LINK lists its value and its segment:offset location in the run file.

/PAUSE

The /PAUSE switch causes MS-LINK to pause in the link session when the switch is encountered. Normally, MS-LINK performs the linking session from beginning to end without stopping. This switch allows the user to swap disks before MS-LINK outputs the run (.EXE) file.

When MS-LINK encounters the /PAUSE switch, it displays the message:

```
About to generate .EXE file
Change disks <hit any key>
```

MS-LINK resumes processing when you press any key.

CAUTION

Do not remove the disk which will receive the list file, or the disk used for the VM.TMP file, if one has been created.

/STACK:<number>

number represents any positive numeric value (in hexadecimal radix) up to 65536 bytes. If a value from 1 to 511 is typed, MS-LINK will use 512. If the /STACK switch is not used for a link session, MS-LINK will calculate the necessary stack size automatically.

All compilers and assemblers should provide information in the object modules that allow the linker to compute the required stack size.

At least one object (input) module must contain a stack allocation statement. If not, MS-LINK will display the following error message:

```
WARNING: NO STACK STATEMENT
```

/NO

/NO is short for NODEFAULTLIBRARYSEARCH. This switch tells MS-LINK to not search the default (product) libraries in the object modules. For example, if you are linking object modules in Pascal, specifying the /NO switch tells MS-LINK to not automatically search the library named PASCAL.LIB to resolve external references.

6.0 ERROR MESSAGES

All errors cause the link session to abort. After the cause has been found and corrected, MS-LINK must be rerun. The following error messages are displayed by MS-LINK:

ATTEMPT TO ACCESS DATA OUTSIDE OF SEGMENT BOUNDS, POSSIBLY BAD OBJECT MODULE

There is probably a bad object file.

BAD NUMERIC PARAMETER

Numeric value is not in digits.

CANNOT OPEN TEMPORARY FILE

MS-LINK is unable to create the file VM.TMP because the disk directory is full. Insert a new disk. Do not remove the disk that will receive the List.MAP file.

ERROR: DUP RECORD TOO COMPLEX

The DUP record in the assembly language module is too complex. Simplify the DUP record in your assembly language program.

ERROR: FIXUP OFFSET EXCEEDS FIELD WIDTH

An assembly language instruction refers to an address with a short instruction instead of a long instruction. Edit your assembly language source and reassemble.

INPUT FILE READ ERROR

There is probably a bad object file.

INVALID OBJECT MODULE

An object module(s) is incorrectly formed or incomplete (as when assembly is stopped in the middle).

SYMBOL DEFINED MORE THAN ONCE

MS-LINK found two or more modules that define a single symbol name.

PROGRAM SIZE OR NUMBER OF SEGMENTS EXCEEDS CAPACITY OF LINKER

The total size may not exceed 384K bytes, and the number of segments may not exceed 255.

REQUESTED STACK SIZE EXCEEDS 64K
Specify a size greater than or equal to 64K bytes with the /STACK switch.

SEGMENT SIZE EXCEEDS 64K
64K bytes is the addressing system limit.

SYMBOL TABLE CAPACITY EXCEEDED
Very many and/or very long names were typed, exceeding the limit of approximately 25K bytes.

TOO MANY EXTERNAL SYMBOLS IN ONE MODULE
The limit is 256 external symbols per module.

TOO MANY GROUPS
The limit is 10 groups.

TOO MANY LIBRARIES SPECIFIED
The limit is 8 libraries.

TOO MANY PUBLIC SYMBOLS
The limit is 1024 public symbols.

TOO MANY SEGMENTS OR CLASSES
The limit is 256 (segments and classes taken together).

UNRESOLVED EXTERNALS: <list>
The external symbols listed have no defining module among the modules or library files specified.

VM READ ERROR
This is a disk error; it is not caused by MS-LINK.

WARNING: NO STACK SEGMENT
None of the object modules specified contains a statement allocating stack space, although the /STACK switch was specified.

WARNING: SEGMENT OF ABSOLUTE OR UNKNOWN TYPE
There is a bad object module, or an attempt has been made to link modules that MS-LINK cannot handle (e.g., an absolute object module).

WRITE ERROR IN TMP FILE
No more disk space remains to expand the VM.TMP file.

WRITE ERROR ON RUN FILE
Usually, there is not enough disk space for the run file.

INDEX

Microsoft® LIB

Library Manager

for 8086 and 8088 Microprocessors

Microsoft Corporation

System Requirements

The Microsoft Linker Utility requires:

50K bytes of memory minimum:
- 40K bytes for code and data
- 10K bytes for run space

Disk drive(s):

1 disk drive if and only if output is sent to the same physical disk from which the input was taken. MS-LINK does not allow time to swap disks during operation on a one-drive configuration. Therefore, two disk drives is a more practical configuration.

Contents

CHAPTER 1

INTRODUCTION

1.1 FEATURES OF MS-LIB

Microsoft LIB is a library manager. With MS-LIB, you can:

Create and modify library files that are used with Microsoft's MS-LINK linker utility

Add object files to a library

Delete modules from a library

Extract modules from a library and place the extracted modules into separate object files

MS-LIB can create either general or special libraries, for a variety of programs or for specific programs. With MS-LIB you can create a library, or you can create a library for one program only. The result is fast linking and more efficient execution for a language compiler or for one program.

You can modify individual modules within a library by extracting the modules, making changes, then adding the modules to the library again. You can also replace an existing module with a different module or with a new version of an existing module.

The command scanner in MS-LIB is also used in Microsoft MS-LINK, MS-Pascal, MS-FORTRAN, and other 16-bit Microsoft products. If you have used any of these products, using MS-LIB should be familiar to you. Command syntax is straightforward, and MS-LIB prompts you for commands that you have not supplied.

1.2 OVERVIEW OF MS-LIB OPERATION

MS-LIB performs five library manager functions:

Deletes modules

Extracts a module and places it in a separate object file

Appends an object file as a module of a library

Replaces a module in the library file with a new module

Creates a library file

During each library session, MS-LIB deletes or extracts modules, then appends new ones to the library file. MS-LIB reads each module into memory, checks it for consistency, and writes it back to the file. If you delete a module, MS-LIB reads that module into memory but does not write it back to the file. When MS-LIB writes back the next module to be retained, it places that module at the end of the last module written. This procedure effectively "closes up" the disk space to keep the library file from growing too large.

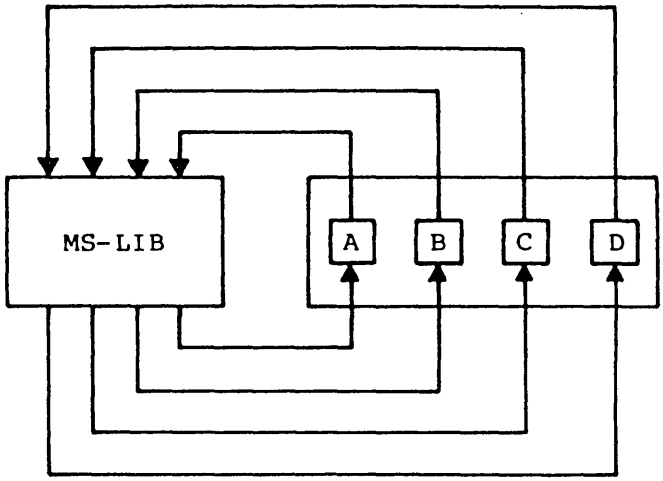
When MS-LIB has read the library file, it appends any new modules to the end of the file. Finally, MS-LIB creates the index, which MS-LINK uses to find modules and symbols in the library file. MS-LIB will output a cross-reference listing of the PUBLIC symbols in the library, if you request such a listing.

Example:

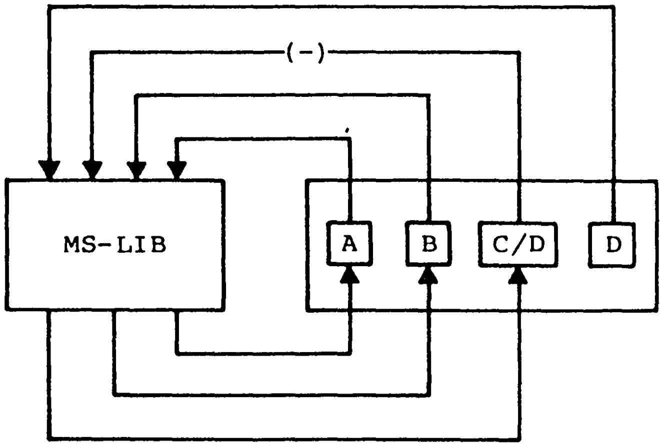
```
LIBx PASCAL+HEAP-HEAP;
```

This command first deletes the library module HEAP from the library file, then adds the file HEAP.OBJ as the last module in the library. Note that the replace function is simply the delete-append functions in succession. Also note that you can specify delete, append, or extract functions in any order. This order of execution prevents confusion in MS-LIB when a new version of a module replaces a version in the library file.

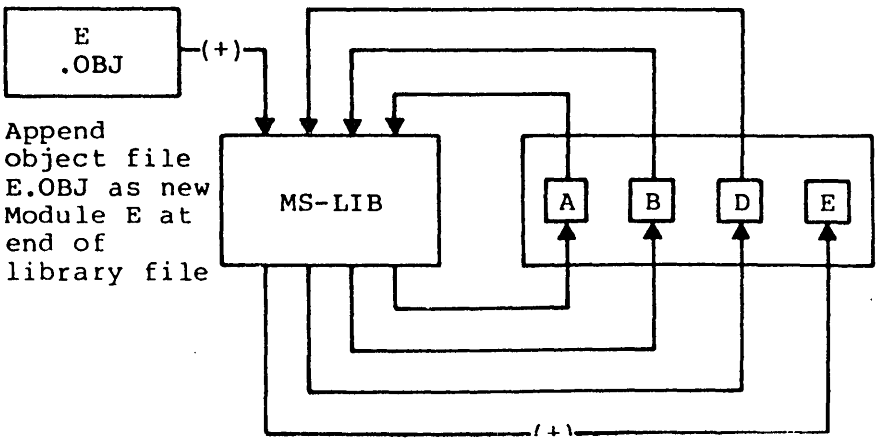
The following figure illustrates the MS-LIB operation.



Consistency check only



Delete Module C; Module D written to space of Module C



Append object file E.OBJ as new Module E at end of library file

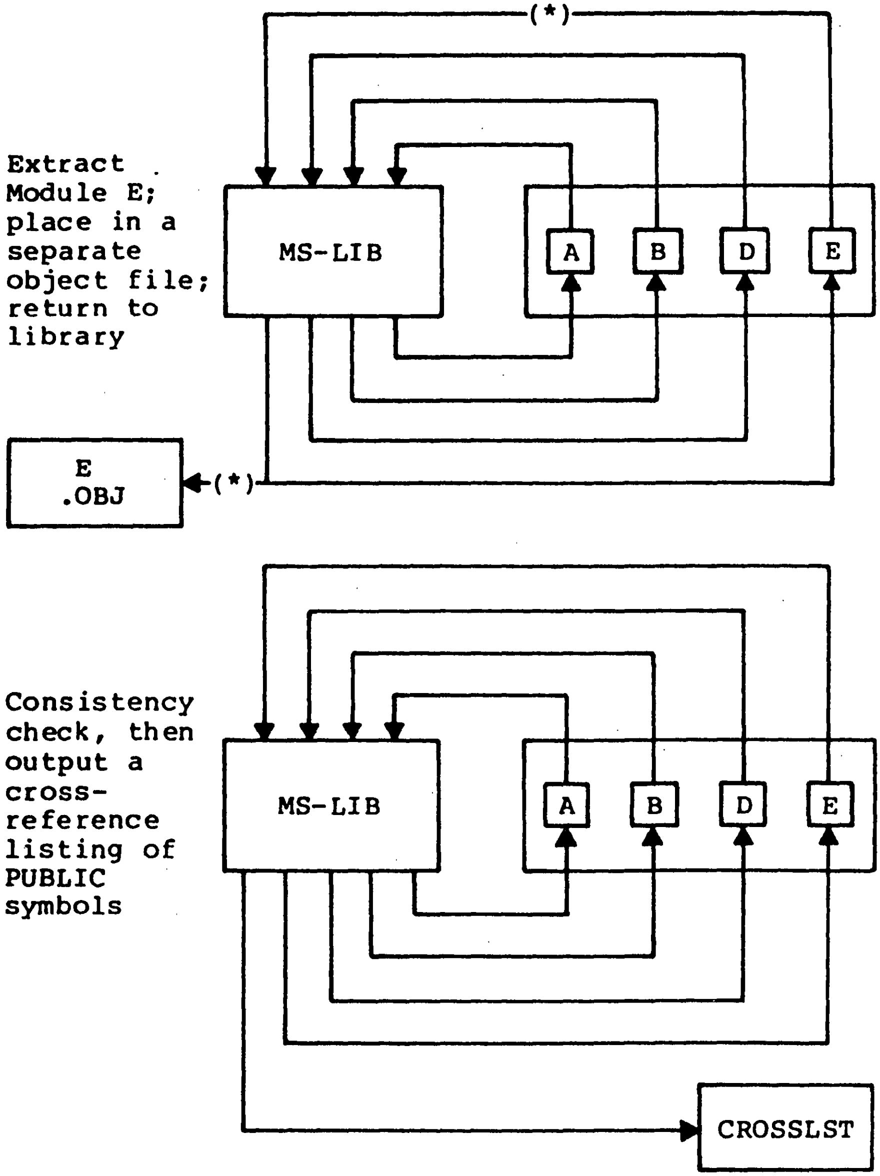


Figure 1. MS-LIB Operation

CHAPTER 2

RUNNING MS-LIB

Running MS-LIB requires two types of commands: a command to start MS-LIB and answers to command prompts. Usually you will type all the commands to MS-LIB on a command line or in response to MS-LIB prompts. As an option, answers to the command prompts may be contained in a response file. Command characters can be used to assist you while giving commands to MS-LIB.

2.1 HOW TO START MS-LIB

There are three ways to start MS-LIB. With the first method, you type the commands as answers to individual prompts. By the second method, you type all commands on the line used to start MS-LIB. As a third option, you can create a response file that contains all the necessary commands.

Summary of Methods to Start MS-LIB

Method 1	LIB
Method 2	LIB <library><operations>,<listing>
Method 3	LIB @<filespec>

2.1.1 Method 1: Prompts

To start MS-LIB with method 1, type:

```
LIB
```

MS-LIB will be loaded into memory. MS-LIB will then display three text prompts that appear one at a time. You answer the prompts, commanding MS-LIB to perform specific tasks.

The command prompts are summarized here and described more fully in the Section 2.2, "Command Prompts."

Summary of Command Prompts

PROMPT	RESPONSES
Library File:	List filename of library to be manipulated. (The default is the filename extension .LIB.)
Operation:	List command character(s) followed by module name(s) or object filename(s). (The default is no changes. The default object filename extension is .OBJ.)
List file:	List filename for a cross-reference listing file. (The default is NUL; i.e., no file.)

NOTE

The distinction between an object file and a module (or object module) is that the file possesses a drive designation (even if it is the default drive) and a filename extension. Object modules possess neither of these.

2.1.2 Method 2: Command Line

Type:

```
LIB <library><operations>,<listing>
```

The entries following LIB are responses to the command prompts. The <library> and <operations> fields and all operations entries must be separated by one of the command characters plus, minus, or asterisk (+, -, or *). If a cross-reference listing is wanted, the name of the file must be separated from the last operations entry by a comma.

where: <library> is the name of a library file. MS-LIB assumes that the filename extension is .OBJ, which you may override by specifying a different extension. If the filename given for the <library> field does not exist, MS-LIB will prompt you:

```
Library file does not exist.  Create?
```

Type Yes to create a new library file. Type No to abort the library session.

<operations> is a command to delete a module, append an object file as a module, or extract a module as an object file from the library file. Use the three command characters plus, minus, and asterisk to direct MS-LIB to append, delete, or extract modules and object files.

<listing> is the name of the file you want to receive the cross-reference listing of PUBLIC symbols in the modules in the library. The list is compiled after all module manipulation has taken place.

If you type a library filename followed immediately by a semicolon, MS-LIB will read through the library file and perform a consistency check. No changes will be made to the modules in the library file.

If you type a library filename followed immediately by a comma and a listing filename, MS-LIB will perform its consistency check of the library file, then produce the cross-reference listing file.

Examples:

```
LIB PASCAL-HEAP+HEAP;
```

This example causes MS-LIB to delete the module HEAP from the library file PASCAL.LIB, then append the object file HEAP.OBJ as the last module of PASCAL.LIB (the module will be named HEAP). The MS-LIB semicolon command character indicates that MS-LIB should use the default responses for the remaining prompts. Refer to Section 2.3, "Command Characters," for more information.

```
LIB PASCAL
```

This example causes MS-LIB to perform a consistency check of the library file PASCAL.LIB. No other action is performed.

```
LIB PASCAL;PASCROSS.PUB
```

This example causes MS-LIB to perform a consistency check of the library file PASCAL.LIB, then output a cross-reference listing file named PASCROSS.PUB.

If you have many operations to perform during a library session, use the ampersand (&) command character to extend the line so that you can type additional object filenames and module names. Be sure to always include one of the command characters for operations (+, -, *) before the name of each module or object filename.

2.1.3 Method 3: Response File

Type:

```
LIB @<filespec>
```

where: <filespec> is the name of a response file. A response file contains answers to the MS-LIB prompts. Method 3 permits you to conduct the MS-LIB session without user responses to the MS-LIB prompts.

IMPORTANT

Before using method 3 to start MS-LIB, you must first create a response file.

A response file has one text line for each prompt. Responses must appear in the same order as the command prompts appear.

Use command characters in the response file the same way you would for responses typed on the keyboard.

When the library session begins, each prompt will be displayed with the responses from the response file. If the response file does not contain answers for all the prompts, MS-LIB will use the default responses. (No changes will be made to the modules currently in the library file, and no cross-reference listing file will be created.)

If you type a library filename followed immediately by a semicolon, MS-LIB will read through the library file and perform a consistency check. No changes will be made to the modules in the library file.

If you type a library filename, a carriage return, a comma, and then a list filename, MS-LIB will perform its consistency check of the library file, then produce the cross-reference listing file.

Example:

```
PASCAL
+CURSOR+HEAP-HEAP*FOIBLES
CROSSLST
```

This response file causes MS-LIB to delete the module HEAP from the PASCAL.LIB library file; extract the module FOIBLES and place it in an object file named FOIBLES.OBJ; then append the object files CURSOR.OBJ and HEAP.OBJ as the last two modules in the library. Then, MS-LIB will create a cross-reference file named CROSSLST.

2.2 COMMAND PROMPTS

You command MS-LIB by typing responses to three text prompts. After you have typed your response to the current prompt, the next appears. When the last prompt has been answered, MS-LIB performs its library management functions without further command. You will see the operating system prompt when MS-LIB has finished the library session successfully. If the library session is unsuccessful, MS-LIB will display the appropriate error message.

MS-LIB prompts you for the name of the library file, the operation(s) you want to perform, and the name you want to give to a cross-reference listing file (if any).

Command Prompts

Library File:

Type the name of the library file that you want to manipulate. MS-LIB assumes that the filename extension is .LIB. You can override this assumption by giving a filename extension when you type the library filename. Because MS-LIB can manage only one library file at a time, only one filename is allowed in response to this prompt. Additional responses, except the semicolon command character, are ignored.

If you type a library filename and follow it immediately with a semicolon command character, MS-LIB will perform a consistency check only, then return to the operating system. Any errors in the file will be displayed.

If the filename you type does not exist, MS-LIB will display the prompt:

    Library file does not exist. Create?

You must type either Yes or No.

Operation:

Type one of the three command characters for manipulating modules (+, -, *); followed immediately (no space) by the module name or the object filename. The plus sign appends an object file as the last module in the library file (see further discussion under the description of plus sign in the next section). The minus sign deletes a module from the library file. The asterisk extracts a module from the library and places it in a separate object file, with the filename taken from the module name and a filename extension .OBJ.

When you have a large number of modules to manipulate (more than can be typed on one line), type an ampersand (&) as the last character on the line. MS-LIB will repeat the Operation: prompt, which permits you to type additional module names and object filenames.

MS-LIB allows you to perform operations on modules and object files in any order you want.

More information about modules is given in the description of each command character.

List file:

If you want a PUBLIC symbols cross-reference list for the modules in the library file, type the name of a file in which you want MS-LIB to place the cross-reference listing. If you do not type a filename, no cross-reference listing is generated.

The response to the List file: prompt is a file specification. You can specify a drive (or device) designation and a filename extension with the filename. The list file is not given a default filename extension. If you want the file to have a filename extension, you must specify it when typing the filename.

The cross-reference listing file contains two lists. The first list is an alphabetical listing of all PUBLIC symbols. Each symbol name is followed by the name of its module. The second list is an alphabetical list of the modules in the library. Under each module name is an alphabetical listing of the PUBLIC symbols in that module.

2.3 COMMAND CHARACTERS

MS-LIB provides six command characters. Three of the command characters are required in response to the Operation: prompt. The other three command characters provide you with helpful commands to MS-LIB.

Plus sign: Use the plus sign (+), followed by an object filename, to append the object file as the last module in the library named in response to the Library File: prompt. When MS-LIB sees the plus sign, it assumes that the filename extension is .OBJ. You may override this assumption by specifying a different filename extension.

MS-LIB strips the drive designation and the extension from the object file specification, leaving only the filename. For example, if the object file to be appended as a module to a library is

```
B:CURSOR.OBJ
```

a response to the Operation: prompt of

```
+B:CURSOR.OBJ
```

will cause MS-LIB to strip off the B: and the .OBJ, leaving only CURSOR. This becomes a module named CURSOR in the library.

Minus sign: Use the minus sign, followed by a module name, to delete a module from the library file. MS-LIB then "closes up" the disk space left empty by the deletion. This cleanup action keeps the library file from growing larger than necessary. Remember that new modules, even replacement modules, are added to the end of the file, not put into space vacated by deleting modules.

Asterisk

Use the asterisk, followed by a module name, to extract the module from the library file and place it into a separate object file. The module will still exist in the library. (The extraction process copies the module to a separate object file.) The module name is used as the filename. MS-LIB adds the default drive designation and the filename extension .OBJ. For example, if the module to be extracted is

```
CURSOR
```

and the current default disk drive is A:, a reponse to the Operation: prompt of

```
*CURSOR
```

causes MS-LIB to extract the module named CURSOR from the library file and make it an object file with the file specification of:

```
A:CURSOR.OBJ
```

The drive designation and filename extension cannot be overridden. You can, however, rename the file, giving a new filename extension; and/or copy the file to a new disk drive, giving a new filename and/or filename extension.

Semicolon

Use a single semicolon (;), followed immediately by a carriage return at any time after responding to the first prompt (i.e., from Library File: on), to select default responses to the remaining prompts. This feature saves time and overrides the need to answer additional prompts.

NOTE

> Once the semicolon has been typed, you can no longer respond to any of the prompts for that library session. Therefore, do not use the semicolon to skip over prompts. To skip prompts, use carriage return.

Example:

```
Library file:  FUN
Operation:  +CURSOR;
```

The remaining prompt will not appear, and MS-LIB will use the default value (no cross-reference file).

Ampersand

Use the ampersand to extend the current line. This command character is only used in response to the Operation: prompt. The number of modules you can append is limited only by disk space. The number of modules you can replace or extract is also limited only by disk space. The number of modules you can delete is limited by the number of modules in the library file.

The line length for a response to any prompt is limited to the line length of your system. For a large number of responses to the Operation: prompt, place an ampersand at the end of a line. MS-LIB will display the Operation: prompt again, and then you can type more responses. For example:

```
Library File:  FUN
Operation:  +CURSOR-HEAP+HEAP*FOIBLES&
Operation:  *INIT+ASSUME+RIDE;
```

MS-LIB will delete the module HEAP; extract the modules FOIBLES and INIT (creating two files, FOIBLES.OBJ and INIT.OBJ); then append the object files CURSOR, HEAP, ASSUME, and RIDE. Note that MS-LIB allows you to type your Operation: reponses in any order. You may use the ampersand character as many times as needed.

CONTROL-C Use <CONTROL-C> to abort the library session at any time. If you type an incorrect response, such as the wrong filename or module name, or an incorrectly spelled filename or module name, you must press <CONTROL-C> to exit MS-LIB; then you must restart MS-LIB. If the error has been typed and you have not pressed the <RETURN> key, you may delete the erroneous characters for that line only.

Summary of Command Characters

Character	Action
+	Appends an object file as the last module
-	Deletes a module from the library
*	Extracts a module and places in an object file
;	Use default responses to remaining prompts
&	Extends current physical line; repeats command prompt
CONTROL-C	Aborts library session

CHAPTER 3

ERROR MESSAGES

The following are MS-LIB error messages:

<symbol> is a multiply defined PUBLIC. Proceed?

Cause: Two modules define the same public symbol. You are asked to confirm the removal of the definition of the old symbol.

Cure: Remove the PUBLIC declaration from one of the object modules and recompile or reassemble. If you respond No, the library will be left in an indeterminate state.

Allocate error on VM.TMP

Cause: Out of disk space

Cannot create extract file

Cause: No room in directory for extract file

Cannot create list file

Cause: No room in directory for library file

Cannot nest response file

Cause: @filespec in response (or indirect) file

MS-LIB cannot open VM.TMP

Cause: There is no room for VM.TMP in disk directory

Cannot write library file

Cause: Out of disk space

Close error on extract file

Cause: Out of disk space

Error: An internal error has occurred

Contact Microsoft Corporation

Fatal Error: Cannot open input file

Cause: You mistyped an object filename

Fatal Error: Module is not in the library
    Cause: You tried to delete a module that is not in the library

Input file read error
    Cause: Bad object module or faulty disk

Invalid object module/library
    Cause: Bad object module and/or library

Library Disk is full
    Cause: No more room on disk

Listing file write error
    Cause: Out of disk space

No library file specified
    Cause: No response to Library File: prompt

Read error on VM.TMP
    Cause: Disk not ready for read

Symbol table capacity exceeded
    Cause: Too many public symbols (about 30K chars in symbols)

Too many object modules
    Cause: More than 500 object modules

Too many public symbols
    Cause: 1024 public symbols maximum

Write error on library/extract file
    Cause: Out of disk space

Write error on VM.TMP
    Cause: Out of disk space

INDEX

Microsoft® CREF

Cross-Reference Utility

for 8086 and 8088 Microprocessors

Microsoft Corporation

System Requirements

The Microsoft CREF Cross-Reference Utility requires:

24K bytes of memory minimum:

- 14K bytes for code
- 10K bytes for run space

Disk drive(s):

1 disk drive if and only if output is sent to the same physical disk from which the input was taken. The Microsoft CREF Cross-Reference Utility does not allow time to swap disks during operation on a one-drive configuration. Therefore, two disk drives is a more practical configuration.

Contents

CHAPTER 1

INTRODUCTION

1.1 FEATURES OF MS-CREF

The Microsoft CREF Cross-Reference Utility can help you in debugging your assembly language programs. MS-CREF outputs an alphabetical listing of all the symbols to a special file created by your assembler. With this listing, you can quickly locate all occurrences of any symbol in your source program by line number.

The cross-reference listing produced by MS-CREF gives you symbol locations, speeding your search and allowing faster debugging.

The MS-CREF listing is used with the symbol table produced by your assembler.

The symbol table listing shows the value, type, and length of each symbol. This information is needed to correct erroneous symbol definitions or uses.

1.2 OVERVIEW OF MS-CREF OPERATION

MS-CREF produces a file with cross-references for symbolic names in your program.

First, you must create a cross-reference file with the assembler. Then, MS-CREF converts this cross-reference file (which has the filename extension .CRF) into an alphabetical listing of the symbols in the file. The cross-reference listing file is given the default filename extension .REF.

Beside each symbol in the listing, MS-CREF lists the line numbers where the symbol occurs in the source program. The line numbers are listed in ascending sequence. The line number where the symbol is defined is indicated by a pound sign (#).

Figure 1 illustrates the MS-CREF operation.

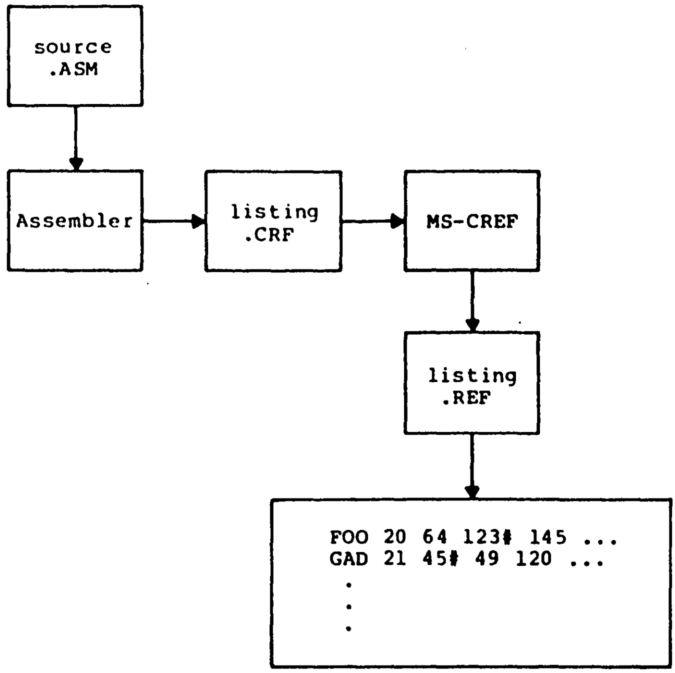


Figure 1. MS-CREF Operation

CHAPTER 2

RUNNING MS-CREF

Running MS-CREF requires two types of commands: a command to start MS-CREF and answers to command prompts. You type all the commands to MS-CREF on a command line or in response to MS-CREF prompts. Command characters can be used to assist you while giving commands to MS-CREF.

Before you can use MS-CREF to create the cross-reference listing, you must first create a cross-reference file using your assembler. This step is described in the next section.

2.1 HOW TO CREATE A CROSS-REFERENCE FILE

A cross-reference file is created during an assembly session. To create a cross-reference file, use the Microsoft Macro Assembler and answer the fourth command prompt with the name of the cross-reference file you want to create.

The fourth assembler prompt is:

```
        Cross-reference [NUL.CRF]:
```

If you do not type a filename in response to this prompt, or if you use the default response, the assembler will not create a cross-reference file. Therefore, you must type a filename if you want to create a cross-reference file.

You may also specify which drive or device you want the file saved on, and the filename extension (if different from .CRF). If you assign a filename extension other than .CRF, you must specify the filename extension when naming the file in response to the first MS-CREF prompt. (Refer to Section 2.2, "How to Start MS-CREF," for a description of MS-CREF prompts.)

You are now ready to use MS-CREF to convert the cross-reference file produced by the assembler into a cross-reference listing.

2.2 HOW TO START MS-CREF

MS-CREF may be started two ways. By the first method, you type the commands as answers to individual prompts. By the second method, you type all commands on the line used to start MS-CREF.

Summary of Methods to Start MS-CREF

==

Method 1	CREF
Method 2	CREF <crffile>,<listing>

==

2.2.1 Method 1: Prompts

To start MS-CREF using prompts, type:

CREF

MS-CREF will be loaded into memory. Then, MS-CREF displays two text prompts that appear one at a time. You answer the prompts to command MS-CREF to convert a cross-reference file into a cross-reference listing.

Command Prompts

Cross reference [.CRF]:

Type the name of the cross-reference file you want MS-CREF to convert to a cross-reference listing. The filename is the name you specified when you directed the assembler to produce the cross-reference file.

MS-CREF assumes that the filename extension is .CRF. If you do not specify a filename extension when you type the cross-reference filename, MS-CREF will look for a file with the name you specify and the filename extension .CRF. If your cross-reference file has a different extension, specify that extension when typing the filename.

Refer to Chapter 4, "Format of MS-CREF Compatible Files," for a description of what MS-CREF expects to see in the cross-reference file. You will need this information only if your cross-reference file was not produced by a Microsoft assembler.

Listing [crffile.REF]:

Type the name you want the cross-reference listing file to have. MS-CREF will automatically give the cross-reference listing the filename extension .REF.

If you want you cross-reference listing to have the same filename as the cross-reference file but with the filename extension .REF, simply press the <RETURN> key when the Listing: prompt appears. If you want your cross-reference listing file to be named anything else, or to have any other filename extension, you must type a response following the Listing: prompt.

If you want the listing file placed on a drive or device other than the default drive, specify that drive or device when typing your response to the Listing: prompt.

2.2.2 Method 2: Command Line

To start MS-CREF using the command line, type:

    CREF <crffile>,<listing>

MS-CREF will be loaded into memory. Then MS-CREF converts your cross-reference file into a cross-reference listing.

The entries following CREF are responses to the command prompts. The <crffile> and <listing> fields must be separated by a comma.

where: <crffile> is the name of the cross-reference file produced by your assembler. MS-CREF assumes that the filename extension is .CRF. You may override this default by specifying a different extension. If the file named for the <crffile> does not exist, MS-CREF will display the message:

    Fatal I/O Error 110

    in File: <crffile>.CRF

MS-CREF will be aborted and the operating system prompt will appear.

<listing> is the name of the file you want to contain the cross-reference listing of symbols in your program.

To select the default filename and extension for the listing file, type a semicolon after the <crffile> name. Refer to the "Command Characters" section for more information on how to use the semicolon.

Examples:

    CREF FUN;

This example causes MS-CREF to process the cross-reference file FUN.CRF and to produce a listing file named FUN.REF.

To give the listing file a different filename, extension, or destination, simply specify it when you type the command line.

```
CREF FUN,B:WORK.ARG
```

This example causes MS-CREF to process the cross-reference file named RUN.CRF and to produce a listing file named WORK.ARG, which will be placed on the disk in drive B:.

2.3 COMMAND CHARACTERS

MS-CREF provides two command characters.

Semicolon

Use a single semicolon (;), followed immediately by a carriage return, at any time after responding to the Cross reference: prompt to select the default response to the Listing: prompt. This feature saves time and overrides the need to answer the Listing: prompt.

If you use the semicolon, MS-CREF gives the listing file the filename of the cross-reference file and the default filename extension .REF.

Example:

```
Cross reference [.CRF]:  FUN;
```

MS-CREF will process the cross-reference file named FUN.CRF and output a listing file named FUN.REF.

CONTROL-C

Use <CONTROL-C> at any time to abort the MS-CREF session. If you make a mistake (for example, typing the wrong filename or incorrectly spelling a filename), you must press <CONTROL-C> to exit MS-CREF, and then restart MS-CREF. If the error has been typed but you have not pressed the <RETURN> key, you may delete the erroneous characters, but for that line only.

2.4 FORMAT OF CROSS-REFERENCE LISTINGS

The cross-reference listing is an alphabetical list of all the symbols in your program. Each page begins with the title of the program or program module. Then the symbols are listed. Following each symbol name is a list of the line numbers where the symbol occurs in your program. The line number for the definition has a pound sign (#) appended to it.

An example of a cross-reference listing appears in the next section.

2.4.1 Example Of Cross-Reference Listing

```
MS-CREF      (vers no.)      (date)

ENTX    PASCAL entry for initializing programs<--comes from
                                            TITLE directive

 Symbol Cross-Reference     (# is definition)   Cref-1

AAAXQQ . . . .   37#    38

BEGHQQ . . . .   83     84#   154    176
BEGOQQ . . . .   33    162
BEGXQQ . . . . 113    126#   164    223

CESXQQ . . . .   97     99#   129
CLNEQQ . . . .   67     68#
CODE . . . . .   37    182
CONST. . . . . 104    104    105    110
CRCXQQ . . . .   93     94#   210    215
CRDXQQ . . . .   95     96#   216
CSXEQQ . . . .   65     66#   149
CURHQQ . . . .   85     86#   155

DATA . . . . .   64#    64    100    110
DGROUP . . . . 110#   111    111    111    127    153    171    172
DOSOFF . . . .   98#   198    199
DOSXQQ . . . . 184    204#   219

ENDHQQ . . . .   87     88#   158
ENDOQQ . . . .   33#   195
ENDUQQ . . . .   31#   197
ENDXQQ . . . . 184    194#
ENDYQQ . . . .   32#   196
ENTGQQ . . . .   30#   187
ENTXCM . . . . 182#   183    221

FREXQQ . . . . 169    170#   178

HDRFQQ . . . .   71     72#   151
HDRVQQ . . . .   73     74#   152
HEAP . . . . .   42     44    110
HEAPBEG. . . .   54#   153    172
HEAPLOW. . . .   43    171

INIUQQ . . . .   31    161

MAIN_STARTUP  109#   111    180
MEMORY . . . .   42     48#    48     49    109    110

PNUXQQ . . . .   69     70    150

RECEQQ . . . .   81     82#
```

```
REFEQQ . . . .  77     78#
REPEQQ . . . .  79     80#
RESEQQ . . . .  75     76#  148
ENTX    PASCAL entry for initializing programs

 Symbol Cross-Reference    (# is definition)   Cref-2

SKTOP. . . . .  59#
SMLSTK . . . . 135    137#
STACK. . . . .  53#    53    60    110
STARTMAIN. . . 163    186#  200
STKBQQ . . . .  89     90#  146
STKHQQ . . . .  91     92#  160
```

CHAPTER 3

ERROR MESSAGES

All errors cause MS-CREF to abort. Control is returned to the operating system.

All error messages are displayed in the following format:

```
Fatal I/O Error <error number>
in File:  <filename>
```

where: <filename> is the name of the file where the error occurs.

<error number> is one of the numbers in the following list of errors:

Number	Error
101	Hard data error Unrecoverable disk I/O error
101	Device name error Illegal device specification (for example, X:FOO.CRF)
103	Internal error Report to Microsoft Corporation
104	Internal error Report to Microsoft Corporation
105	Device offline Disk drive door open, no printer attached, or similar device is offline.
106	Internal error Report to Microsoft Corporation
108	Disk full
110	File not found
111	Disk is write protected
112	Internal error Report to Microsoft Corporation
113	Internal error Report to Microsoft Corporation
114	Internal error Report to Microsoft Corporation
115	Internal error Report to Microsoft Corporation

CHAPTER 4

FORMAT OF MS-CREF COMPATIBLE FILES

MS-CREF will process files other than those generated by Microsoft's assembler, as long as the file conforms to the valid MS-CREF format.

4.1 MS-CREF FILE PROCESSING

MS-CREF reads a stream of bytes from the cross-reference file (or source file), sorts them, then emits them as a printable listing file (the .REF file). The symbols are held in memory as a sorted tree. References to the symbols are held in a linked list.

MS-CREF keeps track of line numbers in the source file by the number of end-of-line characters it encounters. Therefore, every line in the source file must contain at least one end-of-line character (see chart below).

MS-CREF places a heading at the top of every page of the listing. The name MS-CREF uses is passed by your assembler from a TITLE (or similar) directive in your source program. The title must be followed by a title symbol (see chart below). If MS-CREF encounters more than one title symbol in the source file, it will use the last title read for all page headings. If MS-CREF does not encounter a title symbol in the file, the title line on the listing will be blank.

4.2 FORMAT OF SOURCE FILES

MS-CREF uses the first three bytes of the source file as format specification data. The rest of the file is processed as a series of records that either begin or end with a byte that identifies the type of record.

4.2.1 First Three Bytes

The PAGE directive in your assembler, which takes arguments for page length and line length, will pass the following information to the cross-reference file:

First Byte
: The number of lines to be printed per page (page length range is from 1 to 255 lines).

Second Byte
: The number of characters per line (line length range is from 1 to 132 characters).

Third Byte
: The Page Symbol (07) that tells MS-CREF that the two preceding bytes define listing page size.

If MS-CREF does not see these first three bytes in the file, it uses default values for page size (page length is 58 lines; line length is 80 characters).

4.2.2 Control Symbols

The two tables below show the types of records that MS-CREF recognizes and the byte values and placement it uses to recognize record types.

Records have a control symbol (which identifies the record type) either as the first byte of the record or as the last byte.

Records That Begin with a Control Symbol

Byte Value*	Control Symbol	Subsequent Bytes
01	Reference symbol	Record is a reference to a symbol name (1 to 80 characters)
02	Define symbol	Record is a definition of a symbol name (1 to 80 characters)
04	End-of-line	(none)
05	End-of-file	1AH

Records That End with a Control Symbol

Byte Value*	Control Symbol	Preceding Bytes
06	Title defined	Record is title text (1 to 80 characters)
07	Page length/ line length	One byte for page length followed by one byte for line length

*For all record types, the byte value represents a control character, as follows:

01	Control-A
02	Control-B
04	Control-D
05	Control-E
06	Control-F
07	Control-G

The Control Symbols are defined as follows:

Reference symbol
: Record contains the name of a symbol that is referenced. The name may be from 1 to 80 ASCII characters long. Additional characters are truncated.

Define symbol
: Record contains the name of a symbol that is defined. The name may be from 1 to 80 ASCII characters long. Additional characters are truncated.

End-of-line
: Record is an end-of-line symbol character only (04H or Control-D).

End-of-file
: Record is the end-of-file character (1AH).

Title defined
: ASCII characters of the title are to be printed at the top of each listing page. The title may be from 1 to 80 characters long. Additional characters are truncated. The last title definition record encountered is used for the title placed at the top of all pages of the listing. If a title definition record is not encountered, the title line on the listing will be left blank.

Page length/line length
: The first byte of the record contains the number of lines to be printed per page (range is from 1 to 255 lines). The second byte contains the number of characters to be printed per page (range is from 1 to 132 characters). The default page length is 58 lines. The default line length is 80 characters.

The following table illustrates CRF file record contents by byte and length of record.

Summary of CRF File Record Contents

Byte Contents	Length of Record
01 symbol_name	2-81 bytes
02 symbol_name	2-81 bytes
04	1 byte
05 1A	2 bytes
title_text 06	2-81 bytes
PL LL 07	3 bytes

INDEX

Microsoft® DEBUG

Utility

for 8086 and 8088 Microprocessors

Microsoft Corporation

System Requirements

The Microsoft DEBUG Utility requires:

A memory minimum that is program-dependent:
13K bytes for code
Run space is program-dependent

Disk drive(s):
1 disk drive if and only if output is sent to the same physical disk from which the input was taken. Microsoft DEBUG does not allow time to swap disks during operation on a one-drive configuration. Therefore, two disk drives is a more practical configuration.

Contents

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW OF DEBUG

The Microsoft DEBUG Utility (DEBUG) is a debugging program that provides a controlled testing environment for binary and executable object files. Note that EDLIN is used to alter source files; DEBUG is EDLIN's counterpart for binary files. DEBUG eliminates the need to reassemble a program to see if a problem has been fixed by a minor change. It allows you to alter the contents of a file or the contents of a CPU register, and then to immediately reexecute a program to check on the validity of the changes.

All DEBUG commands may be aborted at any time by pressing <CONTROL-C>. <CONTROL-S> suspends the display, so that you can read it before the output scrolls away. Entering any key other than <CONTROL-C> or <CONTROL-S> restarts the display. All of these commands are consistent with the control character functions available at the MS-DOS command level.

1.2 HOW TO START DEBUG

DEBUG may be started two ways. By the first method, you type all commands in response to the DEBUG prompt (a hyphen). By the second method, you type all commands on the line used to start DEBUG.

Summary of Methods to Start DEBUG

Method 1	DEBUG
Method 2	DEBUG [<filespec> [<arglist>]]

1.2.1 Method 1: DEBUG

To start DEBUG using method 1, type:

DEBUG

DEBUG responds with the hyphen (-) prompt, signaling that it is ready to accept your commands. Since no filename has been specified, current memory, disk sectors, or disk files can be worked on by using other commands.

Warnings

1. When DEBUG (Version 2.0) is started, it sets up a program header at offset 0 in the program work area. On previous versions of DEBUG, you could overwrite this header. You can still overwrite the default header if no <filespec> is given to DEBUG. If you are debugging a .COM or .EXE file, however, do not tamper with the program header below address 5CH, or DEBUG will terminate.

2. Do not restart a program after the "Program terminated normally" message is displayed. You must reload the program with the N and L commands for it to run properly.

1.2.2 Method 2: Command Line

To start DEBUG using a command line, type:

DEBUG [<filespec> [<arglist>]

For example, if a <filespec> is specified, then the following is a typical command to start DEBUG:

DEBUG FILE.EXE

DEBUG then loads FILE.EXE into memory starting at 100 hexadecimal in the lowest available segment. The BX:CX registers are loaded with the number of bytes placed into memory.

An <arglist> may be specified if <filespec> is present. The <arglist> is a list of filename parameters and switches that are to be passed to the program <filespec>. Thus, when <filespec> is loaded into memory, it is loaded as if it had been started with the command:

<filespec> <arglist>

Here, <filespec> is the file to be debugged, and the <arglist> is the rest of the command line that is used when <filespec> is invoked and loaded into memory.

CHAPTER 2

COMMANDS

2.1 COMMAND INFORMATION

Each DEBUG command consists of a single letter followed by one or more parameters. Additionally, the control characters and the special editing functions described in the MS-DOS User's Guide, apply inside DEBUG.

If a syntax error occurs in a DEBUG command, DEBUG reprints the command line and indicates the error with an up-arrow (^) and the word "error."

For example:

```
dcs:100 cs:110
    ^ error
```

Any combination of uppercase and lowercase letters may be used in commands and parameters.

The DEBUG commands are summarized in Table 2.1 and are described in detail, with examples, following the description of command parameters.

Table 2.1 DEBUG Commands

DEBUG Command	Function
A[<address>]	Assemble
C<range> <address>	Compare
D[<range>]	Dump
E<address> [<list>]	Enter
F<range> <list>	Fill
G[=<address> [<address>...]]	Go
H<value> <value>	Hex
I<value>	Input
L[<address> [<drive><record><record>]]	Load
M<range> <address>	Move
N<filename>[<filename>]	Name
O<value> <byte>	Output
Q	Quit
R[<register-name>]	Register
S<range> <list>	Search
T[=<address>][<value>]	Trace
U[<range>]	Unassemble
W[<address> [<drive><record><record>]]	Write

2.2 PARAMETERS

All DEBUG commands accept parameters, except the Quit command. Parameters may be separated by delimiters (spaces or commas), but a delimiter is required only between two consecutive hexadecimal values. Thus, the following commands are equivalent:

```
dcs:100 110
d cs:100 110
d,cs:100,110
```

PARAMETER	DEFINITION
<drive>	A one-digit hexadecimal value to indicate which drive a file will be loaded from or written to. The valid values are 0-3. These values designate the drives as follows: 0=A:, 1=B:, 2=C:, 3=D:.
<byte>	A two-digit hexadecimal value to be placed in or read from an address or register.
<record>	A 1- to 3-digit hexadecimal value used to indicate the logical record number on the disk and the number of disk sectors to be written or loaded. Logical records correspond to sectors. However, their numbering differs since they represent the entire disk space.
<value>	A hexadecimal value up to four digits used to specify a port number or the number of times a command should repeat its functions.
<address>	A two-part designation consisting of either an alphabetic segment register designation or a four-digit segment address plus an offset value. The segment designation or segment address may be omitted, in which case the default segment is used. DS is the default segment for all commands except G, L, T, U, and W, for which the default segment is CS. All numeric values are hexadecimal. For example: CS:0100 04BA:0100 The colon is required between a segment designation (whether numeric or alphabetic) and an offset.

<range> Two <address>es: e.g., <address> <address>; or one <address>, an L, and a <value>: e.g., <address> L <value> where <value> is the number of lines the command should operate on, and L80 is assumed. The last form cannot be used if another hex value follows the <range>, since the hex value would be interpreted as the second <address> of the <range>.

Examples:

```
CS:100 110
CS:100 L 10
CS:100
```

The following is illegal:

```
CS:100 CS:110
       ^ error
```

The limit for <range> is 10000 hex. To specify a <value> of 10000 hex within four digits, type 0000 (or 0).

<list> A series of <byte> values or of <string>s. <list> must be the last parameter on the command line.

Example:

```
fcs:100 42 45 52 54 41
```

<string> Any number of characters enclosed in quote marks. Quote marks may be either single (') or double("). If the delimiter quote marks must appear within a <string>, the quote marks must be doubled. For example, the following strings are legal:

```
'This is a "string" is okay.'
'This is a ''string'' is okay.'
```

However, this string is illegal:

```
'This is a 'string' is not.'
```

Similarly, these strings are legal:

```
"This is a 'string' is okay."
"This is a ""string"" is okay."
```

However, this string is illegal:

"This is a "string" is not."

Note that the double quote marks are not necessary in the following strings:

"This is a ''string'' is not necessary."
'This is a ""string"" is not necessary.'

The ASCII values of the characters in the string are used as a <list> of byte values.

NAME

Assemble

PURPOSE

Assembles 8086/8087/8088 mnemonics directly into memory.

SYNTAX

A[<address>]

COMMENTS

If a syntax error is found, DEBUG responds with

```
^Error
```

and redisplays the current assembly address.

All numeric values are hexadecimal and must be entered as 1-4 characters. Prefix mnemonics must be specified in front of the opcode to which they refer. They may also be entered on a separate line.

The segment override mnemonics are CS:, DS:, ES:, and SS:. The mnemonic for the far return is RETF. String manipulation mnemonics must explicitly state the string size. For example, use MOVSW to move word strings and MOVSB to move byte strings.

The assembler will automatically assemble short, near or far jumps and calls, depending on byte displacement to the destination address. These may be overridden with the NEAR or FAR prefix. For example:

```
0100:0500 JMP   502          ; a 2-byte short jump
0100:0502 JMP   NEAR 505     ; a 3-byte near jump
0100:505  JMP   FAR  50A     ; a 5-byte far jump
```

The NEAR prefix may be abbreviated to NE, but the FAR prefix cannot be abbreviated.

DEBUG cannot tell whether some operands refer to a word memory location or to a byte memory location. In this case, the data type must be explicitly stated with the prefix "WORD PTR" or "BYTE PTR". Acceptable abbreviations are "WO" and "BY". For example:

```
NEG     BYTE PTR [128]
DEC     WO [SI]
```

DEBUG also cannot tell whether an operand refers to a memory location or to an immediate operand. DEBUG uses the common convention that operands enclosed in square brackets refer to memory. For example:

```
MOV     AX,21           ; Load AX with 21H
MOV     AX,[21]         ; Load AX with the
                        ; contents
                        ; of memory location 21H
```

Two popular pseudo-instructions are available with Assemble. The DB opcode will assemble byte values directly into memory. The DW opcode will assemble word values directly into memory. For example:

```
DB      1,2,3,4,"THIS IS AN EXAMPLE"
DB      'THIS IS A QUOTE: "'
DB      "THIS IS A QUOTE: '"

DW      1000,2000,3000,"BACH"
```

Assemble supports all forms of register indirect commands. For example:

```
ADD     BX,34[BP+2].[SI-1]
POP     [BP+DI]
PUSH    [SI]
```

All opcode synonyms are also supported. For example:

```
LOOPZ   100
LOOPE   100

JA      200
JNBE    200
```

For 8087 opcodes, the WAIT or FWAIT must be explicitly specified. For example:

```
FWAIT FADD ST,ST(3)     ; This line will assemble
                        ; an FWAIT prefix
LD TBYTE PTR [BX]       ; This line will not
```

NAME

Compare

PURPOSE

Compares the portion of memory specified by <range> to a portion of the same size beginning at <address>.

SYNTAX

C<range> <address>

COMMENTS

If the two areas of memory are identical, there is no display and DEBUG returns with the MS-DOS prompt. If there are differences, they are displayed in this format:

<address1> <byte1> <byte2> <address2>

EXAMPLE

The following commands have the same effect:

C100,1FF 300

or

C100L100 300

Each command compares the block of memory from 100 to 1FFH with the block of memory from 300 to 3FFH.

NAME

Dump

PURPOSE

Displays the contents of the specified region of memory.

SYNTAX

D[<range>]

COMMENTS

If a range of addresses is specified, the contents of the range are displayed. If the D command is typed without parameters, 128 bytes are displayed at the first address (DS:100) after the address displayed by the previous Dump command.

The dump is displayed in two portions: a hexadecimal dump (each byte is shown in hexadecimal value) and an ASCII dump (the bytes are shown in ASCII characters). Nonprinting characters are denoted by a period (.) in the ASCII portion of the display. Each display line shows 16 bytes with a hyphen between the eighth and ninth bytes. At times, displays are split in this manual to fit them on the page. Each displayed line begins on a 16-byte boundary.

If you type the command:

```
dcs:100 110
```

DEBUG displays the dump in the following format:

```
04BA:0100 42 45 52 54 41 ... 4E 44 TOM SAWYER
```

If you type the following command:

```
D
```

the display is formatted as described above. Each line of the display begins with an address, incremented by 16 from the address on the previous line. Each subsequent D (typed without parameters) displays the bytes immediately following those last displayed.

If you type the command:

```
DCS:100 L 20
```

the display is formatted as described above, but 20H bytes are displayed.

If then you type the command:

```
DCS:100 115
```

the display is formatted as described above, but all the bytes in the range of lines from 100H to 115H in the CS segment are displayed.

NAME

Enter

PURPOSE

Enters byte values into memory at the specified <address>.

SYNTAX

E<address>[<list>]

COMMENTS

If the optional <list> of values is typed, the replacement of byte values occurs automatically. (If an error occurs, no byte values are changed.)

If the <address> is typed without the optional <list>, DEBUG displays the address and its contents, then repeats the address on the next line and waits for your input. At this point, the Enter command waits for you to perform one of the following actions:

1. Replace a byte value with a value you type. Simply type the value after the current value. If the value typed in is not a legal hexadecimal value or if more than two digits are typed, the illegal or extra character is not echoed.

2. Press the <SPACE> bar to advance to the next byte. To change the value, simply type the new value as described in (1.) above. If you space beyond an 8-byte boundary, DEBUG starts a new display line with the address displayed at the beginning.

3. Type a hyphen (-) to return to the preceding byte. If you decide to change a byte behind the current position, typing the hyphen returns the current position to the previous byte. When the hyphen is typed, a new line is started with the address and its byte value displayed.

4. Press the <RETURN> key to terminate the Enter command. The <RETURN> key may be pressed at any byte position.

EXAMPLE

Assume that the following command is typed:

```
ECS:100
```

DEBUG displays:

```
04BA:0100  EB._
```

To change this value to 41, type 41 as shown:

```
04BA:0100  EB.41_
```

To step through the subsequent bytes, press the <SPACE> bar to see:

```
04BA:0100  EB.41    10.    00.    BC._
```

To change BC to 42:

```
04BA:0100  EB.41    10.    00.    BC.42_
```

Now, realizing that 10 should be 6F, type the hyphen as many times as needed to return to byte 0101 (value 10), then replace 10 with 6F:

```
04BA:0100  EB.41    10.    00.    BC.42-
04BA:0102  00.-_
04BA:0101  10.6F_
```

Pressing the <RETURN> key ends the Enter command and returns to the DEBUG command level.

NAME

Fill

PURPOSE

Fills the addresses in the <range> with the values in the <list>.

SYNTAX

F<range> <list>

COMMENTS

If the <range> contains more bytes than the number of values in the <list>, the <list> will be used repeatedly until all bytes in the <range> are filled. If the <list> contains more values than the number of bytes in the <range>, the extra values in the <list> will be ignored. If any of the memory in the <range> is not valid (bad or nonexistent), the error will occur in all succeeding locations.

EXAMPLE

Assume that the following command is typed:

```
F04BA:100 L 100 42 45 52 54 41
```

DEBUG fills memory locations 04BA:100 through 04BA:1FF with the bytes specified. The five values are repeated until all 100H bytes are filled.

NAME

Go

PURPOSE

Executes the program currently in memory.

SYNTAX

G[=<address>[<address>...]]

COMMENTS

If only the Go command is typed, the program executes as if the program had run outside DEBUG.

If =<address> is set, execution begins at the address specified. The equal sign (=) is required, so that DEBUG can distinguish the start =<address> from the breakpoint <address>es.

With the other optional addresses set, execution stops at the first <address> encountered, regardless of that address' position in the list of addresses to halt execution or program branching. When program execution reaches a breakpoint, the registers, flags, and decoded instruction are displayed for the last instruction executed. (The result is the same as if you had typed the Register command for the breakpoint address.)

Up to ten breakpoints may be set. Breakpoints may be set only at addresses containing the first byte of an 8086 opcode. If more than ten breakpoints are set, DEBUG returns the BP Error message.

The user stack pointer must be valid and have 6 bytes available for this command. The G command uses an IRET instruction to cause a jump to the program under test. The user stack pointer is set, and the user flags, Code Segment register, and Instruction Pointer are pushed on the user stack. (Thus, if the user stack is not valid or is too small, the operating system may crash.) An interrupt code (0CCH) is placed at the specified breakpoint address(es).

When an instruction with the breakpoint code is encountered, all breakpoint addresses are restored to their original instructions. If execution is not halted at one of the breakpoints, the interrupt codes are not replaced with the original instructions.

EXAMPLE

Assume that the following command is typed:

```
GCS:7550
```

The program currently in memory executes up to the address 7550 in the CS segment. DEBUG then displays registers and flags, after which the Go command is terminated.

After a breakpoint has been encountered, if you type the Go command again, then the program executes just as if you had typed the filename at the MS-DOS command level. The only difference is that program execution begins at the instruction after the breakpoint rather than at the usual start address.

NAME

Hex

PURPOSE

Performs hexadecimal arithmetic on the two parameters specified.

SYNTAX

H<value> <value>

COMMENTS

First, DEBUG adds the two parameters, then subtracts the second parameter from the first. The results of the arithmetic are displayed on one line; first the sum, then the difference.

EXAMPLE

Assume that the following command is typed:

```
H19F 10A
```

DEBUG performs the calculations and then displays the result:

```
02A9   0095
```

NAME

Input

PURPOSE

Inputs and displays one byte from the port specified by <value>.

SYNTAX

```
I<value>
```

COMMENTS

A 16-bit port address is allowed.

EXAMPLE

Assume that you type the following command:

```
I2F8
```

Assume also that the byte at the port is 42H. DEBUG inputs the byte and displays the value:

```
42
```

NAME

Load

PURPOSE

Loads a file into memory.

SYNTAX

L[<address> [<drive> <record> <record>]]

COMMENTS

Set BX:CX to the number of bytes read. The file must have been named either when DEBUG was started or with the N command. Both the DEBUG invocation and the N command format a filename properly in the normal format of a file control block at CS:5C.

If the L command is typed without any parameters, DEBUG loads the file into memory beginning at address CS:100 and sets BX:CX to the number of bytes loaded. If the L command is typed with an address parameter, loading begins at the memory <address> specified. If L is typed with all parameters, absolute disk sectors are loaded, not a file. The <record>s are taken from the <drive> specified (the drive designation is numeric here--0=A:, 1=B:, 2=C:, etc.); DEBUG begins loading with the first <record> specified, and continues until the number of sectors specified in the second <record> have been loaded.

EXAMPLE

Assume that the following commands are typed:

```
A>DEBUG
-NFILE.COM
```

Now, to load FILE.COM, type:

```
L
```

DEBUG loads the file and then displays the DEBUG prompt. Assume that you want to load only portions of a file or certain records from a disk. To do this, type:

```
L04BA:100 2 0F 6D
```

DEBUG then loads 109 (6D hex) records beginning with logical record number 15 into memory beginning at address 04BA:0100. When the records have been loaded, DEBUG simply returns the - prompt.

If the file has a .EXE extension, it is relocated to the load address specified in the header of the .EXE file: the <address> parameter is always ignored for .EXE files. The header itself is stripped off the .EXE file before it is loaded into memory. Thus the size of an .EXE file on disk will differ from its size in memory.

If the file named by the Name command or specified when DEBUG is started is a .HEX file, then typing the L command with no parameters causes DEBUG to load the file beginning at the address specified in the .HEX file. If the L command includes the option <address>, DEBUG adds the <address> specified in the L command to the address found in the .HEX file to determine the start address for loading the file.

NAME

Move

PURPOSE

Moves the block of memory specified by <range> to the location beginning at the <address> specified.

SYNTAX

M<range> <address>

COMMENTS

Overlapping moves (i.e., moves where part of the block overlaps some of the current addresses) are always performed without loss of data. Addresses that could be overwritten are moved first. The sequence for moves from higher addresses to lower addresses is to move the data beginning at the block's lowest address and then to work towards the highest. The sequence for moves from lower addresses to higher addresses is to move the data beginning at the block's highest address and to work towards the lowest.

Note that if the addresses in the block being moved will not have new data written to them, the data there before the move will remain. The M command copies the data from one area into another, in the sequence described, and writes over the new addresses. This is why the sequence of the move is important.

EXAMPLE

Assume that you type:

```
MCS:100 110 CS:500
```

DEBUG first moves address CS:110 to address CS:510, then CS:10F to CS:50F, and so on until CS:100 is moved to CS:500. You should type the D command, using the <address> typed for the M command, to review the results of the move.

NAME

Name

PURPOSE

Sets filenames.

SYNTAX

N<filename>[<filename>...]

COMMENTS

The Name command performs two functions. First, Name is used to assign a filename for a later Load or Write command. Thus, if you start DEBUG without naming any file to be debugged, then the N<filename> command must be typed before a file can be loaded. Second, Name is used to assign filename parameters to the file being debugged. In this case, Name accepts a list of parameters that are used by the file being debugged.

These two functions overlap. Consider the following set of DEBUG commands:

```
-NFILE1.EXE
-L
-G
```

Because of the effects of the Name command, Name will perform the following steps:

1. (N)ame assigns the filename FILE1.EXE to the filename to be used in any later Load or Write commands.

2. (N)ame also assigns the filename FILE1.EXE to the first filename parameter used by any program that is later debugged.

3. (L)oad loads FILE1.EXE into memory.

4. (G)o causes FILE1.EXE to be executed with FILE1.EXE as the single filename parameter (that is, FILE1.EXE is executed as if FILE1.EXE had been typed at the command level).

A more useful chain of commands might look like this:

```
-NFILE1.EXE
-L
-NFILE2.DAT FILE3.DAT
-G
```

Here, Name sets FILE1.EXE as the filename for the subsequent Load command. The Load command loads FILE1.EXE into memory, and then the Name command is used again, this time to specify the parameters to be used by FILE1.EXE. Finally, when the Go command is executed, FILE1.EXE is executed as if FILE1 FILE2.DAT FILE3.DAT had been typed at the MS-DOS command level. Note that if a Write command were executed at this point, then FILE1.EXE--the file being debugged--would be saved with the name FILE2.DAT! To avoid such undesired results, you should always execute a Name command before either a Load or a Write.

There are four regions of memory that can be affected by the Name command:

```
CS:5C  FCB for file 1
CS:6C  FCB for file 2
CS:80  Count of characters
CS:81  All characters typed
```

A File Control Block (FCB) for the first filename parameter given to the Name command is set up at CS:5C. If a second filename parameter is typed, then an FCB is set up for it beginning at CS:6C. The number of characters typed in the Name command (exclusive of the first character, "N") is given at location CS:80. The actual stream of characters given by the Name command (again, exclusive of the letter "N") begins at CS:81. Note that this stream of characters may contain switches and delimiters that would be legal in any command typed at the MS-DOS command level.

EXAMPLE

A typical use of the Name command is:

```
DEBUG PROG.COM
-NPARAM1 PARAM2/C
-G
-
```

In this case, the Go command executes the file in memory as if the following command line had been typed:

```
PROG PARAM1 PARAM2/C
```

Testing and debugging therefore reflect a normal runtime environment for PROG.COM.

NAME

Output

PURPOSE

Sends the <byte> specified to the output port specified by <value>.

SYNTAX

O<value> <byte>

COMMENTS

A 16-bit port address is allowed.

EXAMPLE

Type:

```
O2F8 4F
```

DEBUG outputs the byte value 4F to output port 2F8.

NAME

Quit

PURPOSE

Terminates the DEBUG utility.

SYNTAX

Q

COMMENTS

The Q command takes no parameters and exits DEBUG without saving the file currently being operated on. You are returned to the MS-DOS command level.

EXAMPLE

To end the debugging session, type:

Q<RETURN>

DEBUG has been terminated, and control returns to the MS-DOS command level.

NAME

Register

PURPOSE

Displays the contents of one or more CPU registers.

SYNTAX

R[<register-name>]

COMMENTS

If no <register-name> is typed, the R command dumps the register save area and displays the contents of all registers and flags.

If a register name is typed, the 16-bit value of that register is displayed in hexadecimal, and then a colon appears as a prompt. You then either type a <value> to change the register, or simply press the <RETURN> key if no change is wanted.

The only valid <register-name>s are:

AX	BP	SS	
BX	SI	CS	
CX	DI	IP	(IP and PC both refer
DX	DS	PC	to the Instruction
SP	ES	F	Pointer.)

Any other entry for <register-name> results in a BR Error message.

If F is entered as the <register-name>, DEBUG displays each flag with a two-character alphabetic code. To alter any flag, type the opposite two-letter code. The flags are either set or cleared.

The flags are listed below with their codes for SET and CLEAR:

FLAG NAME	SET	CLEAR
Overflow	OV	NV
Direction	DN Decrement	UP Increment
Interrupt	EI Enabled	DI Disabled
Sign	NG Negative	PL Plus
Zero	ZR	NZ
Auxiliary Carry	AC	NA
Parity	PE Even	PO Odd
Carry	CY	NC

Whenever you type the command RF, the flags are displayed in the order shown above in a row at the beginning of a line. At the end of the list of flags, DEBUG displays a hyphen (-). You may enter new flag values as alphabetic pairs. The new flag values can be entered in any order. You do not have to leave spaces between the flag entries. To exit the R command, press the <RETURN> key. Flags for which new values were not entered remain unchanged.

If more than one value is entered for a flag, DEBUG returns a DF Error message. If you enter a flag code other than those shown above, DEBUG returns a BF Error message. In both cases, the flags up to the error in the list are changed; flags at and after the error are not.

At startup, the segment registers are set to the bottom of free memory, the Instruction Pointer is set to 0100H, all flags are cleared, and the remaining registers are set to zero.

EXAMPLE

Type:

```
R
```

DEBUG displays all registers, flags, and the decoded instruction for the current location. If the location is CS:11A, then the display will look similar to this:

```
AX=0E00 BX=00FF CX=0007 DX=01FF SP=039D BP=0000
SI=005C DI=0000 DS=04BA ES=04BA SS=04BA CS=04BA
IP=011A  NV UP DI NG NZ AC PE NC
04BA:011A  CD21           INT     21
```

If you type:

```
RF
```

DEBUG will display the flags:

```
NV UP DI NG NZ AC PE NC - _
```

Now, type any valid flag designation, in any order, with or without spaces.

For example:

```
NV UP DI NG NZ AC PE NC - PLEICY<RETURN>
```

DEBUG responds only with the DEBUG prompt. To see the changes, type either the R or RF command:

```
RF
NV UP EI PL NZ AC PE CY - _
```

Press <RETURN> to leave the flags this way, or to specify different flag values.

NAME

Search

PURPOSE

Searches the <range> specified for the <list> of bytes specified.

SYNTAX

```
S<range> <list>
```

COMMENTS

The <list> may contain one or more bytes, each separated by a space or comma. If the <list> contains more than one byte, only the first address of the byte string is returned. If the <list> contains only one byte, all addresses of the byte in the <range> are displayed.

EXAMPLE

If you type:

```
SCS:100 110 41
```

DEBUG will display a response similar to this:

```
04BA:0104
04BA:010D
-type:
```

NAME

Trace

PURPOSE

Executes one instruction and displays the contents of all registers and flags, and the decoded instruction.

SYNTAX

T[=<address>][<value>]

COMMENTS

If the optional =<address> is typed, tracing occurs at the =<address> specified. The optional <value> causes DEBUG to execute and trace the number of steps specified by <value>.

The T command uses the hardware trace mode of the 8086 or 8088 microprocessor. Consequently, you may also trace instructions stored in ROM (Read Only Memory).

EXAMPLE

Type:

```
T
```

DEBUG returns a display of the registers, flags, and decoded instruction for that one instruction. Assume that the current position is 04BA:011A; DEBUG might return the display:

```
AX=0E00 BX=00FF CX=0007 DX=01FF SP=039D BP=0000
SI=005C DI=0000 DS=04BA ES=04BA SS=04BA CS=04BA
IP=011A  NV UP DI NG NZ AC PE NC
04BA:011A  CD21           INT     21
```

If you type

```
T=011A 10
```

DEBUG executes sixteen (10 hex) instructions beginning at 011A in the current segment, and then displays all registers and flags for each instruction as it is executed. The display scrolls away until the last instruction is executed. Then the display stops, and you can see the register and flag values for the last few instructions performed. Remember that <CONTROL-S> suspends the display at any point, so that you can study the registers and flags for any instruction.

NAME

Unassemble

PURPOSE

Disassembles bytes and displays the source statements that correspond to them, with addresses and byte values.

SYNTAX

U[<range>]

COMMENTS

The display of disassembled code looks like a listing for an assembled file. If you type the U command without parameters, 20 hexadecimal bytes are disassembled at the first address after that displayed by the previous Unassemble command. If you type the U command with the <range> parameter, then DEBUG disassembles all bytes in the range. If the <range> is given as an <address> only, then 20H bytes are disassembled instead of 80H.

EXAMPLE

Type:

```
U04BA:100 L10
```

DEBUG disassembles 16 bytes beginning at address 04BA:0100:

```
04BA:0100  206472   AND  [SI+72],AH
04BA:0103  69       DB   69
04BA:0104  7665     JBE  016B
04BA:0106  207370   AND  [BP+DI+70],DH
04BA:0109  65       DB   65
04BA:010A  63       DB   63
04BA:010B  69       DB   69
04BA:010C  66       DB   66
04BA:010D  69       DB   69
04BA:010E  63       DB   63
04BA:010F  61       DB   61
```

If you type

```
U04ba:0100 0108
```

The display will show:

```
04BA:0100  206472     AND  [SI+72],AH
04BA:0103  69         DB   69
04BA:0104  7665       JBE  016B
04BA:0106  207370     AND  [BP+DI+70],DH
```

If the bytes in some addresses are altered, the disassembler alters the instruction statements. The U command can be typed for the changed locations, the new instructions viewed, and the disassembled code used to edit the source file.

NAME

Write

PURPOSE

Writes the file being debugged to a disk file.

SYNTAX

W[<address>[<drive> <record> <record>]]

COMMENTS

If you type W with no parameters, BX:CX must already be set to the number of bytes to be written; the file is written beginning from CS:100. If the W command is typed with just an address, then the file is written beginning at that address. If a G or T command has been used, BX:CX must be reset before using the Write command without parameters. Note that if a file is loaded and modified, the name, length, and starting address are all set correctly to save the modified file (as long as the length has not changed).

The file must have been named either with the DEBUG invocation command or with the N command (refer to the Name command earlier in this manual). Both the DEBUG invocation and the N command format a filename properly in the normal format of a file control block at CS:5C.

If the W command is typed with parameters, the write begins from the memory address specified; the file is written to the <drive> specified (the drive designation is numeric here--0=A:, 1=B:, 2=C:, etc.); DEBUG writes the file beginning at the logical record number specified by the first <record>; DEBUG continues to write the file until the number of sectors specified in the second <record> have been written.

WARNING

Writing to absolute sectors is EXTREMELY dangerous because the process bypasses the file handler.

EXAMPLE

Type:

```
W
```

DEBUG will write the file to disk and then display the DEBUG prompt. Two examples are shown below.

```
W
-_
```

```
WCS:100 1 37 2B
```

DEBUG writes out the contents of memory, beginning with the address CS:100 to the disk in drive B:. The data written out starts in disk logical record number 37H and consists of 2BH records. When the write is complete, DEBUG displays the prompt:

```
WCS:100 1 37 2B
-_
```

2.3 ERROR MESSAGES

During the DEBUG session, you may receive any of the following error messages. Each error terminates the DEBUG command under which it occurred, but does not terminate DEBUG itself.

ERROR CODE	DEFINITION
BF	Bad flag You attempted to alter a flag, but the characters typed were not one of the acceptable pairs of flag values. See the Register command for the list of acceptable flag entries.
BP	Too many breakpoints You specified more than ten breakpoints as parameters to the G command. Retype the Go command with ten or fewer breakpoints.
BR	Bad register You typed the R command with an invalid register name. See the Register command for the list of valid register names.
DF	Double flag You typed two values for one flag. You may specify a flag value only once per RF command.

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