microsoft fortran-80 documentation

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Microsoft FORTRAN-80 and associated software are accompanied by the following documents:

1. FORTRAN-80 REFERENCE MANUAL
   provides an extensive description of FORTRAN-80's statements, functions and syntax.

2. FORTRAN-80 USER'S MANUAL
   describes the FORTRAN-80 compiler commands and error messages.

3. MICROSOFT UTILITY SOFTWARE MANUAL
   describes the use of the MACRO-80 Assembler, LINK-80 Linking Loader, and LIB-80 Library Manager with the FORTRAN-80 compiler.

To report software bugs or errors in the documentation, please complete and return the Problem Report at the back of this manual.

MICROSOFT FORTRAN-80

THE MOST COMPLETE IMPLEMENTATION OF THE FORTRAN LANGUAGE FOR 8080 AND Z80 MICROPROCESSORS.

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FORTRAN-80

Microsoft FORTRAN-80 brings the most popular science and engineering programming language to 8080/Z80 microcomputers. FORTRAN-80 is comparable to FORTRAN compilers on large mainframes and minicomputers. The FORTRAN-80 package includes full ANSI Standard FORTRAN X3.9-1966 except the COMPLEX data type.

FORTRAN-80 ENHANCES THE 1966 ANSI STANDARD IN SEVERAL WAYS:

- Single byte LOGICAL variables which can be used as integer quantities in the range +127 to −127.
- DO loops which use LOGICAL variables for tighter, faster execution of small loops.
- Mixed mode arithmetic expressions.
- Hexadecimal constants.
- Hollerith (character) literals accepted.
- Logical operations on integer data. . AND., .OR., .NOT., .XOR. can be used for 8-bit, 16-bit, or 32-bit Boolean operations.
- READ/WRITE End of File or Error Condition transfer. END=n and ERR=n (where n is the statement number) can be included in READ or WRITE statements to transfer control to the statement specified by n when an error or file end is detected.
- ENCODE/DECODE for FORMAT operations to memory.
- IMPLICIT statement for redefining default variable types by specifying a type and a range of initial letters.
- INCLUDE statement for including commonly used subroutines, code, or declarations from another file.
- INTEGER*4 variables and constants using 32 bits in the range of +2,147,483,647 to −2,147,483,648.
- Support for CP/M version 2.x providing access to a maximum of 65,536 records in a file as large as 8 megabytes.

FORTRAN-80 COMPILER

FORTRAN-80 compiles several hundred statements per minute in a single pass. It requires no more than 27K bytes of memory to compile most programs. Additional memory, when available, is used for symbol table storage and optimizations. Compiled programs are relocatable modules that are linked and loaded at runtime.

The FORTRAN-80 compiler optimizes the generated object code as follows:

Common Subexpression Elimination.
Common subexpressions are evaluated once; the value is automatically substituted in subsequent occurrences of the subexpression.

Peephole Optimization.
In special cases, small sections of code can be replaced by more compact code. Example: I=I+1 uses an INX H instruction instead of a DAD.

Constant Folding.
Integer constant expressions are evaluated at compile time.

Branch Optimizations.
The number of conditional jumps in arithmetic and logical IFs is minimized.

The compiler also provides diagnostic output. Descriptive error messages include the preceding twenty characters. At program's end, the compiler generates an error summary. A fully symbolic listing of the generated machine language is also produced. This is supplemented by tables of addresses assigned to labels, variables and constants.

SUBROUTINE LIBRARY

FORTRAN-80 supplies an extensive library of efficient subroutines. Only the necessary subroutines are loaded at runtime. The LIB-80 standard library includes:

ABS	DATAN	DSIN	MAX1
AINT	DATAN2	DSQRT	MIN0
ALOG	DBLE	EXP	MIN1
ALOG10	DCOS	FIX	MOD
AMAX0	DEXP	FLOAT	OUT
AMAX1	DIM	IABS	PEEK
AMIN0	DLOG	IDIM	POKE
AMIN1	DLOG10	IDINT	SIGN
AMOD	DMAX1	INP	SIN
ATAN	DMIN1	INT	SNGL
ATAN2	DMOD	ISIGN	SQRT
COS	DSIGN	MAX0	TANH
DABS			

The library also contains efficient routines for 16-bit and 32-bit integer arithmetic and 32-bit and 64-bit floating point arithmetic.

ASSEMBLER AND LINKER

The FORTRAN-80 package includes the MACRO-80 relocating macro assembler and LINK-80 relocating linking loader.

MACRO-80 relocating assembler resides in approximately 19K. It includes a complete Intel-standard macro facility with IRP, IRPC, REPEAT, local variables and EXITM. MACRO-80 also provides a full set of conditional pseudo-operations, conditional listing control, comment blocks, octal or hex listings and a variable input radix. The assembler accepts both Intel 8080 and Zilog Z80 mnemonics.

LINK-80 relocating loader resolves external references between object modules. LINK-80 performs library searches for system subroutines. It also generates a memory load map displaying the locations of the main program, subroutines and COMMON areas. LINK-80 requires approximately 10K bytes of memory.

CUSTOM I/O DRIVERS

Users may write non-standard I/O drivers for each Logical Unit Number, so interfacing non-standard devices to FORTRAN programs is straightforward.

THE FORTRAN-80 SYSTEM

Versions of FORTRAN-80 are available for various operating systems including Digital Research CP/M®, Tektronix TEKDOS, Intel™ ISIS II, Radio Shack TRSDOS™ Model I and Model II, GenRad RDOS and many others. Microsoft welcomes the opportunity to adapt FORTRAN-80 to OEM systems.

Updates to FORTRAN-80 are announced periodically and are available for a minimal charge.

FORTRAN-80 system (including documentation):	$500.00
FORTRAN-80 documentation only:	$ 20.00

OEM and dealer agreements are available upon request.

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Addendum to: FORTRAN-80 Reference Manual

Random Number Generator

A new function, RAN, has been added to the FORTRAN library routines listed in Table 9-2. RAN is a random number generator that is compatible with Microsoft's BASIC Compiler and BASIC-80 Interpreter. The random number generated is a REAL decimal number between 0 and 1.

The random number generator is called by a statement of the following form:

```
<variable> = RAN(x)
```

If x < 0, the first value of a new sequence of random numbers is returned.

If X = 0, the last random number generated is returned again.

If x > 0, the next random number in the sequence is generated.

ADDENDUM TO: FORTRAN-80 Reference Manual
INTEGER*4 Variables

There are the following restrictions on the use of the new INTEGER*4 extended integer data type:

1. INTEGER*4 variables cannot be used as Logical Unit Numbers in READ or WRITE statements.

2. INTEGER*4 variables cannot be used as array indices.

3. INTEGER*4 variables cannot be used as indices in implied DO loops.

4. INTEGER*4 variables cannot be used in computed or assigned GOTO statements.

fortran-80 user's manual

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fortran-80 user's manual

8202-342-02

Microsoft FORTRAN-80, Release 3.43 July, 1981

Addendum to: FORTRAN-80 User's Manual
(for CP/M Operating Systems)

Add to Section 1.2, Command Format

The FORTRAN-80 Compiler now accepts lower case filenames and device codes at the asterik prompt level.

Add to Section 2.2, FORTRAN Runtime Error Messages

The fatal run-time error **FN** has been removed. This error occured when the program attempted to read a non-existant file. The new DSKDRV.MAC now allows the programmer to use the "ERR=" switch in the READ statement to trap this error. If the "ERR=" switch is not used in the READ statement, and a read is attempted on a non existent file, a fatal error, **IO**, will occur.

ADDENDUM TO: Microsoft FORTRAN-80 User's Manual
Section 4
TEKDOS Release 3.1

If you are using TEKDOS version 3.1 and wish to have line feeds inserted in compiler print listings that are sent directly to the printer, make the following patch in the FORTRAN version 3.4 compiler:

Using the TEKDOS DEBUG program, insert 00 hex (NOP) in locations 2A95 hex, 2A96 hex, and 2A97 hex.

This patch will enable users of printers without an auto-linefeed function to print compiled listings properly.

Microsoft
FORTRAN-80 User's Manual

CONTENTS

SECTION 1

Compiling FORTRAN Programs

1.1 Running the FORTRAN-80 Compiler

The command to run FORTRAN-80 is

```
F80
```

FORTRAN-80 returns the prompt "*", indicating it is ready to accept commands.

NOTE

If you are using the TEKDOS operating system, see Section 4 for proper command formats.

1.2 Command Format

A command to FORTRAN-80 consists of a string of filenames with optional switches. All filenames should follow the operating system's conventions for filenames and extensions. The default extensions supplied by Microsoft software are as follows:

File	CP/M	ISIS-II
FORTRAN source file	FOR	FOR
COBOL source	COB	COB
MACRO-80 source file	MAC	MAC
Relocatable object file	REL	REL
Listing file	PRN	LST
Absolute file	COM	

A command to FORTRAN-80 conveys the name of the source file to be compiled, the names of the file(s) to be created, and which options are desired. The format of an FORTRAN-80 command is:

```
objfile,lstfile=source file
```

Only the equal sign and the source file field are required to create a relocatable object file with the default (source) filename and the default extension REL.

Otherwise, an object file is created only if the

objfile field is filled, and a listing file is created only if the lstfile field is filled.

To compile the source file without producing an object file or listing file, place only a comma to the left of the equal sign. This is a handy procedure that lets you check for syntax errors before compiling to an object file.

Examples:

*=TEST	Compile the program TEST.FOR and place the object file in TEST.REL
*TESTOBJ=TEST.FOR	Compile the program TEST.FOR and place the object file in TESTOBJ.REL
*TEST,TEST=TEST	Compile TEST.FOR, placing the object file in TEST.REL and the listing file in TEST.PRN. (With ISIS-II, the listing file is TEST.LST.)
*,=TEST.FOR	Compile TEST.FOR without creating an object or listing file. Useful for error check.

1.2.1 Devices

Any field in the FORTRAN-80 command string can also specify a device name. The default device name with the CP/M operating system is the currently logged disk. The default device name with the ISIS-II operating system is disk drive 0. The command format is:

dev:objfile,dev:lstfile=dev:source file

The device names are as follows:

Device	CP/M	ISIS-II
Disk drives	A:, B:, C:,...	:F0:, :F1:, :F2:, ...
Line printer	LST:	LST:
Console	TTY:	TTY:
High speed reader	HSR	

Examples:

*,TTY:=TEST	Compile the source file TEST.FOR and list the program on the console. No object code is generated. Useful for error check.
*SMALL,TTY:=B:TEST	Compile TEST.FOR (found on disk drive B), place the object file in SMALL.REL, and list the program on the console.

1.2.2 FORTRAN-80 Compilation Switches

A switch is a letter that is appended to the command string, preceded by a slash. It specifies an optional task to be performed during compilation. More than one switch can be used, but each must be preceded by a slash. (With the TEKDOS operating system, switches are preceded by commas or spaces. See Section 4.)
All switches are optional.

The available switches are:

Switch	Action
O	Print all listing addresses, etc. in octal.
H	Print all listing addresses, etc. in hexadecimal. (Default)
N	Do not list generated code.
R	Force generation of an object file.
L	Force generation of a listing file.
P	Each /P allocates an extra 100 bytes of stack space for use during compilation. Use /P if stack overflow errors occur during compilation. Otherwise not needed.

M	Specifies to the compiler that the generated code should be in a form which can be loaded into ROMs. When a /M is specified, the generated code will differ from normal in the following ways: 1. FORMATs will be placed in the program area, with a "JMP" around them. 2. Parameter blocks (for subprogram calls with more than 3 parameters) will be initialized at runtime, rather than being initialized by the loader.

Examples:

*,TTY:=MYPROG/N	Compile file MYPROG.FOR and list program on terminal but without generated code.
*=TEST/L	Compile TEST.FOR to create object file TEST.REL and listing file TEST.PRN. (With ISIS-II, the listing file is TEST.LST.)
*=BIGGONE/P/P	Compile file BIGGONE.FOR and produce object file BIGGONE.REL. Compiler is allocated 200 extra bytes of stack space.

1.3 Programs in ROM

If a FORTRAN program is intended for ROM, the programmer should be aware of the following ramifications:

1. DATA statements should not be used to initialize RAM. Such initialization is done by the loader, and will therefore not be present at execution. Variables and arrays may be initialized during execution via assignment statements, or by READing into them.

2. FORMATs should not be read into during execution.

3. If the standard library I/O routines are used, DISK files should not be OPENed on any LUNs other than 6, 7, 8, 9, 10. If other LUNs are needed for Disk I/O, $LUNTB should be recompiled with the appropriate addresses pointing to the Disk driver routine.

A library routine, $INIT, sets the stack pointer at the top of available memory (as indicated by the operating system) before execution begins.

The calling convention is:

```
LXI     B,<return address>
JMP     $INIT
```

If the generated code is intended for some other machine, this routine should probably be rewritten. The source of the standard initialize routine is provided on the disk as "INIT.MAC". Only the portion of this routine which sets up the stack pointer should ever be modified by the user. The FORTRAN library already contains the standard initialize routine.

1.4 Sample Compilation

```
A>F80

*EXAMPL,TTY:=EXAMPL

FORTRAN-80 Ver. 3.3 Copyright 1979 (C) By Microsoft - Bytes: 4524
00100            PROGRAM EXAMPLE
00200            INTEGER X
00300            I = 2**8 + 2**9 + 2**10
00400            DO 1 J=1,5
*****   0000'    LXI     H,0700
*****   0003'    SHLD    I
00500   C        CIRCULAR SHIFT I LEFT 3 BITS -- RESULT IN X
00600            CALL CSL3(I,X)
*****   0006'    LXI     H,0001
*****   0009'    SHLD    J
00700            WRITE(3,10) I,X
*****   000C'    LXI     D,X
*****   000F'    LXI     H,I
*****   0012'    CALL    CSL3
*****   0015'    LXI     D,10L
*****   0018'    LXI     H,[     03      00]
*****   001B'    CALL    $W2
00800   1        I=X
*****   001E'    LXI     B,X
*****   0021'    LXI     D,I
*****   0024'    LXI     H,[     01      00]
*****   0027'    MVI     A,03
*****   0029'    CALL    $I0
*****   002C'    CALL    $ND
00900   10       FORMAT(2I15)
*****   002F'    LHLD    X
*****   0032'    SHLD    I
*****   0035'    LHLD    J
*****   0038'    INX     H
*****   0039'    MVI     A,05
*****   003B'    SUB     L
*****   003C'    MVI     A,00
*****   003E'    SBB     H
*****   003F'    JP      0009'
01000            END
*****   0042'    CALL    $EX
*****   0045'    0100
*****   0047'    0300

Program Unit Length=0049 (73) Bytes
Data Area Length=000D (13) Bytes

Subroutines Referenced:

$I0                     CSL3                    $W2
$ND                     $EX
```

```
Variables:

X       0001"           I       0003"                   J 0005"

LABELS:

1L      002F'           10L     0007"

*^C
A>
```

See Section 2.9 of the Microsoft Utility Software Manual for a listing of the MACRO-80 subroutine CSL3.

SECTION 2

Error Messages

2.1 FORTRAN Compiler Error Messages

The FORTRAN-80 Compiler detects two kinds of errors: Warnings and Fatal Errors. When a Warning is issued, compilation continues with the next item on the source line. When a Fatal Error is found, the compiler ignores the rest of the logical line, including any continuation lines. Warning messages are preceded by percent signs (%), and Fatal Errors by question marks (?). The editor line number, if any, or the physical line number is printed next. It is followed by the error code or error message and the last 20 characters scanned at the time the error was detected.

Example:

```
?Line 25: Mismatched Parentheses: I=(I+J))
%Line 16: Missing Integer Variable: I(2*2,
```

When either type of error occurs, the program should be changed so that it compiles without errors. No guarantee is made that a program that compiles with errors will execute sensibly.

Fatal Errors:

Error Number	Message
100	Illegal Statement Number
101	Statement Unrecognizable or Misspelled
102	Illegal Statement Completion
103	Illegal DO Nesting
104	Illegal Data Constant
105	Missing Name
106	Illegal Procedure Name
107	Invalid DATA Constant or Repeat Factor
108	Incorrect Number of DATA Constants
109	Incorrect Integer Constant
110	Invalid Statement Number
111	Not a Variable Name
112	Illegal Logical Form Operator
113	Data Pool Overflow
114	Literal String Too Large
115	Invalid Data List Element in I/O
116	Unbalanced DO Nest
117	Identifier Too Long
118	Illegal Operator
119	Mismatched Parenthesis

```
120   Consecutive Operators
121   Improper Subscript Syntax
122   Illegal Integer Quantity
123   Illegal Hollerith Construction
124   Backwards DO reference
125   Illegal Statement Function Name
126   Illegal Character for Syntax
127   Statement Out of Sequence
128   Missing Integer Quantity
129   Invalid Logical Operator
130   Illegal Item Following INTEGER or
         REAL or LOGICAL
131   Premature End Of File on Input Device
132   Illegal Mixed Mode Operation
133   Function Call with No Parameters
134   Stack Overflow
135   Illegal Statement Following Logical IF
136   Wrong Number of Subscripts
137   File Not Found
```

Warnings:

```
0     Duplicate Statement Label
1     Illegal DO Termination
2     Block Name = Procedure Name
3     Array Name Misuse
4     COMMON Name Usage
5     Wrong Number of Subscripts
6     Array Multiply EQUIVALENCEd within a Group
7     Multiple EQUIVALENCE of COMMON
8     COMMON Base Lowered
9     Non-COMMON Variable in BLOCK DATA
10    Empty List for Unformatted WRITE
11    Non-Integer Expression
12    Operand Mode Not Compatible with Operator
13    Mixing of Operand Modes Not Allowed
14    Missing Integer Variable
15    Missing Statement Number on FORMAT
16    Zero Repeat Factor
17    Zero Format Value
18    Format Nest Too Deep
19    Statement Number Not FORMAT Associated
20    Invalid Statement Number Usage
21    No Path to this Statement
22    Missing Do Termination
23    Code Output in BLOCK DATA
24    Undefined Labels Have Occurred
25    RETURN in a Main Program
26    STATUS Error on READ
27    Invalid Operand Usage
28    Function with no Parameter
29    Hex Constant Overflow
30    Division by Zero
32    Array Name Expected
33    Illegal Argument to ENCODE/DECODE
```

2.2 FORTRAN Runtime Error Messages

Code	Meaning
Warning Errors:	
IB	Input Buffer Limit Exceeded
TL	Too Many Left Parentheses in FORMAT
OB	Output Buffer Limit Exceeded
DE	Decimal Exponent Overflow (Number in input stream had an exponent larger than 99)
IS	Integer Size Too Large
BE	Binary Exponent Overflow
IN	Input Record Too Long
OV	Arithmetic Overflow
CN	Conversion Overflow on REAL to INTEGER Conversion
SN	Argument to SIN Too Large
A2	Both Arguments of ATAN2 are 0
IO	Illegal I/O Operation
BI	Buffer Size Exceeded During Binary I/O
RC	Negative Repeat Count in FORMAT
FW	FORMAT Field Width is Too Small
Fatal Errors:	
ID	Illegal FORMAT Descriptor
F0	FORMAT Field Width is Zero
MP	Missing Period in FORMAT
IR	Real Number Written to INTEGER Format Field
IT	I/O Transmission Error
ML	Missing Left Parenthesis in FORMAT
DZ	Division by Zero, REAL or INTEGER
LG	Illegal Argument to LOG Function (Negative or Zero)
S	QIllegal Argument to SQRT Function (Negative)
DT	Data Type Does Not Agree With FORMAT Specification
EF	EOF Encountered on READ

Runtime errors are surrounded by asterisks as follows:

```
**FW** at address XXXX**
```

The location of the error is disclosed also. Fatal errors cause execution to cease (control is returned to the operating system). Execution continues after a warning error. However, after 20 warnings, execution ceases.

NOTE

It is possible, in rare cases, to get a FORTRAN-80 internal error, as designated by the error code "??". This indicates an internal malfunction of the runtime. If you get the "??" error code, contact Microsoft and report the conditions under which the message appeared.

SECTION 3

FORTRAN-80 Disk Files

NOTE

If you are using the TEKDOS operating system, see Section 4.2, Disk I/O and LUN Assignments.

3.1 Default Disk Filenames

A disk file (random or sequential) that is OPENed by a READ or WRITE statement has a default name that depends upon the LUN and the operating system. For CP/M and ISIS-II, the default filenames are:

FORT06.DAT, FORT07.DAT,..., FORT10.DAT

(For the default filenames used with TEKDOS, see Section 4.)

In each case, the LUN is incorporated into the default file name.

3.2 CALL OPEN

Instead of using READ or WRITE, a disk file may be OPENed using the OPEN subroutine (see the FORTRAN-80 Reference Manual, Section 8.3.2). The format of an OPEN call under CP/M is:

CALL OPEN (LUN, Filename, Drive)

where:

LUN = a Logical Unit Number to be associated with the file (must be an Integer constant or Integer variable with a value between 1 and 10).

Filename = an ASCII name which the operating system will associate with the file. The Filename should be a Hollerith or Literal constant, or a variable or array name, where the variable or array contains the ASCII name. The Filename should be blank-filled to exactly eleven characters.

Drive = the number of the disk drive on which the file exists or will exists (must be an Integer constant or Integer variable within the range

allowed by the operating system). If the Drive specified is 0, the currently selected drive is assumed; 1 is drive A, 2 is drive B, etc.

The form of an OPEN call under ISIS-II is:

```
CALL OPEN (LUN, Filename)
```

where:

LUN = a Logical Unit Number to be associated with the file (must be an Integer constant or Integer variable with a value between 1 and 10).

Filename = an ASCII name which the operating system will associate with the file. The Filename should be a Hollerith or Literal constant, or a variable or array name where the variable or array contains the ASCII name. The Filename should be in the form normally required by ISIS-II, i.e., a device name surrounded by colons, followed by a name of up to 6 characters, a period, an extension of up to 3 characters, and a space (or other non-alphanumeric character). The Filename must be terminated by a non-alphanumeric character.

The following are examples of valid OPEN calls under ISIS-II:

```
CALL OPEN (6, ':F1:FOO.DAT ')

CALL OPEN (1, ':F5:TESTFF.TMP ')

CALL OPEN (4, ':F3:A.B ')
```

3.3 Record Length

The record length of any file accessed randomly under CP/M or ISIS-II is assumed to be 128 bytes (1 sector). Therefore, it is recommended that any file you wish to read randomly be created via FORTRAN (or Microsoft BASIC) random access statements. Random access files created this way (using either binary or formatted WRITE statements) always have 128-byte records. If the WRITE statement does not transfer enough data to fill the record to 128 bytes, then the end of the record is filled with zeros (NULL characters).

SECTION 4

FORTRAN-80 with TEKDOS

4.1 Command Format

The command format for FORTRAN-80 differs slightly under the TEKDOS operating system.

The FORTRAN-80 compiler accepts command lines only. A prompt is not displayed and interactive commands are not accepted. Commands have the same format as TEKDOS assembler commands; i.e., three filename or device name parameters plus optional switches.

F80 [objfile] [lstfile] sourcefile [sw1] [sw2...]

The object and listing file parameters are optional. These files will not be created if the parameters are omitted, however any error messages will still be displayed on the console. The available switches are as described in the Section 1 of this manual, except that the switches are delimited by commas or spaces instead of slashes.

4.2 Disk I/O and LUN Assignments

(See FORTRAN-80 Reference Manual, Section 8.3.)

FORTRAN-80 under TEKDOS does not support random access disk files. Only sequential files are supported.

Logical units 1-4 are assigned to the console and may be used for either input or output.

Logical units 5-10 go through DSKDRV. They default to sequential disk files with the names

FOR05DAT,...FOR10DAT.

These units may be re-assigned to any filename or device using an OPEN call. The form of an OPEN call is:

CALL OPEN(LUN, filename)

where LUN is a logical unit number (Integer variable or constant between 5 and 10), and filename is a Hollerith or Literal constant or variable containing the ASCII filename and/or device. The filename cannot have more than 11

characters, and it must be terminated by a blank or null character.

Examples:

```
CALL OPEN(8,'TSTFIL/1 ')
```

opens TSTFIL on drive 1 and associates it with LUN8.

```
CALL OPEN(5,'REMO ')
```

opens LUN5 for device REMO.

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MICROSOFT FORTRAN-80
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Contents

SECTION 1

INTRODUCTION

FORTRAN is a universal, problem oriented programming language designed to simplify the preparation and check-out of computer programs. The name of the language - FORTRAN - is an acronym for FORmula TRANslator.

The syntactical rules for using the language are rigorous and require the programmer to define fully the characteristics of a problem in a series of precise statements. These statements, called the source program, are translated by a system program called the FORTRAN processor into an object program in the machine language of the computer on which the program is to be executed.

This manual defines the FORTRAN source language for the 8080 and Z-80 microcomputers. This language includes the American National Standard FORTRAN language as described in ANSI document X3.9-1966, approved on March 7, 1966, plus a number of language extensions and some restrictions. These language extensions and restrictions are described in the text of this document and are listed in Appendix A.

NOTE

This FORTRAN differs from the Standard in that it does not include the COMPLEX data type.

Examples are included throughout the manual to illustrate the construction and use of the language elements. The programmer should be familiar with all aspects of the language to take full advantage of its capabilities.

Section 2 describes the form and components of an FORTRAN-80 source program. Sections 3 and 4 define data types and their expressional relationships. Sections 5 through 9 describe the proper construction and usage of the various statement classes.

SECTION 2

FORTRAN PROGRAM FORM

FORTRAN-80 source programs consist of one program unit called the Main program and any number of program units called subprograms. A discussion of subprogram types and methods of writing and using them is in Section 9 of this manual.

Programs and program units are constructed of an ordered set of statements which precisely describe procedures for solving problems and which also define information to be used by the FORTRAN processor during compilation of the object program. Each statement is written using the FORTRAN character set and following a prescribed line format.

2.1 FORTRAN CHARACTER SET

To simplify reference and explanation, the FORTRAN character set is divided into four subsets and a name is given to each.

2.1.1 LETTERS

A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
V,W,X,Y,Z,$

No distinction is made between upper and lower case letters. However, for clarity and legibility, exclusive use of upper case letters is recommended.

2.1.2 DIGITS

0,1,2,3,4,5,6,7,8,9

Strings of digits representing numeric quantities are normally interpreted as decimal numbers. However, in certain statements, the interpretation is in the Hexadecimal number system in which case the letters A, B, C, D, E, F may also be used as Hexadecimal digits. Hexadecimal usage is defined in the descriptions of statements in which such notation is allowed.

2.1.3 ALPHANUMERICS

A sub-set of characters made up of all letters and all digits.

2.1.4 SPECIAL CHARACTERS

	Blank
=	Equality Sign
+	Plus Sign
-	Minus Sign
*	Asterisk
/	Slash
(	Left Parenthesis
)	Right Parenthesis
,	Comma
.	Decimal Point

NOTES:

1. FORTRAN program lines consist of 80 character positions or columns, numbered 1 through 80. They are divided into four fields.

2. The following special characters are classified as Arithmetic Operators and are significant in the unambiguous statement of arithmetic expressions.

+	Addition or Positive Value
-	Subtraction or Negative Value
*	Multiplication
/	Division

3. The other special characters have specific application in the syntactical expression of the FORTRAN language and in the construction of FORTRAN statements.

4. Any printable character may appear in a Hollerith or Literal field.

2.2 FORTRAN LINE FORMAT

A FORTRAN program line consists of up to 80 columns, divided into four fields:

1. Statement Label (or Number) field- Columns 1 through 5 (See definition of statement labels).

2. Continuation character field-
   Column 6

3. Statement field-
   Columns 7 through 72

4. Indentification field-
   Columns 73 through 80

The identification field is available for any purpose the FORTRAN programmer may desire and is ignored by the FORTRAN processor.

The lines of a FORTRAN statement are placed in Columns 1 through 72 formatted according to line types. The four line types, their definitions, and column formats are:

1. Initial Line -- the first or only line of each statement.

    1. Columns 1-5 may contain a statement label to identify the statement.

    2. Column 6 must be blank.

    3. Columns 7-72 contain all or part of the statement.

    4. An initial line may begin anywhere within the statement field.

    Example:

```
C THE STATEMENT BELOW CONSISTS
C    OF AN INITIAL LINE
C
        A= .5*SQRT(3-2.*C)
```

2. Continuation Line -- used when additional lines of coding are required to complete a statement originating with an initial line.

    1. Columns 1-5 are ignored, unless Column 1 contains a C.

    2. If Column 1 contains a C, it is a comment line.

    3. Column 6 must contain a character other than zero or blank.

    4. Columns 7-72 contain the continuation of the statement.

    5. There may be as many continuation lines as needed to complete the statement.

Example:

```
C  THE STATEMENTS BELOW ARE AN INITIAL LINE
C       AND 2 CONTINUATION LINES
C
  63  BETA(1,2) =
     1      A6BAR**7-(BETA(2,2)-A5BAR*50
     2      +SQRT (BETA(2,1)))
```

3. Comment line -- used for source program annotation at the convenience of the programmer.

   1. Column 1 contains the letter C.

   2. Columns 2 - 72 are used in any desired format to express the comment or they may be left blank.

   3. A comment line may be followed only by an initial line, an END line, or another comment line.

   4. Comment lines have no effect on the object program and are ignored by the FORTRAN processor except for display purposes in the listing of the program.

      Example:

```
C     COMMENT LINES ARE INDICATED BY THE
C          CHARACTER C IN COLUMN 1.
C  THESE ARE COMMENT LINES
```

4. END line -- the last line of a program unit.

   1. Columns 1-5 may contain a statement label.

   2. Column 6 must be blank.

   3. Columns 7-72 contain the END statement.

   4. Each FORTRAN program unit must have an END line as its last line to inform the Processor that it is at the physical end of the program unit.

   5. An END line may follow any other type line.

A statement label may be placed in columns 1-5 of a FORTRAN statement initial line and is used for

reference purposes in other statements.

The following considerations govern the use of statement labels:

1. The label is an integer from 1 to 99999.

2. The numeric value of the label, leading zeros and blanks are not significant.

3. A label must be unique within a program unit.

4. A label on a continuation line is ignored by the FORTRAN Processor.

Example:

```
C  EXAMPLES OF STATEMENT LABELS
C
  1
  101
99999
 763
```

2.3 STATEMENTS

Individual statements deal with specific aspects of a procedure described in a program unit and are classified as either executable or non-executable.

Executable statements specify actions and cause the FORTRAN Processor to generate object program instructions. There are three types of executable statements:

1. Replacement statements.

2. Control statements.

3. Input/Output statements.

Non-executable statements describe to the processor the nature and arrangement of data and provide information about input/output formats and data initialization to the object program during program loading and execution. There are five types of non-executable statements:

1. Specification statements.

2. DATA Initialization statements.

3. FORMAT statements.

4. FUNCTION defining statements.

5. Subprogram statements.

The proper usage and construction of the various types of statements are described in Sections 5 through 9.

2.4 INCLUDE STATEMENT

The INCLUDE statement causes the compiler to bring an outside FORTRAN source program into the current program. The format of the statement is

INCLUDE<filename>

Use of INCLUDE eliminates the need to repeat an often-used sequence of statements in the current source file.

SECTION 3

DATA REPRESENTATION / STORAGE FORMAT

The FORTRAN Language prescribes a definitive method for identifying data used in FORTRAN programs by name and type.

3.1 DATA NAMES AND TYPES

3.1.1 NAMES

1. Constant - An explicitly stated datum.
2. Variable - A symbolically identified datum.
3. Array - An ordered set of data in 1, 2 or 3 dimensions.
4. Array Element - One member of the set of data of an array.

3.1.2 TYPES

1. Integer -- Precise representation of integral numbers (positive, negative or zero) having precision to 5 digits in the range -32768 to +32767 inclusive (-2**15 to 2**15-1).
2. Real -- Approximations of real numbers (positive, negative or zero) represented in computer storage in 4-byte, floating-point form. Real data are precise to 7+ significant digits and their magnitude may lie between the approximate limits of 10**-38 and 10**38 (2**-127 and 2**127).
3. Double Precision -- Approximations of real numbers (positive, negative or zero) represented in computer storage in 8-byte, floating-point form. Double Precision data are precise to 16+ significant digits in the same magnitude range as real data.
4. Logical -- One byte representations of the truth values "TRUE" or "FALSE" with "FALSE defined to have an internal representation of zero. The constant .TRUE. has the value -1, however any non-zero value will be treated as .TRUE. in a Logical IF statement. In addition, Logical types may be used as one byte signed integers in the range -128 to +127, inclusive.

5. Hollerith -- A string of any number of characters from the computer's character set. All characters including blanks are significant. Hollerith data require one byte for storage of each character in the string.

6. Extended Integer -- INTEGER*4 is an extended precision representation using 32-bit two's complement (four 8-bit bytes) for 9+ significant digits in the range -2147483648 to +2147483647 inclusive (-2**31 to 2**31-1).

   Integer*4 variables cannot be used as Logical Unit Numbers, array indices, implied DO loop indices, or as the control variable in computed or assigned GOTO statements.

3.2 CONSTANTS

FORTRAN constants are identified explicitly by stating their actual value. The plus (+) character need not precede positive valued constants.

Formats for writing constants are shown in Table 3-1.

Table 3-1. CONSTANT FORMATS

TYPE	FORMATS AND RULES OF USE	EXAMPLES
INTEGER	1. 1 to 5 decimal digits interpreted as a decimal number.	-763 1 +00672
	2. A preceding plus (+) or minus (-) sign is optional.	-32768 +32767
	3. No decimal point (.) or comma (,) is allowed but spaces are permitted in the source program.	- 32 767
	4. Value range: -32768 through +32767 (.i.e., -2**15 through 2**15-1).	
REAL	1. A decimal number with precision to 7 digits and represented in one of the following forms: a. + or -.f + or -i.f b. + or -i.E+ or -e + or -.fE+ or -e + or -i.fE+ or -e where i, f, and e are each strings representing integer, fraction, and exponent respectively.	345. -.345678 +345.678 +.3E3 -73E4
	2. Plus (+) and minus (-) characters are optional.	
	3. In the form shown in 1 b above, if r represents any of the forms preceding E+ or -e (i.e., rE+ or -e), the value of the constant is interpreted as r times 10**e, where -38=E=38.	

TYPE	FORMATS AND RULES OF USE	EXAMPLES
	4. If the constant preceding E+ or -e contains more significant digits than the precision for real data allows, truncation occurs, and only the most significant digits in the range will be represented.	
DOUBLE PRECISION	A decimal number with precision to 16 digits. All formats and rules are identical to those for REAL constants, except D is used in place of E. Note that a real constant is assumed single precision unless it contains a "D" exponent.	+345.678 +.3D3 -73D4
LOGICAL	.TRUE. generates a non-zero byte (hexadecimal FF) and .FALSE. generates a byte in which all bits are 0. If logical values are used as one-byte integers, the rules for use are the same as for type INTEGER, except that the range allowed is -128 to +127, inclusive.	.TRUE. .FALSE.

TYPE	FORMATS AND RULES OF USE	EXAMPLES
LITERAL	In the literal form, any number of characters may be enclosed by single quotation marks. The form is as follows: 'X1X2X3...Xn' where each Xi is any character other than '. Two quotation marks in succession may be used to represent the quotation mark character within the string, i.e., if X2 is to be the quotation mark character, the string appears as the following: 'X1''X3...Xn'	
HEXADECIMAL	1. The letter Z or X followed by a single quote, up to 4 hexadecimal digits (0-9 and A-F) and a single quote is recognized as a hexadecimal value. 2. A hexadecimal constant is right justified in its storage value.	Z'12' X'AB1F' Z'FFFF' X'1F'
INTEGER*4	1. One to ten decimal digits interpreted as a decimal number. 2. A preceding plus or minus sign is optional. 3. No decim1 point or comma is allowed, but spaces are permitted in the source program. 4. Value range: -2147483648 through 2147483647 (i.e., -2**31 through 2**31-1).	1234567890 0 -2147483647 - 2 147 483 647

3.3 VARIABLES

Variable data are identified in FORTRAN statements by symbolic names. The names are unique strings of from 1 to 6 alphanumeric characters of which the first is a letter.

NOTE

System variable names and runtime subprogram names are distinguished from other variable names in that they begin with the dollar sign character ($). It is therefore strongly recommended that in order to avoid conflicts, symbolic names in FORTRAN source programs begin with some letter other than "$".

Examples:

I5, TBAR, B23, ARRAY, XFM79, MAX, A1$C

Variable data are classified into four types: INTEGER, REAL, DOUBLE PRECISION and LOGICAL. The specification of type is accomplished in one of the following ways:

1. Implicit typing in which the first letter of the symbolic name specifies Integer or Real type. Unless explicitly typed (2., below), symbolic names beginning with I, J, K, L, M or N represent Integer variables, and symbolic names beginning with letters other than I, J, K, L, M or N represent Real variables.

   Integer Variables

   ITEM
   J1
   MODE
   K123
   N2

Real Variables

BETA
H2
ZAP
AMAT
XID

2. Variables may be typed explicitly. That is, they may be given a particular type without reference to the first letters of their names. Variables may be explicitly typed as INTEGER, REAL, DOUBLE PRECISION or LOGICAL. The specific statements used in explicitly typing data are described in Section 6.

Variable data receive their numeric value assignments during program execution or, initially, in a DATA statement (Section 6).

Hollerith or Literal data may be assigned to any type variable. Sub-paragraph 3.6 contains a discussion of Hollerith data storage.

3.4 ARRAYS AND ARRAY ELEMENTS

An array is an ordered set of data characterized by the property of dimension. An array may have 1, 2 or 3 dimensions and is identified and typed by a symbolic name in the same manner as a variable except that an array name must be so declared by an "array declarator." Complete discussions of the array declarators appear in Section 6 of this manual. An array declarator also indicates the dimensionality and size of the array. An array element is one member of the data set that makes up an array. Reference to an array element in a FORTRAN statement is made by appending a subscript to the array name. The term array element is synonymous with the term subscripted variable used in some FORTRAN texts and reference manuals.

An initial value may be assigned to any array element by a DATA statement or its value may be derived and defined during program execution.

3.5 SUBSCRIPTS

A subscript follows an array name to uniquely identify an array element. In use, a subscript in a FORTRAN statement takes on the same representational meaning as a subscript in familiar algebraic notation.

Rules that govern the use of subscripts are as follows:

1. A subscript contains 1, 2 or 3 subscript expressions (see 4 below) enclosed in parentheses.

2. If there are two or three subscript expressions within the parentheses, they must be separated by commas.

3. The number of subscript expressions must be the same as the specified dimensionality of the Array Declarator except in EQUIVALENCE statements (Section 6).

4. A subscript expression is written in one of the following forms:

```
K   C*V     V-K
V   C*V+K   C*V-K
V+K
```

   where C and K are integer constants and V is an integer variable name (see Section 4 for a discussion of expression evaluation).

5. Subscripts themselves may not be subscripted. Examples:

```
X(2*J-3,7)    A(I,J,K)    I(20)    C(L-2)    Y(I)
```

3.6 DATA STORAGE ALLOCATION

Allocation of storage for FORTRAN data is made in numbers of storage units. A storage unit is the memory space required to store one real data value (4 bytes).

Table 3-2 defines the word formats of the three data types.

Hexadecimal data may be associated (via a DATA statement) with any type data. Its storage allocation is the same as the associated datum.

Hollerith or literal data may be associated with any data type by use of DATA initializaton statements (Section 6).

Up to eight Hollerith characters may be associated with Double Precision type storage, up to four with Real or Integer*4, up to two with Integer*2, and one with Logical type storage.

TABLE 3-2. STORAGE ALLOCATION BY DATA TYPES

TYPE	ALLOCATION
INTEGER	2 bytes/ 1/2 storage unit

S	Binary Value

Negative numbers are the two's complement of positive representations. The storage order is reversed. The least significant byte is followed by the most significant byte.

LOGICAL — 1 byte/ 1/4 storage unit

Zero	(false) or	non-zero	(true)

A non-zero valued byte indicates true (the logical constant .TRUE. is represented by the hexadecimal value FF). A zero valued byte indicates false.

When used as an arithmetic value, a Logical datum is treated as an Integer in the range -128 to +127.

REAL — 4 bytes/ 1 storage unit

Characteristic	S	Mantissa (hi)
Mantissa(mid)		Mantissa (low)

The first byte is the characteristic expressed in excess 200 (octal) notation; i.e., a value of 200 (octal) corresponds to a binary exponent of 0. Values less than 200 (octal) correspond to negative exponents, and values greater than 200 correspond to positive exponents. By definition, if the characteristic is zero, the entire number is zero.

The next three bytes constitute the mantissa. The mantissa is always normalized such that the high order bit is one, eliminating the need to actually save that bit. The high bit is used instead to indicate the sign of the number. A one indicates a negative number, and zero indicates a positive number. The mantissa is assumed to be a binary fraction whose binary point is to the left of the mantissa. The format of the mantissa is "signed magnitude." The bytes are stored in

reverse order: mantissa low order, followed by mid order, high order, and characteristic.

DOUBLE PRECISION

8 bytes/ 2 storage units

The internal form of Double Precision data is identical with that of Real data except Double Precision uses 4 extra bytes for the matissa.

INTEGER*4

4 bytes/ 1 storage unit

Negative numbers are represented in two's complement form. The bytes are stored in reverse order, least significant to most significant.

TABLE 3-3. EQUIVALENT DATA TYPES AND SIZES

Equivalent Representations	Size in Bytes
BYTE	1
INTEGER*1	1
LOGICAL	1
INTEGER	2
INTEGER*2	2
LOGICAL*2	2
INTEGER*4	4
LOGICAL*4	4
REAL	4
REAL*4	4
DOUBLE PRECISION	8
REAL*8	8

SECTION 4

FORTRAN EXPRESSIONS

A FORTRAN expression is composed of a single operand or a string of operands connected by operators. Two expression types --Arithmetic and Logical-- are provided by FORTRAN. The operands, operators and rules of use for both types are described in the following paragraphs.

4.1 ARITHMETIC EXPRESSIONS

The following rules define all permissible arithmetic expression forms:

1. A constant, variable name, array element reference or FUNCTION reference (Section 9) standing alone is an expression.

   Examples:

   ```
   S(I)      JOBNO   217     17.26   SQRT(A+B)
   ```

2. If E is an expression whose first character is not an operator, then +E and -E are called signed expressions.

   Examples:

   ```
   -S +JOBNO  -217    +17.26  -SQRT(A+B)
   ```

3. If E is an expression, then (E) means the quantity resulting when E is evaluated.

   Examples:

   ```
   (-A)      -(JOBNO)      -(X+1)  (A-SQRT(A+B))
   ```

4. If E is an unsigned expression and F is any expression, then: F+E, F-E, F*E, F/E and F**E are all expressions.

   Examples:

   ```
   -(B(I,J)+SQRT(A+B(K,L)))
   1.7E-2**(X+5.0)
   -(B(I+3,3*J+5)+A)
   ```

5. An evaluated expression may be Integer, Extended Integer, Real, Double Precision, or Logical. The type is determined by the data types of the elements of the expression. If

the elements of the expression are not all of the same type, the type of the expression is determined by the element having the highest type. The type hierarchy (highest to lowest) is as follows: DOUBLE PRECISION, REAL, INTEGER*4, INTEGER, LOGICAL.

6. Expressions may contain nested parenthesized elements as in the following:

```
A*(Z-((Y+X)/T))**J
```

where Y+X is the innermost element, (Y+X)/T is the next innermost, Z-((Y+X)/T) the next. In such expressions, care should be taken to see that the number of left parentheses and the number of right parentheses are equal.

4.2 EXPRESSION EVALUATION

Arithmetic expressions are evaluated according to the following rules:

1. Parenthesized expression elements are evaluated first. If parenthesized elements are nested, the innermost elements are evaluated, then the next innermost until the entire expression has been evaluated.

2. Within parentheses and/or wherever parentheses do not govern the order or evaluation, the hierarchy of operations in order of precedence is as follows:

   a. FUNCTION evaluation
   b. Exponentiation
   c. Multiplication and Division
   d. Addition and Subtraction

Example:

The expression

```
A*(Z-((Y+R)/T))**J+VAL
```

is evaluated in the following sequence:

```
e1 = Y+R
e2 = (e1)/T
e3 = Z-e2
e4 = e3**J
e5 = A*e4
e6 = e5+VAL
```

3. The expression X**Y**Z is not allowed. It should be written as follows:

   (X**Y)**Z or X**(Y**Z)

4. Use of an array element reference requires the evaluation of its subscript. Subscript expressions are evaluated under the same rules as other expressions.

4.3 LOGICAL EXPRESSIONS

A Logical Expression may be any of the following:

1. A single Logical Constant (i.e., .TRUE. or .FALSE.), a Logical variable, Logical Array Element or Logical FUNCTION reference (see FUNCTION, Section 9).

2. Two arithmetic expressions separated by a relational operator (i.e., a relational expression).

3. Logical operators acting upon logical constants, logical variables, logical array elements, logical FUNCTIONS, relational expressions or other logical expressions.

The value of a logical expression is always either .TRUE. or .FALSE.

4.3.1 RELATIONAL EXPRESSIONS

The general form of a relational expression is as follows:

```
e1 r e2
```

where e1 and e2 are arithmetic expressions and r is a relational operator. The six relational operators are as follows:

.LT.	Less Than
.LE.	Less than or equal to
.EQ.	Equal to
.NE.	Not equal to
.GT.	Greater than
.GE.	Greater than or equal to

The value of the relational expression is .TRUE. if the condition defined by the operator is met. Otherwise, the value is .FALSE.

Examples:

```
A.EQ.B
(A**J).GT.(ZAP*(RHO*TAU-ALPH))
```

4.3.2 LOGICAL OPERATORS

Table 4-1 lists the logical operations. U and V denote logical expressions.

Table 4-1. Logical Operations

.NOT.U	The value of this expression is the logical complement of U (i.e., 1 bits become 0 and 0 bits become 1).
U.AND.V	The value of this expression is the logical product of U and V (i.e., there is a 1 bit in the result only where the corresponding bits in both U and V are 1.
U.OR.V	The value of this expression is the logical sum of U and V (i.e., there is a 1 in the result if the corresponding bit in U or V is 1 or if the corresponding bits in both U and V are 1.
U.XOR.V	The value of this expression is the exclusive OR of U and V (i.e., there is a one in the result if the corresponding bits in U and V are 1 and 0 or 0 and 1 respectively.

Examples:

If U = 01101100 and V = 11001001 , then

```
.NOT.U  = 10010011
U.AND.V = 01001000
U.OR.V  = 11101101
U.XOR.V = 10100101
```

The following are additional considerations for construction of Logical expressions:

1. Any Logical expression may be enclosed in parentheses. However, a Logical expression to which the .NOT. operator is applied must be enclosed in parentheses if it contains two or more elements.

2. In the hierarchy of operations, parentheses may be used to specify the ordering of the expression evaluation. Within parentheses, and where parentheses do not dictate evaluation order, the order is understood to be as follows:

   a. FUNCTION Reference
   b. Exponentiation (**)
   c. Multiplication and Division (* and /)
   d. Addition and Subtraction (+ and -)
   e. .LT., .LE., .EQ., .NE., .GT., .GE.
   f. .NOT.
   g. .AND.
   h. .OR., .XOR.

   Examples:

   The expression

```
X .AND. Y .OR. B(3,2) .GT. Z
```

   is evaluated as

```
e1 = B(3,2).GT.Z
e2 = X .AND. Y
e3 = e2 .OR. e1
```

   The expression

```
X .AND. (Y .OR. B(3,2) .GT. Z)
```

   is evaluated as

```
e1 = B(3,2) .GT. Z
e2 = Y .OR. e1
e3 = X .AND. e2
```

3. It is invalid to have two contiguous logical operators except when the second operator is .NOT. That is,

   .AND..NOT.

   and

   .OR..NOT.

   are permitted.

   Example:

   A.AND..NOT.B is permitted

   A.AND..OR.B is not permitted

4.4 HOLLERITH, LITERAL, AND HEXADECIMAL CONSTANTS IN EXPRESSIONS

Hollerith, Literal, and Hexadecimal constants are allowed in expressions in place of Integer constants. These special constants always evaluate to an Integer value and are therefore limited to a length of two bytes. The only exceptions to this are:

1. Long Hollerith or Literal constants may be used as subprogram parameters.

2. Hollerith, Literal, or Hexadecimal constants may be up to four bytes long in DATA statements when associated with Real variables, or up to eight bytes long when associated with Double Precision variables.

SECTION 5

REPLACEMENT STATEMENTS

Replacement statements define computations and are used similarly to equations in normal mathematical notation. They are of the following form:

```
v = e
```

where v is any variable or array element and e is an expression.

FORTRAN semantics defines the equality sign (=) as meaning to be replaced by rather than the normal is equivalent to. Thus, the object program instructions generated by a replacement statement will, when executed, evaluate the expression on the right of the equality sign and place that result in the storage space allocated to the variable or array element on the left of the equality sign.

The following conditions apply to replacement statements:

1. Both v and the equality sign must appear on the same line. This holds even when the statement is part of a logical IF statement (section 7).

   Example:

```
C IN A REPLACEMENT STATEMENT THE '='
C     MUST BE IN THE INITIAL LINE.
      A(5,3) =
     1     B(7,2) + SIN(C)
```

   The line containing v= must be the initial line of the statement unless the statement is part of a logical IF statement. In that case the v= must occur no later than the end of the first line after the end of the IF.

2. If the data types of the variable, v, and the expression, e, are different, then the value determined by the expression will be converted, if possible, to conform to the typing of the variable. Table 5-1 shows which type expressions may be equated to which type of variable. Y indicates a valid replacement and N indicates an invalid replacement. Footnotes to Y indicate conversion considerations.

Table 5-1. Replacement By Type

Variable Types	Expression Types (e)				
	Integer	Real	Logical	Double	Ext Int
Integer	Y	Ya	Yb	Ya	Yg
Real	Yc	Y	Yc	Ye	Yc
Logical	Yd	Ya	Y	Ya	Yd
Double	Yc	Y	Yc	Y	Yc
Ext Int	Yf	Yh	Yb,f	Yh	Y

a. The Real expression value is converted to Integer, truncated if necessary to conform to the range of Integer data.
b. The sign is extended through the second byte.
c. The variable is assigned the Real approximation of the Integer value of the expression.
d. The variable is assigned the truncated value of the Integer expression (the low-order byte is used, regardless of sign).
e. The variable is assigned the rounded value of the Real expression.
f. The sign is extended through the third and fourth bytes.
g. The variable is assigned the truncated value of the Extended Integer expression.
h. The expression value is converted to Extended Integer and truncated to conform to the range of Extended Integer data.

SECTION 6

SPECIFICATION STATEMENTS

Specification statements are non-executable, non-generative statements which define data types of variables and arrays, specify array dimensionality and size, allocate data storage or otherwise supply determinative information to the FORTRAN processor. DATA intialization statements are non-executable, but generate object program data and establish initial values for variable data.

6.1 SPECIFICATION STATEMENTS

There are seven kinds of specification statements. They are as follows:

IMPLICIT statements
Type, EXTERNAL, and DIMENSION statements
COMMON statements
EQUIVALENCE statements
DATA initialization statements

All specification statements are grouped at the beginning of a program unit and must be ordered as they appear above. Specification statements may be preceded only by a FUNCTION, SUBROUTINE, PROGRAM or BLOCK DATA statement. All specification statements must precede statement functions and the first executable statement.

6.2 ARRAY DECLARATORS

Three kinds of specification statements may specify array declarators. These statements are the following:

Type statements
DIMENSION statements
COMMON statements

Of these, DIMENSION statements have the declaration of arrays as their sole function. The other two serve dual purposes. These statements are defined in subparagraphs 6.3, 6.5 and 6.6.

Array declarators are used to specify the name, dimensionality and sizes of arrays. An array may be declared only once in a program unit.

An array declarator has one of the following forms:

```
ui (k)
ui (k1,k2)
ui (k1,k2,k3)
```

where ui is the name of the array, called the declarator name, and the k's are integer constants.

Array storage allocation is established upon appearance of the array declarator. Such storage is allocated linearly by the FORTRAN processor where the order of ascendancy is determined by the first subscript varying most rapidly and the last subscript varying least rapidly.

For example, if the array declarator AMAT(3,2,2) appears, storage is allocated for the 12 elements in the following order:

AMAT(1,1,1), AMAT(2,1,1), AMAT(3,1,1), AMAT(1,2,1), AMAT(2,2,1), AMAT(3,2,1), AMAT(1,1,2), AMAT(2,1,2), AMAT(3,1,2), AMAT(1,2,2), AMAT(2,2,2), AMAT(3,2,2)

6.3 TYPE STATEMENTS

Variable, array and FUNCTION names are automatically typed Integer or Real by the 'predefined' convention unless they are changed by Type statements. For example, the type is Integer if the first letter of an item is I, J, K, L, M or N. Otherwise, the type is Real.

Type statements provide for overriding or confirming the pre-defined convention by specifying the type of an item. In addition, these statements may be used to declare arrays.

Type statements have the following general form:

```
t v1,v2,...vn
```

where t represents one of the terms INTEGER, INTEGER*1, INTEGER*2, INTEGER*4, REAL, REAL*4, REAL*8, DOUBLE PRECISION, LOGICAL, LOGICAL*1, LOGICAL*2, LOGICAL*4, or BYTE. Each v is an array declarator or a variable, array or FUNCTION name. The INTEGER*1, INTEGER*2, INTEGER*4, REAL*4, REAL*8, LOGICAL*1, LOGICAL*2, LOGICAL*4 types are allowed for readability and compatibility with other FORTRANs.

Example:

```
REAL AMAT(3,3,5),BX,IETA,KLPH
```

NOTE

1. AMAT and BX are redundantly typed.
2. IETA and KLPH are unconditionally declared Real.
3. AMAT(3,3,5) is a constant array declarator specifying an array of 45 elements.

Example:

```
INTEGER M1, HT, JMP(15), FL
```

NOTE

M1 is redundantly typed here. Typing of HT and FL by the pre-defined convention is overridden by their appearance in the INTEGER statement. JMP(15) is a constant array declarator. It redundantly types the array elements as Integer and communicates to the processor the storage requirements and dimensionality of the array.

Example:

```
LOGICAL L1, TEMP
```

NOTE

All variables, arrays or FUNCTIONs required to be typed Logical must appear in a LOGICAL statement, since no starting letter indicates these types by the default convention.

6.4 EXTERNAL STATEMENTS

EXTERNAL statements have the following form:

```
EXTERNAL ul,u2,...,un
```

where each ui is a SUBROUTINE, BLOCK DATA or FUNCTION name. When the name of a subprogram is used as an argument in a subprogram reference, it must have appeared in a preceding EXTERNAL statement.

When a BLOCK DATA subprogram is to be included in a program load, its name must have appeared in an EXTERNAL statement within the main program unit.

For example, if SUM and AFUNC are subprogram names to be used as arguments in the subroutine SUBR, the following statements would appear in the calling program unit:

```
.
.
.
EXTERNAL SUM, AFUNC
.
.
.
.
CALL SUBR(SUM,AFUNC,X,Y)
```

6.5 DIMENSION STATEMENTS

A DIMENSION statement has the following form:

```
DIMENSION u2,u2,u3,...,un
```

where each ui is an array declarator.

Example:

```
DIMENSION RAT(5,5),BAR(20)
```

This statement declares two arrays - the 25 element array RAT and the 20 element array BAR.

6.6 COMMON STATEMENTS

COMMON statements are non-executable, storage allocating statements which assign variables and arrays to a storage area called COMMON storage and provide the facility for various program units to share the use of the same storage area.

COMMON statements are expressed in the following form:

```
COMMON /y1/a1/y2/a2/.../yn/an
```

where each yi is a COMMON block storage name and each ai is a sequence of variable names, array names or constant array declarators, separated by commas. The elements in ai make up the COMMON block storage area specified by the name yi. If any yi is omitted leaving two consecutive slash characters (//), the block of storage so indicated is called blank COMMON. If the first block name (y1) is omitted, the two slashes may be omitted.

Example:

```
      COMMON /AREA/A,B,C/BDATA/X,Y,Z,
     X               FL,ZAP(30)
```

In this example, two blocks of COMMON storage are allocated - AREA with space for three variables and BDATA, with space for four variables and the 30 element array, ZAP.

Example:

```
      COMMON //A1,B1/CDATA/ZOT(3,3)
     X             //T2,Z3
```

In this example, A1, B1, T2 and Z3 are assigned to blank COMMON in that order. The pair of slashes preceding A1 could have been omitted.

CDATA names COMMON block storage for the nine element array, ZOT and thus ZOT (3,3) is an array declarator. ZOT must not have been previously declared. (See "Array Declarators," Paragraph 6.3.)

Additional Considerations:

1. The name of a COMMON block may appear more than once in the same COMMON statement, or in more than one COMMON statement.

2. A COMMON block name is made up of from 1 to 6 alphanumeric characters, the first of which must be a letter.

3. A COMMON block name must be different from any subprogram names used throughout the program.

4. The size of a COMMON area may be increased by the use of EQUIVALENCE statements. See "EQUIVALENCE Statements," Paragraph 6.7.

5. The lengths of COMMON blocks of the same name need not be identical in all program units where the name appears. However, if the lengths differ, the program unit specifying the greatest length must be loaded first (see the discussion of LINK-80 in the User's Guide). The length of a COMMON area is the number of storage units required to contain the variables and arrays declared in the COMMON statement (or statements) unless expanded by the use of EQUIVALENCE statements.

6.7 EQUIVALENCE STATEMENTS

Use of EQUIVALENCE statements permits the sharing of the same storage unit by two or more entities. The general form of the statement is as follows:

```
EQUIVALENCE (u1),(u2),...,(un)
```

where each ui represents a sequence of two or more variables or array elements, separated by commas. Each element in the sequence is assigned the same storage unit (or portion of a storage unit) by the processor. The order in which the elements appear is not significant.

Example:

```
EQUIVALENCE (A,B,C)
```

The variables A, B and C will share the same storage unit during object program execution.

If an array element is used in an EQUIVALENCE statement, the number of subscripts must be the same as the number of dimensions established by the array declarator, or it must be one, where the one subscript specifies the array element's number relative to the first element of the array.

Example:

If the dimensionaliity of an array, Z, has been declared as Z(3,3) then in an EQUIVALENCE statement Z(6) and Z(3,2) have the same meaning.

Additonal Considerations:

1. The subscripts of array elements must be integer constants.

2. An element of a multi-dimensional array may be referred to by a single subscript, if desired.

3. Variables may be assigned to a COMMON block through EQUIVALENCE statements.

   Example:

```
COMMON /X/A,B,C
EQUIVALENCE (A,D)
```

   In this case, the variables A and D share the first storage unit in COMMON block X.

4. EQUIVALENCE statements can increase the size of a block indicated by a COMMON statement by adding more elements to the end of the block.

   Example:

```
DIMENSION R(2,2)
COMMON /Z/W,X,Y
EQUIVALENCE (Y,R(3))
```

   The resulting COMMON block will have the following configuration:

Variable	Storage Unit
W = R(1,1)	0
X = R(2,1)	1
Y = R(1,2)	2
R(2,2)	3

   The COMMON block established by the COMMON statement contains 3 storage units. It is expanded to 4 storage units by the EQUIVALENCE statement.

   COMMON block size may be increased only from the last element established by the COMMON statement forward; not from its first element backward.

Note that EQUIVALENCE (X,R(3)) would be invalid in the example. The COMMON statement established W as the first element in the COMMON block and an attempt to make X and R(3) equivalent would be an attempt to make R(1) the first element.

5. It is invalid to EQUIVALENCE two elements of the same array or two elements belonging to the same or different COMMON blocks.

   Example:

```
      DIMENSION XTABLE (20), D(5)
      COMMON A,B(4)/ZAP/C,X
            .
     .
     .
      EQUIVALENCE (XTABLE (6),A(7),
     X          B(3),XTABLE(15)),
     Y          (B(3),D(5))
     .
     .
     .
```

This EQUIVALENCE statement has the following errors:

1. It attempts to EQUIVALENCE two elements of the same array, XTABLE(6) and XTABLE(15).

2. It attempts to EQUIVALENCE two elements of the same COMMON block, A(7) and B(3).

3. Since A is not an array, A(7) is an illegal reference.

4. Making B(3) equivalent to D(5) extends COMMON backwards from its defined starting point.

6.8 DATA INITIALIZATION STATEMENT

The DATA initialization statement is a non-executable statement which provides a means of compiling data values into the object program and assigning these data to variables and array elements referenced by other statements.

The statement is of the following form:

DATA list/u1,u2,...,un/,list.../uk,uk+1,...uk+n/

where "list" represents a list of variable, array or array element names, and the ui are constants

corresponding in number to the elements in the list. An exception to the one-for-one correspondence of list items to constants is that an array name (unsubscripted) may appear in the list, and as many constants as necessary to fill the array may appear in the corresponding position between slashes. Instead of ui, it is permissible to write k*ui in order to declare the same constant, ui, k times in succession. k must be a positive integer. Dummy arguments may not appear in the list.

Example:

```
      DIMENSION C(7)
      DATA A, B, C(1),C(3)/14.73,
     X           -8.1,2*7.5/
```

This implies that

A=14.73, B=-8.1, C(1)=7.5, C(3)=7.5

The type of each constant ui must match the type of the corresponding item in the list, except that a Hollerith or Literal constant may be paired with an item of any type.

When a Hollerith or Literal constant is used, the number of characters in its string should be no greater than four times the number of storage units required by the corresponding item, i.e., 1 character for a Logical variable, up to 2 characters for an Integer variable and 4 or fewer characters for a Real variable.

If fewer Hollerith or Literal characters are specified, trailing blanks are added to fill the remainder of storage.

Hexadecimal data are stored in a similar fashion. If fewer Hexadecimal characters are used, sufficient leading zeros are added to fill the remainder of the storage unit.

The examples below illustrate many of the features of the DATA statement.

```
      DIMENSION HARY (2)
      DATA HARY,B/  4HTHIS, 4H OK.
     1           ,7.86/


      REAL  LIT(2)
      LOGICAL LT,LF
      DIMENSION  H4(2,2),PI3(3)
      DATA A1,B1,K1,LT,LF,H4(1,1),H4(2,1),
     1    H4(1,2),H4(2,2),PI3/5.9,2.5E-4,
     2      64,.FALSE.,.TRUE.,1.75E-3,
     3      0.85E-1,2*75.0,1.,2.,3.14159/,
     4      LIT(1)/'NOGO'/
```

6.9 IMPLICIT STATEMENT

The IMPLICIT statement is used to redefine default variable types. The syntax is:

```
IMPLICIT type(range),type(range),...
```

where type is one of the following: INTEGER, REAL, LOGICAL, DOUBLE PRECISION, BYTE, INTEGER*1, INTEGER*2, INTEGER*4, REAL*4, REAL*8

and range is a list of alphabetic characters separated by commas or hyphens.

Examples:

```
IMPLICIT INTEGER(A,W-Z),REAL(B-V)
```

All variables (not otherwise declared) starting with the letters A, W, X, Y, Z will be type INTEGER. All variables starting with the letters B through V will be type REAL.

```
IMPLICIT INTEGER(I-N),REAL(A-H,O-Z)
```

This is the default definition.

Any IMPLICIT statements must appear in a program grouped with the Type and DIMENSION statements. IMPLICIT statements must appear before any other specification statements. If the IMPLICIT statement appears after any Type or DIMENSION statements, the types of the variables already declared will not be affected.

SECTION 7

FORTRAN CONTROL STATEMENTS

FORTRAN control statements are executable statements which affect and guide the logical flow of a FORTRAN program. The statements in this category are as follows:

1. GO TO statements:
    1. Unconditional GO TO
    2. Computed GO TO
    3. Assigned GO TO
2. ASSIGN
3. IF statements:
    1. Arithmetic IF
    2. Logical IF
4. DO
5. CONTINUE
6. STOP
7. PAUSE
8. CALL
9. RETURN
10. END

When statement labels of other statements are a part of a control statement, such statement labels must be associated with executable statements within the same program unit in which the control statement appears.

7.1 GO TO STATEMENTS

7.1.1 UNCONDITIONAL GO TO

Unconditional GO TO statements are used whenever control is to be transferred unconditionally to some other statement within the program unit.

The statement is of the following form:

```
GO TO k
```

where k is the statement label of an executable statement in the same program unit.

Example:

```
      GO TO 376
310   A(7) = V1 -A(3)
         .
         .
         .
376   A(2) =VECT
      GO TO 310
```

In these statements, statement 376 is ahead of statement 310 in the logical flow of the program of which they are a part.

7.1.2 COMPUTED GO TO

Computed GO TO statements are of the form:

```
GO TO (k1,k2,...,n),j
```

where the ki are statement labels, and j is an integer variable, $1 \leq j \leq n$.

This statement causes transfer of control to the statement labeled kj. If $j < 1$ or $j > n$, control will be passed to the next statement following the Computed GOTO.

Example:

```
      J=3
      .
      .
      .
      GO TO(7, 70, 700, 7000, 70000), J
310   J=5
      GO TO 325
```

When J = 3, the computed GO TO transfers control to statement 700. Changing J to equal 5 changes the transfer to statement 70000. Making J = 0 or J = 6 would cause control to be transferred to statement 310.

7.1.3 ASSIGNED GO TO

Assigned GO TO statements are of the following form:

```
GO TO j,(k1,k2,...,kn)

  or

GOTO J
```

where J is an integer variable name, and the ki are statement labels of executable statements. This statement causes transfer of control to the statement whose label is equal to the current value of J.

Qualifications

1. The ASSIGN statement must logically precede an assigned GO TO.

2. The ASSIGN statement must assign a value to J which is a statement label included in the list of k's, if the list is specified.

Example:

```
GO TO LABEL,(80,90, 100)
```

Only the statement labels 80, 90 or 100 may be assigned to LABEL.

7.2 ASSIGN STATEMENT

This statement is of the following form:

```
ASSIGN j TO i
```

where j is a statement label of an executable statement and i is an integer variable.

The statement is used in conjunction with each assigned GO TO statement that contains the integer variable i. When the assigned GO TO is executed, control will be transferred to the statement labeled j.

Example:

```
ASSIGN 100 TO LABEL
.
.
.
ASSIGN 90 TO LABEL
GO TO LABEL, (80,90,100)
```

7.3 IF STATEMENT

IF statements transfer control to one of a series of statements depending upon a condition. Two types of IF statements are provided:

Arithmetic IF
Logical IF

7.3.1 ARITHMETIC IF

The arithmetic IF statement is of the form:

```
IF(e) m1,m2,m3
```

where e is an arithmetic expression and m1, m2 and m3 are statement labels.

Evaluation of expression e determines one of three transfer possibilities:

If e is:	Transfer to:
< 0	m1
= 0	m2
> 0	m3

Examples:

Statement	Expression Value	Transfer to
IF (A)3,4,5	15	5
IF (N-1)50,73,9	0	73
IF (AMTX(2,1,2))7,2,1	-256	7

7.3.2 LOGICAL IF

The Logical IF statement is of the form:

```
IF (u)s
```

where u is a Logical expression and s is any executable statement except a DO statement (see 7.4) or another Logical IF statement. The Logical expression u is evaluated as .TRUE. or .FALSE. Section 4 contains a discussion of Logical expressions.

Control Conditions:

If u is FALSE, the statement s is ignored and control goes to the next statement following the Logical IF statement. If, however, the expression is TRUE, then control goes to the statement s, and subsequent program control follows normal conditions.

If s is a replacement statement (v = e, Section 5), the variable and equality sign (=) must be on the same line, either immediately following IF(u) or on a separate continuation line with the line spaces following IF(u) left blank. See example 4 below.

Examples:

```
1.  IF(I.GT.20) GO TO 115

2.  IF(Q.AND.R) ASSIGN 10 TO J

3.  IF(Z) CALL DECL(A,B,C)

4.  IF(A.OR.B.LE.PI/2)I=J

5.  IF(A.OR.B.LE.PI/2)
   X    I =J
```

7.4 DO STATEMENT

The DO statement, as implemented in FORTRAN, provides a method for repetitively executing a series of statements. The statement takes of one of the two following forms:

1) `DO k i = m1,m2,m3`

or

2) `DO k i = m1,m2`

where k is a statement label, i is an integer or logical variable, and m1, m2 and m3 are integer constants or integer or logical variables.

If m3 is 1, it may be omitted as in 2) above.

The following conditions and restrictions govern the use of DO statements:

1. The DO and the first comma must appear on the initial line.

2. The statement labeled k, called the terminal statement, must be an executable statement.

3. The terminal statement must physically follow its associated DO, and the executable statements following the DO, up to and including the terminal statement, constitute the range of the DO statement.

4. The terminal statement may not be an Arithmetic IF, GO TO, RETURN, STOP, PAUSE or another DO.

5. If the terminal statement is a logical IF and its expression is .FALSE., then the statements in the DO range are reiterated.

   If the expression is .TRUE., the statement of the logical IF is executed and then the statements in the DO range are reiterated. The statement of the logical IF may not be a GO TO, Arithmetic IF, RETURN, STOP or PAUSE.

6. The controlling integer variable, i, is called the index of the DO range. The index must be positive and may not be modified by any statement in the range.

7. If m1, m2, and m3 are Integer*1 variables or constants, the DO loop will execute faster and be shorter, but the range is limited to 127

iterations. For example, the loop overhead for a DO loop with a constant limit and an increment of 1 depends upon the type of the index variable as follows:

Index Variable Type	Overhead Microseconds	Bytes
INTEGER*2	35.5	19
INTEGER*1	24	14

8. During the first execution of the statements in the DO range, i is equal to m1; the second execution, i = m1+m3; the third, i=m1+2*m3, etc., until i is equal to the highest value in this sequence less than or equal to m2, and then the DO is said to be satisfied. The statements in the DO range will always be executed at least once, even if m1 $\leq$ m2.

When the DO has been satisfied, control passes to the statement following the terminal statement, otherwise control transfers back to the first executable statement following the DO statement.

Example:

The following example computes

$$\sum_{i=1}^{100} Ai$$ where a is a one-dimensional array

```
100   DIMENSION A(100)
  .
  .
  .
      SUM = A(1)
      DO 31 I = 2,100
   31 SUM =SUM + A(I)

      END
```

9. The range of a DO statement may be extended to include all statements which may logically be executed between the DO and its terminal statement. Thus, parts of the DO range may be situated such that they are not physically between the DO statement and its terminal statement but are executed logically in the DO range. This is called the extended range.

   Example:

```
       DIMENSION A(500), B(500)
   .
   .
   .
       DO 50 I = 10, 327, 3
   .
   .
   .
       IF (V7 -C*C) 20,15,31
30         .
   .
   .
50     A(I) = B(I) + C
   .
   .
   .
20     C = C - .05
       GO TO 50
31     C=C+ .0125
       GO TO 30
```

10. It is invalid to transfer control into the range of a DO statement not itself in the range or extended range of the same DO statement.

11. Within the range of a DO statement, there may be other DO statements, in which case the DO's must be nested. That is, if the range of one DO contains another DO, then the range of the inner DO must be entirely included in the range of the outer DO.

    The terminal statement of the inner DO may also be the terminal statement of the outer DO.

For example, given a two dimensional array A of 15 rows and 15 columns, and a 15 element one-dimensional array B, the following statements compute the 15 elements of array C to the formula:

$$Ck = \sum_{j=1}^{15} AkjBm, \quad k = 1,2,\ldots,15$$

```
      DIMENSION A(15,15), B(15), C(15)
.
.
.
      DO 80 K =1,15
      C(K) = 0.0
      DO 80 J=1,15
80    C(K) = C(K) +A(K,J) * B(J)
.
.
.
```

7.5 CONTINUE STATEMENT

CONTINUE is classified as an executable statement. However, its execution does nothing. The form of the CONTINUE statement is as follows:

```
CONTINUE
```

CONTINUE is frequently used as the terminal statement in a DO statement range when the statement which would normally be the terminal statement is one of those which are not allowed or is only executed conditionally.

Example:

```
      DO 5 K = 1,10
      .
      .
      .
      IF (C2) 5,6,6
    6 CONTINUE
      .
      .
      .
      C2 = C2 +.005
    5 CONTINUE
```

7.6 STOP STATEMENT

A STOP statement has one of the following forms:

```
STOP

or

STOP c
```

where c is any string of one to six characters.

When STOP is encountered during execution of the object program, the characters c (if present) are displayed on the operator control console and execution of the program terminates.

The STOP statement, therefore, constitutes the logical end of the program.

7.7 PAUSE STATEMENT

A PAUSE statement has one of the following forms:

```
PAUSE

or

PAUSE c
```

where c is any string of up to six characters.

When PAUSE is encountered during execution of the object program, the characters c (if present) are displayed on the operator control console and execution of the program ceases.

The decision to continue execution of the program is not under control of the program. If execution is resumed through intervention of an operator without otherwise changing the state of the processor, the normal execution sequence, following PAUSE, is continued.

Execution may be terminated by typing a "T" at the operator console. Typing any other character will cause execution to resume.

7.8 CALL STATEMENT

CALL statements control transfers into SUBROUTINE subprograms and provide parameters for use by the subprograms. The general forms and detailed discussion of CALL statements appear in Section 9, FUNCTIONS AND SUBPROGRAMS.

7.9 RETURN STATEMENT

The form, use and interpretation of the RETURN statement is described in Section 9.

7.10 END STATEMENT

The END statement must physically be the last statement of any FORTRAN program. It has the following form:

```
END
```

The END statement is an executable statement and may have a statement label. It causes a transfer of control to be made to the system exit routine $EX, which returns control to the operating system.

SECTION 8

INPUT / OUTPUT

FORTRAN provides a series of statements which define the control and conditions of data transmission between computer memory and external data handling or mass storage devices such as magnetic tape, disk, line printer, punched card processors, keyboard printers, etc.

These statements are grouped as follows:

1. Formatted READ and WRITE statements which cause formatted information to be transmitted between the computer and I/O devices.

2. Unformatted READ and WRITE statements which transmit unformatted binary data in a form similar to internal storage.

3. Auxiliary I/O statements for positioning and demarcation of files.

4. ENCODE and DECODE statements for transferring data between memory locations.

5. FORMAT statements used in conjunction with formatted record transmission to provide data conversion and editing information between internal data representation and external character string forms.

8.1 FORMATTED READ/WRITE STATEMENTS

8.1.1 FORMATTED READ STATEMENTS

A formatted READ statement is used to transfer information from an input device to the computer.

Two forms of the statement are available, as follows:

```
READ (u,f,ERR=L1,END=L2) k

or

READ (u,f,ERR=L1,END=L2)
```

where:

u - specifies a Physical and Logical Unit Number and may be either an unsigned integer or an integer variable in the range 1 through 10. If an Integer variable is used, an Integer value must be assigned to it prior to execution of the READ statement.

Units 1, 3, 4, and 5 are preassigned to the console Teletypewriter. Unit 2 is preassigned to the Line Printer (if one exists). Units 6-10 are preassigned to Disk Files (see User's Manual, Section 3). These units, as well as units 11-255, may be re-assigned by the user (see Appendix B).

f - is the statement label of the FORMAT statement describing the type of data conversion to be used within the input transmission or it may be an array name, in which case the formatting information may be input to the program at the execution time. (See Section 8.7.10)

L1- is the FORTRAN label on the statement to which the I/O processor will transfer control if an I/O error is encountered.

L2- is the FORTRAN label on the statement to which the I/O processor will transfer control if an End-of-File is encountered.

k - is a list of variable names, separated by commas, specifying the input data.

READ (u,f)k is used to input a number of items, corresponding to the names in the list k, from the file on logical unit u, and using the FORMAT statement f to specify the external representation of these items (see FORMAT statements, 8.7). The ERR= and END= clauses are optional. If not specified, I/O errors and End-of-Files cause fatal runtime errors.

The following notes further define the function of the READ (u,f)k statement:

1. Each time execution of the READ statement begins, a new record from the input file is read.

2. The number of records to be input by a single READ statement is determined by the list, k, and format specifications.

3. The list k specifies the number of items to be read from the input file and the locations into which they are to be stored.

4. Any number of items may appear in a single list and the items may be of different data types.

5. If there are more quantities in an input record than there are items in the list, only the number of quantities equal to the number of items in the list are transmitted. Remaining quantities are ignored.

6. Exact specifications for the list k are described in 8.6.

Examples:

1. Assume that four Integer data entries are stored in a sequential disk file and that the values have field widths of 3, 4, 2 and 5 respectively. The statements

```
      READ(5,20)K,L,M,N
   20 FORMAT(I3,I4,I2,I5)
```

will read the file and assign the input data to the variables K, L, M and N.

See 8.7 for complete description of FORMAT statements.

2. Input the quantities of an array (ARRY):

```
READ(6,21)ARRY
```

Only the name of the array needs to appear in the list (see 8.6). All elements of the array ARRY will be read and stored using the appropriate formatting specified by the FORMAT statement labeled 21.

READ(u,k) may be used in conjunction with a FORMAT statement to read H-type alphanumeric data into an existing H-type field (see Hollerith Conversions, 8.7.3).

For example, the statements

```
   READ(I,25)
   .
   .
   .
25 FORMAT(10HABCDEFGHIJ)
```

cause the next 10 characters of the file on input device I to be read and replace the characters ABCDEFGHIJ in the FORMAT statement.

8.1.2 FORMATTED WRITE STATEMENTS

A formatted WRITE statement is used to transfer information from the computer to an output device.

Two forms of the statement are available, as follows:

```
WRITE(u,f,ERR=L1,END=L2)k
```

or

```
WRITE (u,f,ERR=L1,END=L2)
```

where:

u - specifies a Logical Unit Number.

f - is the statement label of the FORMAT statement describing the type of data conversion to be used with the output transmission.

L1- specifies an I/O error branch.

L2- specifies an EOF branch.

k - is a list of variable names separated by commas, specifying the output data.

WRITE (u,f)k is used to output the data specified in the list k to a file on logical unit u using the FORMAT statement f to specify the external representation of the data (see FORMAT statements, 8.7). The following notes further define the function of the WRITE statement:

1. Several records may be output with a single WRITE statement, with the number determined by the list and FORMAT specifications.

2. Successive data are output until the data specified in the list are exhausted.

3. If output is to a device which specifies fixed length records and the data specified in the list do not fill the record, the remainder of the record is filled with blanks.

Example:

```
WRITE(2,10)A,B,C,D
```

The data assigned to the variables A, B, C and D are output to Logical Unit Number 2, formatted according to the FORMAT statement labeled 10.

WRITE(u,f) may be used to write alphanumeric information when the characters to be written are specified within the FORMAT statement. In this case a variable list is not required.

For example, to write the characters 'H CONVERSION' on unit 1,

```
      WRITE(1,26)
      .
      .
      .
   26 FORMAT ('H CONVERSION')
```

8.2 UNFORMATTED READ/WRITE

Unformatted I/O (i.e. without data conversion) is accomplished using the statements:

READ(u,ERR=L1,END=L2) k

WRITE(u,ERR=L1,END=L2) k

where:

u - specifies a Logical Unit Number.

L1- specifies an I/O error branch.

L2- specifies an EOF branch.

k - is a list of variable names, separated by commas, specifying the I/O data.

The following notes define the functions of unformatted I/O statements.

1. Unformatted READ/WRITE statements perform memory-image transmission of data with no data conversion or editing.

2. The amount of data transmitted corresponds to the number of variables in the list k.

3. The total length of the list of variable names in an unformatted READ must not be longer than the record length. If the logical record length and the length of the list are the same, the entire record is read. If the length of the list is shorter than the logical record length the unread items in the record are skipped.

4. The WRITE(a)k statement writes one logical record.

5. A logical record may extend across more than one physical record.

8.3 DISK FILE I/O

A READ or WRITE to a disk file (LUN 6-10) automatically OPENs the file for I/O. The file remains open until closed by an ENDFILE command (see Section 8.4) or until normal program termination.

NOTE

Exercise caution when doing sequential output to disk files. If output is done to an existing file, the existing file will be deleted and replaced with a new file of the same name.

8.3.1 RANDOM DISK I/O

SEE ALSO SECTION 3 OF YOUR MICROSOFT FORTRAN USER'S MANUAL.

For random disk access, the record number is specified by using the REC=n option in the READ or WRITE statement. For example:

```
I = 10
WRITE (6,20,REC=I,ERR=50) X, Y, Z
  .
  .
  .
```

This program segment writes record 10 on LUN 6. If a previous record 10 exists, it is written over. If no record 10 exists, the file is extended to create one. Any attempt to read a non-existent record results in an I/O error.

8.3.2 OPEN SUBROUTINE

Alternatively, a file may be OPENed using the OPEN subroutine. LUNs 1-5 may also be assigned to disk files with OPEN. The OPEN subroutine allows the program to specify a filename and device to be associated with a LUN.

An OPEN of a non-existent file creates a null file of the appropriate name. An OPEN of an existing file followed by sequential output deletes the existing file. An OPEN of an existing file followed by an input allows access to the current contents of the file.

The form of an OPEN call varies under different operating systems. See your Microsoft FORTRAN User's Manual, Section 3.

8.4 AUXILIARY I/O STATEMENTS

Three auxiliary I/O statements are provided:

```
BACKSPACE u
REWIND u
ENDFILE u
```

The actions of all three statements depend on the LUN with which they are used (see Appendix B). When the LUN is for a terminal or line printer, the three statements are defined as no-ops.

When the LUN is for a disk drive, the ENDFILE and REWIND commands allow further program control of disk files. ENDFILE u closes the file associated with LUN u. REWIND u closes the file associated with LUN u, then opens it again. BACKSPACE is not implemented at this time, and therefore causes an error if used.

8.5 ENCODE/DECODE

ENCODE and DECODE statements transfer data, according to format specifications, from one section of memory to another. DECODE changes data from ASCII format to the specified format. ENCODE changes data of the specified format into ASCII format. The two statements are of the form:

```
ENCODE(a,f) k
DECODE(a,f) k
```

where:

a is an array name
f is FORMAT statement number
k is an I/O List

DECODE is analogous to a READ statement, since it causes conversion from ASCII to internal format. ENCODE is analogous to a WRITE statement, causing conversion from internal formats to ASCII.

NOTE

Care should be taken that the array A is always large enough to contain all of the data being processed. There is no check for overflow. An ENCODE operation which overflows the array will probably wipe out important data following the array. A DECODE operation which overflows will attempt to process the data following the array.

8.6 INPUT/OUTPUT LIST SPECIFICATIONS

Most forms of READ/WRITE statements may contain an ordered list of data names which identify the data to be transmitted. The order in which the list items appear must be the same as that in which the corresponding data exists (Input), or will exist (Output) in the external I/O medium.

Lists have the following form:

```
m1,m2,...,mn
```

where the mi are list items separated by commas, as shown.

8.6.1 LIST ITEM TYPES

A list item may be a single datum identifier or a multiple data identifier.

1. A single datum identifier item is the name of a variable or array element.

   Examples:

   ```
   A
   C(26,1),R,K,D
   B,I(10,10),S,F(1,25)
   ```

   NOTE

   Sublists are not implemented.

2. Multiple data identifier items are in two forms:

   a. An array name appearing in a list without subscript(s) is considered equivalent to the listing of each successive element of the array.

   Example:

   If B is a two dimensional array, the list item B is equivalent to: B(1,1),B(2,1),B(3,1)...., B(1,2),B(2,2)...,B(j,k).

   where j and k are the subscript limits of B.

   b. DO-implied items are lists of one or more single datum identifiers or other DO-implied items followed by a comma character and an expression of the form:

   i = m1,m2,m3 or i = m1,m2

   and enclosed in parentheses.

   The elements i,m1,m2,m3 have the same meaning as defined for the DO statement. The DO implication applies to all list items enclosed in parentheses with the implication.

Examples:

DO-Implied Lists	Equivalent Lists
(X(I),I=1,4)	X(1),X(2),X(3),X(4)
(Q(J),R(J),J=1,2)	Q(1),R(1),Q(2),R(2)
(G(K),K=1,7,3)	G(1),G(4),G(7)
((A(I,J),I=3,5),J=1,9,4)	A(3,1),A(4,1),A(5,1) A(3,5),A(4,5),A(5,5) A(3,9),A(4,9),A(5,9)
(R(M),M=1,2),I,ZAP(3)	R(1),R(2),I,ZAP(3)
(R(3),T(I),I=1,3)	R(3),T(1),R(3),T(2), R(3),T(3)

Thus, the elements of a matrix, for example, may be transmitted in an order different from the order in which they appear in storage. The array A(3,3) occupies storage in the order A(1,1),A(2,1), A(3,1),A(1,2),A(2,2),A(3,2), A(1,3),A(2,3),A(3,3). By specifying the transmission of the array with the DO-implied list item ((A(I,J),J=1,3),I=1,3), the order of transmission is:
A(1,1),A(1,2),A(1,3),A(2,1),A(2,2),
A(2,3),A(3,1),A(3,2),A(3,3)

8.6.2 SPECIAL NOTES ON LIST SPECIFICATIONS

1. The ordering of a list is from left to right with repetition of items enclosed in parentheses (other than as subscripts) when accompanied by controlling DO-implied index parameters.

2. Arrays are transmitted by the appearance of the array name (unsubscripted) in an input/output list.

3. Constants may appear in an input/output list only as subscripts or as indexing parameters.

4. For input lists, the DO-implying elements i, m1, m2 and m3 may not appear within the parentheses as list items.

Examples:

1. READ (1,20) (I,J,A(I),I=1,J,2) is not allowed

2. READ(1,20)I,J,(A(I),I=1,J,2) is allowed

3. WRITE(1,20)(I,J,A(I),I=1,J,2) is allowed

Consider the following examples:

```
DIMENSION A(25)

A(1) = 2.1
A(3) = 2.2
A(5) = 2.3
J = 5

WRITE (1,20) J,(I,A(I),I=1,J,2)
.
.
.
```

the output of this WRITE statement is

```
5,1,2.1,3,2.2,5,2.3
```

1. Any number of items may appear in a single list.

2. In a formatted transmission (READ(u,f)k, WRITE(u,f)k) each item must have the correct type as specified by a FORMAT statement.

8.7 FORMAT STATEMENTS

FORMAT statements are non-executable, generative statements used in conjunction with formatted READ and WRITE statements. They specify conversion methods and data editing information as the data is transmitted between computer storage and external media representation.

FORMAT statements require statement labels for reference (f) in the READ(u,f)k or WRITE(u,f)k statements.

The general form of a FORMAT statement is as follows:

```
m FORMAT (s1,s2,...,sn/s1',s2',...,sn'/...)
```

where m is the statement label and each si is a field descriptor. The word FORMAT and the parentheses must be present as shown. The slash (/) and comma (,) characters are field separators and are described in a separate subparagraph. The field is defined as that part of an external record occupied by one transmitted item.

8.7.1 FIELD DESCRIPTORS

Field descriptors describe the sizes of data fields and specify the type of conversion to be exercised upon each transmitted datum. The FORMAT field descriptors may have any of the following forms:

Descriptor	Classification
rFw.d rGw.d rEw.d rDw.d rIw	Numeric Conversion
rLw	Logical Conversion
rAw nHh1h2...hn 'l1l2...ln'	Hollerith Conversion
nX	Spacing Specification
mP	Scaling Factor

where:

1. w and n are positive integer constants defining the field width (including digits, decimal points, algebraic signs) in the external data representation.

2. d is an integer specifying the number of fractional digits appearing in the external data representation.

3. The characters F, G, E, D, I, A and L indicate the type of conversion to be applied to the items in an input/output list.

4. r is an optional, non-zero integer indicating that the descriptor will be repeated r times.

5. The hi and li are characters from the FORTRAN character set.

6. m is an integer constant (positive, negative, or zero) indicating scaling.

8.7.2 NUMERIC CONVERSIONS

Input operations with any of the numeric conversions will allow the data to be represented in a "Free Format"; i.e., commas may be used to separate the fields in the external representation.

F-type conversion

Form: Fw.d

Real or Double Precision type data are processed using this conversion. w characters are processed of which d are considered fractional.

F-output

Values are converted and output as minus sign (if negative), followed by the integer portion of the number, a decimal point and d digits of the fractional portion of the number. If a value does not fill the field, it is right justified in the field and enough preceding blanks to fill the field are inserted. If a value requires more field positions than allowed by w, the first w-1 digits of the value are output, preceded by an asterisk.

F-Output Examples:

FORMAT Descriptor	Internal Value	Output (b=blank)
F10.4	368.42	bb368.4200
F7.1	-4786.361	-4786.4
F8.4	8.7E-2	bb0.0870
F6.4	4739.76	*.7600
F7.3	-5.6	b-5.600

* Note the loss of leading digits in the 4th line above.

F-Input

(See the description under E-Input below.)

E-type Conversion

Form: Ew.d

Real or Double Precision type data are processed using this conversion. w characters are processed of which d are considered fractional.

E-Output

Values are converted, rounded to d digits, and output as:

1. a minus sign (if negative),

2. a zero and a decimal point,

3. d decimal digits,

4. the letter E,

5. the sign of the exponent (minus or blank),

6. two exponent digits,

in that order. The values as described are right justified in the field w with preceding blanks to fill the field if necessary. The field width w should satisfy the relationship:

$$w > d + 7$$

Otherwise significant characters may be lost. Some E-Output examples follow:

FORMAT Descriptor	Internal Value	Output (b=blank)
E12.5	76.573	bb.76573Eb02
E14.7	-32672.354	-b.3267235Eb05
E13.4	-0.0012321	bb-b.1232E-02
E8.2	76321.73	b.76Eb05

E-Input

Data values which are to be processed under E, F, or G conversion can be a relatively loose format in the external input medium. The format is identical for either conversion and is as follows:

1. Leading spaces (ignored)

2. A + or - sign (an unsigned input is assumed to be positive)

3. A string of digits

4. A decimal point

5. A second string of digits

6. The character E

7. A + or - sign

8. A decimal exponent

Each item in the list above is optional; but the following conditions must be observed:

1. If FORMAT items 3 and 5 (above) are present, then 4 is required.

2. If FORMAT item 8 is present, then 6 or 7 or both are required.

3. All non-leading spaces are considered zeros.

Input data can be any number of digits in length, and correct magnitudes will be developed, but precision will be maintained only to the extent specified in Section 3 for Real data.

E- and F- and G- Input Examples:

FORMAT Descriptor	Input (b=blank)	Internal Value
E10.3	+0.23756+4	+2375.60
E10.3	bbbbb17631	+17.631
G8.3	b1628911	+1628.911
F12.4	bbbb-6321132	-632.1132

Note in the above examples that if no decimal point is given among the input characters, the d in the FORMAT specification establishes the decimal point in conjunction with an exponent, if given. If a decimal point is included in the input characters, the d specification is ignored.

The letters E, F, and G are interchangeable in the input format specifications. The end result is the same.

D-Type Conversions

D-Input and D-Output are identical to E-Input and E-Output except the exponent may be specified with a "D" instead of an "E."

G-Type Conversions

Form: Gw.d

Real or Double Precision type data are processed using this conversion. w characters are processed of which d are considered significant.

G-Input:

(See the description under E-Input)

G-Output:

The method of output conversion is a function of the magnitude of the number being output. Let n be the magnitude of the number. The following table shows how the number will be output:

Magnitude	Equivalent Conversion
.1 <= n < 1	F(w-4).d,4X
1 <= n < 10	F(w-4).(d-1),4X
.	.
.	.
.	.
$10^{d-2} <= n < 10^{d-1}$	F(w-4).1,4X
$10^{d-1} <= n < 10^{d}$	F(w-4).0,4X
Otherwise	Ew.d

I-Conversions

Form: Iw

Only Integer data may be converted by this form of conversion. w specifies field width.

I-Output:

Values are converted to Integer constants. Negative values are preceded by a minus sign. If the value does not fill the field, it is right justified in the field and enough preceding blanks to fill the field are inserted. If the value exceeds the field width, only the least significant w-1 characters are output preceded by an asterisk.

Examples:

FORMAT Descriptor	Internal Value	Output (b=blank)
I6	+281	bbb281
I6	-23261	-23261
I3	126	126
I4	-226	-226

I-Input:

A field of w characters is input and converted to internal integer format. A minus sign may precede the integer digits. If a sign is not present, the value is considered positive.

Integer values in the range -32768 to 32767 are accepted. Non-leading spaces are treated as zeros.

Examples:

Format Descriptor	Input (b=blank)	Internal Value
I4	b124	124
I4	-124	-124
I7	bb6732b	67320
I4	1b2b	1020

8.7.3 HOLLERITH CONVERSIONS

A-Type Conversion

The form of the A conversion is as follows:

Aw

This descriptor causes unmodified Hollerith characters to be read into or written from a specified list item.

The maximum number of actual characters which may be transmitted between internal and external representations using Aw is four times the number of storage units in the corresponding list item (i.e., 1 character for logical items, 2 characters for Integer items, 4 characters for Real items and 8 characters for Double Precision items).

A-Output:

If w is greater than 4n (where n is the number of storage units required by the list item), the

external output field will consist of w-4n blanks followed by the 4n characters from the internal representation. If w is less than 4n, the external output field will consist of the leftmost w characters from the internal representation.

Examples:

Format Descriptor	Internal	Type	Output (b=blanks)
A1	A1	Integer	A
A2	AB	Integer	AB
A3	ABCD	Real	ABC
A4	ABCD	Real	ABCD
A7	ABCD	Real	bbbABCD

A-Input:

If w is greater than 4n (where n is the number of storage units required by the corresponding list item), the rightmost 4n characters are taken from the external input field. If w is less than 4n, the w characters appear left justified with w-4n trailing blanks in the internal representation.

Examples:

Format Descriptor	Input Characters	Type	Internal (b=blank)
A1	A	Integer	Ab
A3	ABC	Integer	AB
A4	ABCD	Integer	AB
A1	A	Real	Abbb
A7	ABCDEFG	Real	DEFG

H-Conversion

The forms of H conversion are as follows:

nHh1h2...hn

'h1h2...hn'

These descriptors process Hollerith character strings between the descriptor and the external field, where each hi represents any character from the ASCII character set.

NOTE

Special consideration is required if an apostrophe (') is to be used within the literal string in the second form. An apostrophe character within the string is represented by two successive apostrophes. See the examples below.

H-Output:

The n characters hi, are placed in the external field. In the nHh1h2...hn form the number of characters in the string must be exactly as specified by n. Otherwise, characters from other descriptors will be taken as part of the string. In both forms, blanks are counted as characters.

Examples:

Format Descriptor			Output (b=blank)
1HA	or	'A'	A
8HbSTRINGb	or	'bSTRINGb'	bSTRINGb
11HX(2,3)=12.0	or	'X(2,3)=12.0'	X(2,3)=12.0
11HIbSHOULDN'T	or	'IbSHOULDN''T'	IbSHOULDN'T

H-Input

The n characters of the string hi are replaced by the next n characters from the input record. This results in a new string of characters in the field descriptor.

FORMAT Descriptor			Input (b=blank)	Resultant Descriptor
4H1234	or	'1234'	ABCD	4HABCD or 'ABCD'
7HbbFALSE	or	'bbFALSE'	bFALSEb	7HbFALSEb or 'bFALSEb'
6Hbbbbbb	or	'bbbbbb'	MATRIX	6HMATRIX or 'MATRIX'

8.7.4 LOGICAL CONVERSIONS

The form of the logical conversion is as follows:

Lw

L-Output:

If the value of an item in an output list

corresponding to this descriptor is 0, an F will be output; otherwise, a T will be output. If w is greater than 1, w-1 leading blanks precede the letters.

Examples:

FORMAT Descriptor	Internal Value	Output (b=blank)
L1	=0	F
L1	<>0	T
L5	<>0	bbbbT
L7	=0	bbbbbbF

L-Input

The external representation occupies w positions. It consists of optional blanks followed by a "T" or "F", followed by optional characters.

8.7.5 X DESCRIPTOR

The form of X conversion is as follows:

nX

This descriptor causes no conversion to occur, nor does it correspond to an item in an input/output list. When used for output, it causes n blanks to be inserted in the output record. Under input circumstances, this descriptor causes the next n characters of the input record to be skipped. Note that 1X is required, as X alone will not work.

Output Examples:

FORMAT Statement	Output (b=blank)
3 FORMAT (1HA,4X,2HBC)	AbbbbBC
7 FORMAT (3X,4HABCD,1X)	bbbABCDb

Input Examples:

FORMAT Statement	Input String	Resultant Input
10 FORMAT (F4.1,3X,F3.0)	12.5ABC120	12.5,120
5 FORMAT (7X,I3)	1234567012	012

8.7.6 P DESCRIPTOR

The P descriptor is used to specify a scaling factor for real conversions (F, E, D, G). The form is nP where n is an integer constant (positive, negative, or zero).

The scaling factor is automatically set to zero at the beginning of each formatted I/O call (each READ or WRITE statement). If a P descriptor is encountered while scanning a FORMAT, the scale factor is changed to n. The scale factor remains changed until another P descriptor is encountered or the I/O terminates.

Effects of Scale Factor on Input:

During E, F, or G input the scale factor takes effect only if no exponent is present in the external representation. In that case, the internal value will be a factor of 10**n less than the external value (the number will be divided by 10**n before being stored).

Effect of Scale Factor on Output:

E-Output, D-Output:

The coefficient is shifted left n places relative to the decimal point, and the exponent is reduced by n (the value remains the same).

F-Output:

The external value will be 10**n times the internal value.

G-Output:

The scale factor is ignored if the internal value is small enough to be output using F conversion. Otherwise, the effect is the same as for E output.

8.7.7 SPECIAL CONTROL FEATURES OF FORMAT STATEMENTS

8.7.7.1 Repeat Specifications

1. The E, F, D, G, I, L and A field descriptors may be indicated as repetitive descriptors by using a repeat count r in the form rEw.d, rFw.d, rGw.d, rIw, rLw, rAw. The following pairs of FORMAT statements are equivalent:

```
  66   FORMAT (3F8.3,F9.2)
C  IS EQUIVALENT TO:
   66  FORMAT (F8.3,F8.3,F8.3,F9.2)

   14  FORMAT (2I3,2A5,2E10.5)
C   IS EQUIVALENT TO:
   14  FORMAT (I3,I3,A5,A5,E10.5,E10.5)
```

2. Repetition of a group of field descriptors is accomplished by enclosing the group in parentheses preceded by a repeat count. Absence of a repeat count indicates a count of one. Up to two levels of parentheses, including the parentheses required by the FORMAT statement, are permitted.

   Note the following equivalent statements:

```
   22  FORMAT (I3,4(F6.1,2X))
C  IS EQUIVALENT TO:
   22  FORMAT (I3,F6.1,2X,F6.1,2X,F6.1,2X,
     1    F6.1,2X)
```

3. Repetition of FORMAT descriptors is also initiated when all descriptors in the FORMAT statement have been used but there are still items in the input/output list that have not been processed. When this occurs the FORMAT descriptors are re-used starting at the first opening parenthesis in the FORMAT statement. A repeat count preceding the parenthesized descriptor(s) to be re-used is also active in the re-use. This type of repetitive use of FORMAT descriptors terminates processing of the current record and initiates the processing of a new record each time the re-use begins. Record demarcation under these circumstances is the same as in the paragraph 8.7.7.2 below.

Input Example:

```
      DIMENSION A(100)
      READ (3,13) A
      .
      .
      .
   13 FORMAT (5F7.3)
```

In this example, the first 5 quantities from each of 20 records are input and assigned to the array elements of the array A.

Output Example:

```
      .
      .
      .
      WRITE (6,12)E,F,K,L,M,KK,LL,MM,K3,L3,M3
      .
      .
      .
   12 FORMAT (2F9.4,3(3I7,/))
```

In this example, three records are written. Record 1 contains E, F, K, L and M. Because the descriptor 3I7 is reused twice, Record 2 contains KK, LL and MM and Record 3 contains K3, L3 and M3.

8.7.7.2 Field Separators

Two adjacent descriptors must be separated in the FORMAT statement by either a comma or one or more slashes.

Example:

2H0K/F6.3 or 2H0K,F6.3

The slash not only separates field descriptors, but it also specifies the demarcation of formatted records.

Each slash terminates a record and sets up the next record for processing. The remainder of an input record is ignored; the remainder of an output record is filled with blanks. Successive slashes (///.../) cause successive records to be ignored on input and successive blank records to be written on output.

Output example:

```
      DIMENSION A(100),J(20)
      .
      .
      .
      WRITE (7,8) J,A
 8    FORMAT (10I7/10I7/50F7.3/50F7.3)
```

In this example, the data specified by the list of the WRITE statement are output to unit 7 according to the specifications of FORMAT statement 8. Four records are written as follows:

Record 1	Record 2	Record 3	Record 4
J(1)	J(11)	A(1)	A(51)
J(2)	J(12)	A(2)	A(52)
.	.	.	.
.	.	.	.
.	.	.	.
J(10)	J(20)	A(50)	A(100)

Input Example:

```
      DIMENSION B(10)
      .
      .
      .
      READ (4,17) B
 17   FORMAT(F10.2/F10.2//8F10.2)
```

In this example, the two array elements B(1) and B(2) receive their values from the first data fields of successive records (the remainders of the two records are ignored). The third and fourth records are ignored and the remaining elements of the array are filled from the fifth record.

8.7.8 FORMAT CONTROL, LIST SPECIFICATIONS AND RECORD DEMARCATION

The following relationships and interactions between FORMAT control, input/output lists and record demarcation should be noted:

1. Execution of a formatted READ or WRITE statement initiates FORMAT control.

2. The conversion performed on data depends on information jointly provided by the elements in the input/output list and field descriptors in the FORMAT statement.

3. If there is an input/output list, at least one descriptor of types E, F, D, G, I, L or A must be present in the FORMAT statement.

4. Each execution of a formatted READ statement causes a new record to be input.

5. Each item in an input list corresponds to a string of characters in the record and to a descriptor of the types E, F, G, I, L or A in the FORMAT statement.

6. H and X descriptors communicate information directly between the external record and the field descriptors without reference to list items.

7. On input, whenever a slash is encountered in the FORMAT statement or the FORMAT descriptors have been exhausted and re-use of descriptors is initiated, processing of the current record is terminated and the following occurs:

   a. Any unprocessed characters in the record are ignored.

   b. If more input is necessary to satisfy list requirements, the next record is read.

8. A READ statement is terminated when all items in the input list have been satisfied if:

   a. The next FORMAT descriptor is E, F, G, I, L or A.

   b. The FORMAT control has reached the last outer right parenthesis of the FORMAT statement.

   If the input list has been satisfied, but the next FORMAT descriptor is H or X, more data are processed (with the possibility of new records being input) until one of the above conditions exists.

9. If FORMAT control reaches the last right parenthesis of the FORMAT statement but there are more list items to be processed, all or part of the descriptors are reused. (See item 3 in the description of Repeat Specifications, sub-paragraph 8.7.7.1)

10. When a Formatted WRITE statement is executed, records are written each time a slash is encountered in the FORMAT statement or FORMAT control has reached the rightmost right parenthesis. The FORMAT control terminates in one of the two methods described for READ termination in 8 above. Incomplete records are filled with blanks to maintain record lengths.

8.7.9 FORMAT CARRIAGE CONTROL

Formatted I/O to a console or printer uses the first character of each record for carriage control. The carriage control character is never printed. The carriage control character determines what action will be taken before the line is printed. The options are as follows:

Control Character	Action Taken Before Printing
0	Skip 2 lines
1	Insert Form Feed
+	No advance
Other	Skip 1 line

Formatted I/O to disk does not require the first character of each record to be a carriage control character. Records are terminated by a carriage return character (X'0D'). There are no line-feeds (X'0A') in the file unless written there explicitly.

8.7.10 FORMAT SPECIFICATIONS IN ARRAYS

The FORMAT reference, f, of a formatted READ or WRITE statement (See 8.1) may be an array name instead of a statement label. If such reference is made, at the time of execution of the READ/WRITE statement the first part of the information contained in the array, taken in natural order, must constitute a valid FORMAT specification. The array may contain non-FORMAT information following the right parenthesis that ends the FORMAT specification.

The FORMAT specification which is to be inserted in the array has the same form as defined for a FORMAT statement (i.e., it begins with a left parenthesis and ends with a right parenthesis).

The FORMAT specification may be inserted in the array by use of a DATA initialization statement, or

by use of a READ statement together with an Aw FORMAT. Example:

Assume the FORMAT specification

```
(3F10.3,4I6)
```

or a similar 12 character specification is to be stored into an array. The array must allow a minimum of 3 storage units.

The FORTRAN coding below shows the various methods of establishing the FORMAT specification and then referencing the array for a formatted READ or WRITE.

```
C  DECLARE A REAL ARRAY
       DIMENSION A(3), B(3), M(4)
C  INITIALIZE FORMAT WITH DATA STATEMENT
       DATA A/'(3F1','0.3,',',4I6)'/
       .
       .
       .
C  READ DATA USING FORMAT SPECIFICATIONS
C       IN ARRAY A
       READ(6,A) B, M

C  DECLARE AN INTEGER ARRAY
       DIMENSION IA(4), B(3), M(4)
       .
       .
       .
C  READ FORMAT SPECIFICATIONS
       READ (7,15) IA
C  FORMAT FOR INPUT OF FORMAT SPECIFICATIONS
   15  FORMAT (4A2)
       .
       .
       .
C  READ DATA USING PREVIOUSLY INPUT
C       FORMAT SPECIFICATION
       READ (7,IA) B,M
       .
       .
       .
```

SECTION 9

FUNCTIONS AND SUBPROGRAMS

The FORTRAN language provides a means for defining and using often needed programming procedures such that the statement or statements of the procedures need appear in a program only once but may be referenced and brought into the logical execution sequence of the program whenever and as often as needed.

These procedures are as follows:

1. Statement functions.
2. Library functions.
3. FUNCTION subprograms.
4. SUBROUTINE subprograms.

Each of these procedures has its own unique requirements for reference and defining purposes. These requirements are discussed in subsequent paragraphs of this section. However, certain features are common to the whole group or to two or more of the procedures. These common features are as follows:

1. Each of these procedures is referenced by its name which, in all cases, is one to six alphanumeric characters of which the first is a letter.
2. The first three are designated as "functions" and are alike in that:
    1. They are always single valued (i.e., they return one value to the program unit from which they are referenced).
    2. They are referred to by an expression containing a function name.
    3. They must be typed by type specification statements if the data type of the single-valued result is to be different from that indicated by the pre-defined convention.
3. FUNCTION subprograms and SUBROUTINE subprograms are considered program units.

In the following descriptions of these procedures, the term calling program means the program unit or procedure in which a reference to a procedure is made, and the term "called program" means the procedure to which a reference is made.

9.1 THE PROGRAM STATEMENT

The PROGRAM statement provides a means of specifying a name for a main program unit. The form of the statement is:

```
PROGRAM name
```

If present, the PROGRAM statement must appear before any other statement in the program unit. The name consists of 1-6 alphanumeric characters, the first of which is a letter. If no PROGRAM statement is present in a main program, the compiler assigns a name of $MAIN to that program.

9.2 STATEMENT FUNCTIONS

Statement functions are defined by a single arithmetic or logical assignment statement and are relevant only to the program unit in which they appear. The general form of a statement function is as follows:

```
f(a1,a2,...an) = e
```

where f is the function name, the ai are dummy arguments and e is an arithmetic or logical expression.

Rules for ordering, structure and use of statement functions are as follows:

1. Statement function definitions, if they exist in a program unit, must precede all executable statements in the unit and follow all specification statements.

2. The ai are distinct variable names or array elements, but, being dummy variables, they may have the same names as variables of the same type appearing elsewhere in the program unit.

3. The expression e is constructed according to the rules in SECTION 4 and may contain only references to the dummy arguments and non-Literal constants, variable and array element references, utility and mathematical function references and references to previously defined statement functions.

4. The type of any statement function name or argument that differs from its pre-defined convention type must be defined by a type specification statement.

5. The relationship between f and e must conform to the replacement rules in Section 5.

6. A statement function is called by its name followed by a parenthesized list of arguments. The expression is evaluated using the arguments specified in the call, and the reference is replaced by the result.

7. The ith parameter in every argument list MUST agree in type with the ith dummy in the statement function.

The example below shows a statement function and a statement function call.

```
C  STATEMENT FUNCTION DEFINITION
C
      FUNC1(A,B,C,D) = ((A+B)**C)/D


C  STATEMENT FUNCTION CALL
C
      A12=A1-FUNC1(X,Y,Z7,C7)
```

9.3 LIBRARY FUNCTIONS

Library functions are a group of utility and mathematical functions which are "built-in" to the FORTRAN system. Their names are pre-defined to the Processor and automatically typed. The functions are listed in Tables 9-1 and 9-2. In the tables, arguments are denoted as a1,a2,...,an, if more than one argument is required; or as a if only one is required. A library function is called when its name is used in an arithmetic expression. Such a reference takes the following form:

f(a1,a2,...an)

where f is the name of the function and the ai are actual arguments. The arguments must agree in type, number and order with the specifications indicated in Tables 9-1 and 9-2.

In addition to the functions listed in 9-1 and 9-2, four additional library subprograms are provided to enable direct access to the 8080 (or Z80) hardware. These are:

PEEK, POKE, INP, OUT

For the following:
b, b1, and b2 are BYTE constants or variables
i is an INTEGER constant or variable

PEEK and INP are Logical functions; POKE and OUT are subroutines. PEEK and POKE allow direct access to any memory location. PEEK(i) returns the contents of the memory location specified by i. CALL POKE(i,b) causes the contents of the memory location specified by i to be replaced by the contents of b. INP and OUT allow direct access to the I/O ports. INP(b) does an input from port b and returns the 8-bit value input. CALL OUT(b1,b2) outputs the value of b2 to the port specified by b1.

RAN is another function in the FORTRAN library. RAN is a random number generator that is compatible with Microsoft's BASIC Compiler and BASIC-80 interpreter. The random number generated is a REAL decimal number between 0 and 1. The random number generator is called by a statement of the following form:

```
<variable> = RAN(x)
```

If x < 0, the first value of a new sequence of random numbers is returned.

If x = 0, the last random number generated is returned again.

If x > 0, the next random number in the sequence is generated.

Examples using library functions:

```
A1 = B+FLOAT (I7)

MAGNI = ABS(KBAR)

PDIF = DIM(C,D)

S3 = SIN(T12)

ROOT = (-B+SQRT(B**2-4.*A*C))/
1              (2.*A)
```

TABLE 9-1

Intrinsic Functions

Function Name	Definition	Types Argument	Types Function
ABS	|a|	Real	Real
IABS		Integer	Integer
DABS		Double	Double
AINT	Sign of a times lar-	Real	Real
INT	gest integer <=|a|	Real	Integer
IDINT		Double	Integer
AMOD	a1(mod a2)	Real	Real
MOD		Integer	Integer
AMAX0	Max(a1,a2,...)	Integer	Real
AMAX1		Real	Real
MAX0		Integer	Integer
MAX1		Real	Integer
DMAX1		Double	Double
AMIN0	Min(a1,a2,...)	Integer	Real
AMIN1		Real	Real
MIN0		Integer	Integer
MIN1		Real	Integer
DMIN1		Double	Double
FLOAT	Conversion from Integer to Real	Integer	Real
IFIX	Conversion from Real to Integer	Real	Integer
SIGN	Sign of a2 times |a1|	Real	Real
ISIGN		Integer	Integer
DSIGN		Double	Double
DIM	a1 - Min(a1,a2)	Real	Real
IDIM		Integer	Integer
SNGL		Double	Real
DBLE		Real	Double

TABLE 9-2

Basic External Functions

Name	Number of Arguments	Type Definition	Argument	Function
EXP	1	e**a	Real	Real
DEXP	1		Double	Double
ALOG	1	ln (a)	Real	Real
DLOG	1		Double	Double
ALOG10	1	log10(a)	Real	Real
DLOG10	1		Double	Double
SIN	1	sin (a)	Real	Real
DSIN	1		Double	Double
COS	1	cos (a)	Real	Real
DCOS	1		Double	Double
TANH	1	tanh (a)	Real	Real
SQRT	1	(a) ** 1/2	Real	Real
DSQRT	1		Double	Double
ATAN	1	arctan (a)	Real	Real
DATAN	1		Double	Double
ATAN2	2	arctan (a1/a2)	Real	Real
DATAN2	2		Double	Double
DMOD	2	a1(mod a2)	Double	Double

9.4 FUNCTION SUBPROGRAMS

A program unit which begins with a FUNCTION statement is called a FUNCTION subprogram.

A FUNCTION statement has one of the following forms:

```
t FUNCTION f(a1,a2,...an)
```

or

```
FUNCTION f(a1,a2,...an)
```

where:

1. t is either INTEGER, REAL, DOUBLE PRECISION or LOGICAL or is empty as shown in the second form.

2. f is the name of the FUNCTION subprogram.

3. The ai are dummy arguments of which there must be at least one and which represent variable names, array names or dummy names of SUBROUTINE or other FUNCTION subprograms.

9.5 CONSTRUCTION OF FUNCTION SUBPROGRAMS

Construction of FUNCTION subprograms must comply with the following restrictions:

1. The FUNCTION statement must be the first statement of the program unit.

2. Within the FUNCTION subprogram, the FUNCTION name must appear at least once on the left side of the equality sign of an assignment statement or as an item in the input list of an input statement. This defines the value of the FUNCTION so that it may be returned to the calling program.

   Additional values may be returned to the calling program through assignment of values to dummy arguments.

Example:

```
      FUNCTION Z7(A,B,C)
       .
       .
       .
      Z7 = 5.*(A-B) + SQRT(C)
       .
       .
       .
C     REDEFINE ARGUMENT
      B=B+Z7
       .
       .
       .
      RETURN
       .
       .
       .
      END
```

3. The names in the dummy argument list may not appear in EQUIVALENCE, COMMON or DATA statements in the FUNCTION subprogram.

4. If a dummy argument is an array name, then an array declarator must appear in the subprogram with dimensioning information consistant with that in the calling program.

5. A FUNCTION subprogram may contain any defined FORTRAN statements other than BLOCK DATA statements, SUBROUTINE statements, another FUNCTION statement or any statement which references either the FUNCTION being defined or another subprogram that references the FUNCTION being defined.

6. The logical termination of a FUNCTION subprogram is a RETURN statement and there must be at least one of them.

7. A FUNCTION subprogram must physically terminate with an END statement.

Example:

```
      FUNCTION SUM (BARY,I,J)
      DIMENSION BARY(10,20)
      SUM = 0.0
      DO 8 K=1,I
      DO8 M = 1,J
    8 SUM = SUM + BARY(K,M)
      RETURN
      END
```

9.6 REFERENCING A FUNCTION SUBPROGRAM

FUNCTION subprograms are called whenever the FUNCTION name, accompanied by an argument list, is used as an operand in an expression. Such references take the following form:

f(a1,a2,...,an)

where f is a FUNCTION name and the ai are actual arguments. Parentheses must be present in the form shown.

The arguments ai MUST agree in type, order and number with the dummy arguments in the FUNCTION statement of the called FUNCTION subprogram. There is no type conversion of arguments. There must be at least one argument. Arguments may be any of the following:

1. A variable name.

2. An array element name.

3. An array name.

4. An expression.

5. A SUBROUTINE or FUNCTION subprogram name.

6. A Hollerith or Literal constant.

If an ai is a subprogram name, that name must have previously been distinguished from ordinary variables by appearing in an EXTERNAL statement and the corresponding dummy arguments in the called FUNCTION subprograms must be used in subprogram references.

If ai is a Hollerith or Literal constant, the corresponding dummy variable should encompass enough storage units to correspond exactly to the amount of storage needed by the constant.

When a FUNCTION subprogram is called, program control goes to the first executable statement following the FUNCTION statement.

The following examples show references to FUNCTION subprograms.

```
Z10 = FT1+Z7(D,T3,RHO)

DIMENSION DAT(5,5)
.
.
.
S1 = TOT1 + SUM(DAT,5,5)
```

9.7 SUBROUTINE SUBPROGRAMS

A program unit which begins with a SUBROUTINE statement is called a SUBROUTINE subprogram. The SUBROUTINE statement has one of the following forms:

SUBROUTINE s (a1,a2,...,an)

or

SUBROUTINE s

where s is the name of the SUBROUTINE subprogram and each ai is a dummy argument which represents a variable or array name or another SUBROUTINE or FUNCTION name.

9.8 CONSTRUCTION OF SUBROUTINE SUBPROGRAMS

1. The SUBROUTINE statement must be the first statement of the subprogram.

2. The SUBROUTINE subprogram name must not appear in any statement other than the initial SUBROUTINE statement.

3. The dummy argument names must not appear in EQUIVALENCE, COMMON or DATA statements in the subprogram.

4. If a dummy argument is an array name then an array declarator must appear in the subprogram with dimensioning information consistant with that in the calling program.

5. If any of the dummy arguments represent values that are to be determined by the SUBROUTINE subprogram and returned to the calling program, these dummy arguments must appear within the subprogram on the left side of the equality sign in a replacement statement, in the input list of an input statement or as a parameter within a subprogram reference.

6. A SUBROUTINE may contain any FORTRAN statements other than BLOCK DATA statements, FUNCTION statements, another SUBROUTINE statement, a PROGRAM statement or any statement which references the SUBROUTINE subprogram being defined or another subprogram which references the SUBROUTINE subprogram being defined.

7. A SUBROUTINE subprogram may contain any number of RETURN statements. It must have at least one.

8. The RETURN statement(s) is the logical termination point of the subprogram.

9. The physical termination of a SUBROUTINE subprogram is an END statement.

10. If an actual argument transmitted to a SUBROUTINE subprogram by the calling program is the name of a SUBROUTINE or FUNCTION subprogram, the corresponding dummy argument must be used in the called SUBROUTINE subprogram as a subprogram reference.

Example:

```
C  SUBROUTINE TO COUNT POSITIVE ELEMENTS
C          IN AN ARRAY
       SUBROUTINE COUNT P(ARRY,I,CNT)
       DIMENSION ARRY(7)
       CNT = 0
       DO 9 J=1,I
       IF(ARRY(J))9,5,5
   9   CONTINUE
       RETURN
   5   CNT = CNT+1.0
       GO TO 9
       END
```

9.9 REFERENCING A SUBROUTINE SUBPROGRAM

A SUBROUTINE subprogram may be called by using a CALL statement. A CALL statement has one of the following forms:

```
CALL s(a1,a2,...,an)
```

or

```
CALL s
```

where s is a SUBROUTINE subprogram name and the ai are the actual arguments to be used by the subprogram. The ai must agree in type, order and number with the corresponding dummy arguments in the subprogram-defining SUBROUTINE statement.

The arguments in a CALL statement must comply with the following rules:

1. FUNCTION and SUBROUTINE names appearing in the argument list must have previously appeared in an EXTERNAL statement.

2. If the called SUBROUTINE subprogram contains a variable array declarator, then the CALL statement must contain the actual name of the array and the actual dimension specifications as arguments.

3. If an item in the SUBROUTINE subprogram dummy argument list is an array, the corresponding item in the CALL statement argument list must be an array.

When a SUBROUTINE subprogram is called, program control goes to the first executable statement following the SUBROUTINE statement.

Example:

```
      DIMENSION DATA(10)
      .
      .
      .
C  THE STATEMENT BELOW CALLS THE
C       SUBROUTINE IN THE PREVIOUS PARAGRAPH
C
      CALL COUNTP(DATA,10,CPOS)
```

9.10 RETURN FROM FUNCTION AND SUBROUTINE SUBPROGRAMS

The logical termination of a FUNCTION or SUBROUTINE subprogram is a RETURN statement which transfers control back to the calling program. The general form of the RETURN statement is simply the word

RETURN

The following rules govern the use of the RETURN statement:

1. There must be at least one RETURN statement in each SUBROUTINE or FUNCTION subprogram.

2. RETURN from a FUNCTION subprogram is to the instruction sequence of the calling program following the FUNCTION reference.

3. RETURN from a SUBROUTINE subprogram is to the next executable statement in the calling program which would logically follow the CALL statement.

4. Upon return from a FUNCTION subprogram the single-valued result of the subprogram is available to the evaluation of the expression from which the FUNCTION call was made.

5. Upon return from a SUBROUTINE subprogram the values assigned to the arguments in the SUBROUTINE are available for use by the calling program.

Example:

```
Calling Program Unit
.
.
.
    CALL SUBR(Z9,B7,R1)
.
.
.

Called Program Unit

    SUBROUTINE SUBR(A,B,C)
    READ(3,7) B
    A = B**C
    RETURN
7   FORMAT(F9.2)
    END
```

In this example, Z9 and B7 are made available to the calling program when the RETURN occurs.

9.11 PROCESSING ARRAYS IN SUBPROGRAMS

If a calling program passes an array name to a subprogram, the subprogram must contain the dimension information pertinent to the array. A subprogram must contain array declarators if any of its dummy arguments represent arrays or array elements.

For example, a FUNCTION subprogram designed to compute the average of the elements of any one dimension array might be the folowing:

```
      Calling Program Unit

      DIMENSION Z1(50),Z2(25)
      .
      .
      .
      A1 = AVG(Z1,50)
      .
      .
      .
      A2 = A1-AVG(Z2,25)
      .
      .
      .

      Called Program Unit

      FUNCTION AVG(ARG,I)
      DIMENSION ARG(50)
      SUM = 0.0
      DO 20 J=1,I
20    SUM = SUM + ARG(J)
      AVG = SUM/FLOAT(I)
      RETURN
      END
```

Note that actual arrays to be processed by the FUNCTION subprogram are dimensioned in the calling program and the array names and their actual dimensions are transmitted to the FUNCTION subprogram by the FUNCTION subprogram reference. The FUNCTION subprogram itself contains a dummy array and specifies an array declarator.

Dimensioning information may also be passed to the subprogram in the paramater list. For example:

```
Calling Program Unit

DIMENSION A(3,4,5)
.
.
.
CALL SUBR(A,3,4,5)
.
.
.
END

Called Program Unit

SUBROUTINE SUBR(X,I,J,K)
DIMENSION X(I,J,K)
.
.
.
RETURN
END
```

It is valid to use variable dimensions only when the array name and all of the variable dimensions are dummy arguments. The variable dimensions must be type Integer. It is invalid to change the values of any of the variable dimensions within the called program.

9.12 BLOCK DATA SUBPROGRAMS

A BLOCK DATA subprogram has as its only purpose the initialization of data in a COMMON block during loading of a FORTRAN object program. BLOCK DATA subprograms begin with a BLOCK DATA statement of the following form:

BLOCK DATA [subprogram-name]

and end with an END statement. Such subprograms may contain only Type, EQUIVALENCE, DATA, COMMON and DIMENSION statements and are subject to the following considerations:

1. If any element in a COMMON block is to be initialized, all elements of the block must be listed in the COMMON statement even though they might not all be initialized.

2. Initialization of data in more than one COMMON block may be accomplished in one BLOCK DATA subprogram.

3. There may be more than one BLOCK DATA subprogram loaded at any given time.

4. Any particular COMMON block item should only be initialized by one program unit.

Example:

```
      BLOCK DATA
      LOGICAL A1
      COMMON/BETA/B(3,3)/GAM/C(4)
      COMMON/ALPHA/A1,F,E,D
      DATA B/1.1,2.5,3.8,3*4.96,
     12*0.52,1.1/,C/1.2E0,3*4.0/
      DATA A1/.TRUE./,E/-5.6/
```

9.13 PROGRAM CHAINING

Programs may be loaded and executed (CHAINed) by a FORTRAN program through the CALL FCHAIN facility. The general syntax is:

```
CALL FCHAIN ('filename')
```

where filename is a valid operating-system-dependent file specification of a machine executable file. The exact syntax varies under different operating systems. Refer to the "Microsoft FORTRAN-80 User's Manual", Section 3.

RULES:

1. 'filename' must be valid according to your operating system's rules.

2. The program CHAINed must be a "MAIN" program. That is, one having an ENTRY Point. FORTRAN, COBOL, and assembly language subroutines do not conntain a "MAIN" entry point.

3. Parameters may not be passed to CHAINed programs.

4. Illegal filename, Illegal drive specification, File not found, Out of memory, and Disk read errors will result in a fatal **IO** Error.

APPENDIX A

Language Extensions and Restrictions

The FORTRAN-80 language includes the following extensions to ANSI Standard FORTRAN (X3.9-1966).

1. If c is used in a 'STOP c' or 'PAUSE c' statement, c may be any six ASCII characters.

2. Error and End-of-File branches may be specified in READ and WRITE statements using the ERR= and END= options.

3. The standard subprograms PEEK, POKE, INP, and OUT have been added to the FORTRAN library.

4. Statement functions may use subscripted variables.

5. Hexadecimal constants may be used wherever Integer constants are normally allowed.

6. The literal form of Hollerith data (character string between apostrophe characters) is permitted in place of the standard nH form.

7. Holleriths and Literals are allowed in expressions in place of Integer constants.

8. There is no restriction to the number of continuation lines.

9. Mixed mode expressions and assignments are allowed, and conversions are done automatically.

FORTRAN-80 places the following restrictions upon Standard FORTRAN.

1. The COMPLEX data type is not implemented.

2. The specification statements must appear in the following order:

    1. PROGRAM, SUBROUTINE, FUNCTION, BLOCK DATA

    2. Type, EXTERNAL, DIMENSION

    3. COMMON

    4. EQUIVALENCE

    5. DATA

    6. Statement Functions

3. A different amount of computer memory is allocated for each of the data types: Integer, Real, Double Precision, Logical.

4. The equal sign of a replacement statement and the first comma of a DO statement must appear on the initial statement line.

5. In Input/Output list specifications, sublists enclosed in parentheses are not allowed.

Descriptions of these language extensions and restrictions are included at the appropriate points in the text of this document.

APPENDIX B

I/O Interface

Input/Output operations are table-dispatched to the driver routine for the proper Logical Unit Number. $LUNTB is the dispatch table. It contains one 2-byte driver address for each possible LUN. It also has a one-byte entry at the beginning, which contains the maximum LUN plus one.

The initial run-time package provides for 10 LUN's (1 - 10). Units 1, 3, 4, and 5 are preassigned to the console (TTY). Unit 2 is preassigned to the Line Printer. Units 6-10 are preassigned to Disk Files (see User's Manual, Section 3).

Any of these may be redefined by the user simply by changing the appropriate entries in $LUNTB. The runtime system uses LUN 3 for errors and other user communication. Therefore, LUN 3 should correspond to the operator console. The initial structure of $LUNTB is shown in the listings following this appendix.

It is also possible to add LUNs to $LUNTB. If you do this, change the MAXLUN+1 byte at the label $LUNTB, and make sure you also change the value of MAXLUN in the DSKDRV.MAC module.

The device drivers also contain local dispatch tables. Note that $LUNTB contains one address for each device, yet there are really seven possible operations per device:

1) Formatted Read
2) Formatted Write
3) Unformatted Read
4) Unformatted Write
5) Rewind
6) Backspace
7) Endfile

Each device driver contains up to seven routines. The starting addresses of each of these seven routines are placed at the beginning of the driver, in the exact order listed above. The entry in $LUNTB then points to this local table, and the runtime system indexes into it to get the address of the appropriate routine to handle the requested I/O operation.

The following conventions apply to the individual I/O routines:

1. Location $BF contains the data buffer address for READs and WRITEs.

2. For a WRITE, the number of bytes to write is in location $BL.

3. For a READ, the number of bytes read should be returned in $BL.

4. All I/O operations set the condition codes before exit to indicate an error condition, end-of-file condition, or normal return:

   a) CY=1, Z=don't care - I/O error
   b) CY=0, Z=0 - end-of-file encountered
   c) CY=0, Z=1 - normal return

   The runtime system checks the condition codes after calling the driver. If they indicate a non-normal condition, control is passed to the label specified by "ERR=" or "END=" or, if no label is specified, a fatal error results.

5. $IOERR is a global routine which prints an "ILLEGAL I/O OPERATION" message (non-fatal). This routine may be used if there are some operations not allowed on a particular device (i.e. Unformatted I/O on a TTY).

NOTE

The I/O buffer has a fixed maximum length of 132 bytes. If a driver allows an input operation to write past the end of the buffer, essential runtime variables may be affected. The consequences are unpredictable.

The listings following this appendix contain an example driver for a TTY. REWIND, BACKSPACE, and ENDFILE are implemented as No-Ops and Unformatted I/O as an error. This is the TTY driver provided with the runtime package.

```
                                00100   ;       TTY I/O DRIVER
                                00200
0000                            00300           EXT     $IOERR,$BL,$BF,$ERR,$TTYIN,$TTYOT
0012                            00400   IRECER  EQU     022     ;INPUT RECORD TOO LONG
0000                            00500           ENTRY   $DRV3
0000  0013 '                    00600   $DRV3:  DW      DRV3FR  ;FORMATTED READ
0002  0042 '                    00700           DW      DRV3FW  ;FORMATTED WRITE
0004  0010 '                    00800           DW      DRV3BR  ;BINARY READ
0006  0010 '                    00900           DW      DRV3BW  ;BINARY WRITE
0008  000E '                    01000           DW      DRV3RE  ;REWIND
000A  000E '                    01100           DW      DRV3BA  ;BACKSPACE
000C  000E '                    01200           DW      DRV3EN  ;ENDFILE
000E  AF                        01300   DRV3EN: XRA     A       ;THESE OPERATIONS ARE
                                01400                           ;NO-OPS FOR TTY
000E                            01500   DRV3RE  EQU     DRV3EN
000E                            01600   DRV3BA  EQU     DRV3EN
000F  C9                        01700           RET
0010  C3 0000 *                 01800   DRV3BW: JMP     $IOERR  ;ILLEGAL OPERATIONS
                                01900                           ;(PRINT ERROR AND RETURN)
0010                            02000   DRV3BR  EQU     DRV3BW
0013  AF                        02100   DRV3FR: XRA     A       ;READ
0014  32 0000 *                 02200           STA     $BL     ;ZERO BUFFER LENGTH
0017  CD 0000 *                 02300   DRV31:  CALL    $TTYIN  ;INPUT A CHAR
001A  E6 7F                     02400           ANI     0177    ;AND OFF PARITY
001C  FE 0A                     02500           CPI     10      ;IGNORE LINE FEEDS
001E  CA 0017 '                 02600           JZ      DRV31
0021  F5                        02700           PUSH    PSW     ;SAVE IT
0022  2A 0015 *                 02800           LHLD    $BL     ;GET CHAR POSIT IN BUFFER
0025  26 00                     02900           MVI     H,0     ;ONLY 1 BYTE
0027  EB                        03000           XCHG
0028  2A 0000 *                 03100           LHLD    $BF     ;GET BUFFER ADDR
002B  19                        03200           DAD     D       ;ADD OFFSET
002C  F1                        03300           POP     PSW     ;GET CHAR
002D  77                        03400           MOV     M,A     ;PUT IT IN BUFFER
002E  13                        03500           INX     D       ;INCREMENT $BL
002F  EB                        03600           XCHG
0030  22 0023 *                 03700           SHLD    $BL     ;SAVE IT
0033  FE 0D                     03800           CPI     015     ;CR?
0035  C8                        03900           RZ              ;YES--DONE
0036  7D                        04000           MOV     A,L     ;$BL
0037  FE 80                     04100           CPI     128     ;MAX IS DECIMAL 128
0039  DA 0017 '                 04200           JC      DRV31   ;GET NEXT CHAR
003C  CD 0000 *                 04300           CALL    $ERR
003F  12                        04400           DB      IRECER  ;INPUT RECORD TOO LONG
0040  AF                        04500           XRA     A       ;CLEAR FLAGS
0041  C9                        04600           RET
0042  3A 0031 *                 04700   DRV3FW: LDA     $BL     ;BUFFER LENGTH
0045  B7                        04800           ORA     A
```

```
0046  C8              04900           RZ              ;EMPTY BUFFER
0047  2A 0029 *       05000           LHLD    $BF     ;BUFFER ADDRESS
004A  3D              05100           DCR     A       ;DECREMENT LENGTH
004B  F5              05200           PUSH    PSW     ;SAVE IT
004C  3E 0D           05300           MVI     A,13    ;CR
004E  CD 0000 *       05400           CALL    $TTYOT  ;OUTPUT IT
0051  7E              05500           MOV     A,M     ;GET FIRST CHAR IN BUFFER
0052  FE 2B           05600           CPI     '+'
0054  CA 0079 '       05700           JZ      DR3FW2  ;NO LINE FEEDS
0057  FE 31           05800           CPI     '1'
0059  C2 0064 '       05900           JNZ     DR3FW1  ;NOT FORM FEED
005C  3E 0C           06000           MVI     A,12    ;FORM FEED
005E  CD 004F *       06100           CALL    $TTYOT  ;OUTPUT IT
0061  C3 0079 '       06200           JMP     DR3FW2
0064  3E 0A           06300 DR3FW1:   MVI     A,10    ;LF
0066  CD 005F *       06400           CALL    $TTYOT
0069  7E              06500           MOV     A,M     ;GET CHAR BACK
006A  FE 20           06600           CPI     ' '
006C  CA 0079 '       06700           JZ      DR3FW2  ;NO MORE LINE FEEDS
006F  FE 30           06800           CPI     '0'
0071  C2 0079 '       06900           JNZ     DR3FW2  ;NO MORE LINE FEEDS
0074  3E 0A           07000           MVI     A,10    ;LF
0076  CD 0067 *       07100           CALL    $TTYOT
0079  F1              07200 DR3FW2:   POP     PSW     ;GET LENGTH BACK
007A  23              07300           INX     H       ;INCREMENT PTR
007B  C8              07400 DRV32:    RZ
007C  F5              07500           PUSH    PSW     ;SAVE CHAR COUNT
007D  7E              07600           MOV     A,M     ;GET NEXT CHAR
007E  23              07700           INX     H       ;INCREMENT PTR
007F  CD 0077 *       07800           CALL    $TTYOT  ;OUTPUT CHAR
0082  F1              07900           POP     PSW     ;GET COUNT
0083  3D              08000           DCR     A       ;DECREMENT IT
0084  C3 007B '       08100           JMP     DRV32   ;ONE MORE TIME
0087                  08200           END
```



```
$IOERR  0011*   $BL     0043*   $BF     0048*   $ERR    003D*
$TTYIN  0018*   $TTYOT  0080*   IRECER  0012    $DRV3   0000'
DRV3FR  0013'   DRV3FW  0042'   DRV3BR  0010'   DRV3BW  0010'
DRV3RE  000E'   DRV3BA  000E'   DRV3EN  000E'   DRV31   0017'
DR3FW2  0079'   DR3FW1  0064'   DRV32   007B'
```

```
        MAC80 1.0       PAGE    1


                        00100   ;COMMENT *
                        00200   ;       DRIVER ADDRESSES FOR LUN'S 1 THROUGH 10
                        00210   ;
0001                    00220   LPT     EQU     1               ;UNIT 2 IS LPT
0001                    00230   DSK     EQU     1               ;UNITS 6-10 ARE DSK
0000                    00235   DTC     EQU     0               ;DTC COMMUNICATIONS UNIT 4
                        00240   ;
                        00300
0000                    00400           ENTRY   $LUNTB
0000                    00500           EXT     $DRV3
0000    08              00600   $LUNTB: DB      013                     ;MAX LUN + 1
0001    0000 *           00700          DW      $DRV3   ;THEY ALL POINT TO $DRV3 FOR NOW
0003                    00800           IFF     LPT
                        00900           DW      $DRV3
0003                    01000           ENDIF
0003                    01100           IFT     LPT
0003                    01200           EXT     LPTDRV
0003    0000 *          01300           DW      LPTDRV
0005                    01400           ENDIF
0005    0001 *          01500           DW      $DRV3
0007                    01510           IFF     DTC
0007    0005 *          01600           DW      $DRV3
0009                    01602           ENDIF
0009                    01604           IFT     DTC
                        01605           EXT     $CMDRV
                        01606           DW      $CMDRV
0009                    01608           ENDIF
0009    0007 *          01700           DW      $DRV3
000B                    01800           IFF     DSK
                        01900           DW      $DRV3
                        02000           DW      $DRV3
                        02100           DW      $DRV3
                        02200           DW      $DRV3
                        02300           DW      $DRV3
000B                    02400           ENDIF
000B                    02500           IFT     DSK
000B                    02600           EXT     DSKDRV
000B    0000 *          02700           DW      DSKDRV
000D    000B *          02800           DW      DSKDRV
000F    000D *          02900           DW      DSKDRV
0011    000F *          03000           DW      DSKDRV
0013    0011 *          03100           DW      DSKDRV
0015                    03200           ENDIF
0015                    03300           END


        MAC80 1.0       PAGE    2

LPT     0001    DSK     0001    DTC     0000    $LUNTB  0000'
$DRV3   0009*   LPTDRV  0003*   DSKDRV  0013*
```

APPENDIX C

Subprogram Linkages

This appendix defines a normal subprogram call as generated by the FORTRAN compiler. It is included to facilitate linkages between FORTRAN programs and those written in other languages, such as 8080 Assembly.

A subprogram reference with no parameters generates a simple "CALL" instruction. The corresponding subprogram should return via a simple "RET." (CALL and RET are 8080 opcodes - see the assembly manual or 8080 reference manual for explanations.)

A subprogram reference with parameters results in a somewhat more complex calling sequence. Parameters are always passed by reference (i.e., the thing passed is actually the address of the low byte of the actual argument). Therefore, parameters always occupy two bytes each, regardless of type.

The method of passing the parameters depends upon the number of parameters to pass:

1. If the number of parameters is less than or equal to 3, they are passed in the registers. Parameter 1 will be in HL, 2 in DE (if present), and 3 in BC (if present).

2. If the number of parameters is greater than 3, they are passed as follows:

    1. Parameter 1 in HL.

    2. Parameter 2 in DE.

    3. Parameters 3 through n in a contiguous data block. BC will point to the low byte of this data block (i.e., to the low byte of parameter 3).

Note that, with this scheme, the subprogram must know how many parameters to expect in order to find them. Conversely, the calling program is responsible for passing the correct number of parameters. Neither the compiler nor the runtime system checks for the correct number of parameters.

If the subprogram expects more than 3 parameters, and needs to transfer them to a local data area, there is a system subroutine which will perform this transfer. This argument

transfer routine is named $AT, and is called with HL pointing to the local data area, BC pointing to the third parameter, and A containing the number of arguments to transfer (i.e., the total number of arguments minus 2). The subprogram is responsible for saving the first two parameters before calling $AT. For example, if a subprogram expects 5 parameters, it should look like:

```
SUBR:   SHLD    P1          ;SAVE PARAMETER 1
        XCHG
        SHLD    P2          ;SAVE PARAMETER 2
        MVI     A,3         ;NO. OF PARAMETERS LEFT
        LXI     H,P3        ;POINTER TO LOCAL AREA
        CALL    $AT         ;TRANSFER THE OTHER 3 PARAMETERS
        .
        .
        .
        [Body of subprogram]
        .
        .
        .
        RET                 ;RETURN TO CALLER
P1:     DS      2           ;SPACE FOR PARAMETER 1
P2:     DS      2           ;SPACE FOR PARAMETER 2
P3:     DS      6           ;SPACE FOR PARAMETERS 3-5
```

When accessing parameters in a subprogram, don't forget that they are pointers to the actual arguments passed.

NOTE

It is entirely up to the programmer to see to it that the arguments in the calling program match in number, type, and length with the parameters expected by the subprogram. This applies to FORTRAN subprograms, as well as those written in assembly language.

FORTRAN Functions (Section 9) return their values in registers or memory depending upon the type. Logical results are returned in (A), Integers in (HL). Extended integers and Reals return results in memory at $AC. Double Precision Reals return results in memory at $DAC. $AC and $DAC are the addresses of the low bytes of the mantissas.

APPENDIX D

ASCII CHARACTER CODES

DECIMAL	CHAR.	DECIMAL	CHAR.	DECIMAL	CHAR.
000	NUL	043	+	086	V
001	SOH	044	,	087	W
002	STX	045	-	088	X
003	ETX	046	.	089	Y
004	EOT	047	/	090	Z
005	ENQ	048	0	091	[
006	ACK	049	1	092	\
007	BEL	050	2	093	]
008	BS	051	3	094	^
009	HT	052	4	095	_
010	LF	053	5	096	`
011	VT	054	6	097	a
012	FF	055	7	098	b
013	CR	056	8	099	c
014	SO	057	9	100	d
015	SI	058	:	101	e
016	DLE	059	;	102	f
017	DC1	060	<	103	g
018	DC2	061	=	104	h
019	DC3	062	>	105	i
020	DC4	063	?	106	j
021	NAK	064	@	107	k
022	SYN	065	A	108	l
023	ETB	066	B	109	m
024	CAN	067	C	110	n
025	EM	068	D	111	o
026	SUB	069	E	112	p
027	ESCAPE	070	F	113	q
028	FS	071	G	114	r
029	GS	072	H	115	s
030	RS	073	I	116	t
031	US	074	J	117	u
032	SPACE	075	K	118	v
033	!	076	L	119	w
034	"	077	M	120	x
035	#	078	N	121	y
036	$	079	O	122	z
037	%	080	P	123	{
038	&	081	Q	124	|
039	'	082	R	125	}
040	(	083	S	126	~
041	)	084	T	127	DEL
042	*	085	U		

LF=Line Feed FF=Form Feed CR=Carriage Return DEL=Rubout

APPENDIX E

Referencing FORTRAN-80 Library Subroutines

The FORTRAN-80 library contains a number of subroutines that may be referenced by the user from FORTRAN or assembly programs.

1. Referencing Arithmetic Routines

In the following descriptions, $AC refers to the floating accumulator; $AC is the address of the low byte of the mantissa. $AC+3 is the address of the exponent. $DAC refers to the DOUBLE PRECISION accumulator; $DAC is the address of the low byte of the mantissa. $DAC+7 is the address of the DOUBLE PRECISION exponent.

All arithmetic routines (addition, subtraction, multiplication, division, exponentiation) adhere to the following calling conventions.

1. Argument 1 is passed in the registers:
   Integer in [HL]
   Real in $AC
   Double in $DAC

2. Argument 2 is passed either in registers, or in memory depending upon the type:

   a. Integers are passed in [HL], or [DE] if [HL] contains Argument 1.

   b. Real and Double Precision values are passed in memory pointed to by [HL]. ([HL] points to the low byte of the mantissa.)

The following arithmetic routines are contained in the Library:

Function	Name	Argument 1 Type	Argument 2 Type
Addition	$AY	Integer*4	Integer
	$Al	Integer*4	Integer*4
	$AA	Real	Integer
	$AE	Real	Integer*4
	$AB	Real	Real
	$AQ	Double	Integer
	$AV	Double	Integer*4
	$AR	Double	Real
	$AU	Double	Double
Division	$D9	Integer	Integer
	$DY	Integer*4	Integer
	$Dl	Integer*4	Integer*4
	$DA	Real	Integer
	$DE	Real	Integer*4
	$DB	Real	Real
	$DQ	Double	Integer
	$DV	Double	Integer*4
	$DR	Double	Real
	$DU	Double	Double
Exponentiation	$E9	Integer	Integer
	$EY	Integer*4	Integer
	$El	Integer*4	Integer*4
	$EA	Real	Integer
	$EE	Real	Integer*4
	$EB	Real	Real
	$EQ	Double	Integer
	$EV	Double	Integer*4
	$ER	Double	Real
	$EU	Double	Double
Multiplication	$M9	Integer	Integer
	$MY	Integer*4	Integer
	$Ml	Integer*4	Integer*4
	$MA	Real	Integer
	$ME	Real	Integer*4
	$MB	Real	Real
	$MQ	Double	Integer
	$MV	Double	Integer*4
	$MR	Double	Real
	$MU	Double	Double
Subtraction	$SY	Integer*4	Integer
	$Sl	Integer*4	Integer*4
	$SA	Real	Integer
	$SE	Real	Integer*4
	$SB	Real	Real
	$SQ	Double	Integer
	$SV	Double	Integer*4
	$SR	Double	Real
	$SU	Double	Double

Additional Library routines are provided for converting between value types. Arguments are always passed to and returned by these conversion routines in the appropriate registers:

Logical in [A]

Integer in [HL]

Extended Integer in $AC

Real in $AC

Double Precision REAL in $DAC

Name	Function
$CD	Integer to Integer*4
$CA	Integer to Real
$CC	Integer to Double
$C4	Integer*4 to Integer
$C5	Integer*4 to Real
$C6	Integer*4 to Logical
$C7	Integer*4 to Double
$CH	Real to Integer
$CL	Real to Integer*4
$CJ	Real to Logical
$CK	Real to Double
$CX	Double to Integer
$C0	Double to Integer*4
$CY	Double to Real
$CZ	Double to Logical

2. Referencing Intrinsic Functions

Intrinsic Functions are passed their parameters in H,L and D,E. If there are three arguments, B,C contains the third parameter. If there are more than three arguments, B,C contains a pointer to a block in memory that holds the remaining parameters. Each of these parameters is a pointer to an argument. (See Appendix B.)

For a MIN or MAX function, the number of arguments is passed in A.

NOTE

None of the functions (except INP and OUT) may take a byte variable as an argument. Byte variables must first be converted to the type expected by the function. Otherwise, results will be unpredictable.

3. Formatted READ and WRITE Routines

A READ or WRITE statement calls one of the following routines:

$W2 (2 parameters) $W5 (5 parameters)	Initialize for an I/O transfer to a device (WRITE)
$R2 (2 parameters) $R5 (5 parameters)	Initialize for an I/O transfer from a device (READ)

These routines adhere to the following calling conventions:

1. H,L points to the LUN

2. D,E points to the beginning of the FORMAT statement

3. If the routine has five parameters, then B,C points to a block of three parameters:

    a. the address for an ERR= branch

    b. the address for an EOF= branch

    c. the address for a REC= value

The routines that transfer values into the I/O buffer are:

$I0	transfers integers
$I1	transfers real numbers
$I2	transfers logicals
$I3	transfers double precision numbers
$I4	transfers extended integers (4 bytes)

Transfer routines adhere to the following calling conventions:

1. H,L points to a location that contains the number of dimensions for the variables in the list

2. D,E points to the first value to be transferred

3. B,C points to the second value to be transferred if there are exactly two values to be transferred by this call. If there are more than two values, B,C points to a block that contains pointers to the second through nth values.

4. Register A contains the number of parameters (including H,L) generated by this call.

The routine $ND terminates the I/O process.

Example:

```
        EXTRN   $W2,$IO,$ND
        ENTRY   TEST
TEST:   LXI     H,LUN
        LXI     D,FORMAT
        CALL    $W2

        LXI     H,DIMENS
        LXI     D,NUMBER
        MVI     A,2
        CALL    $IO

        CALL    $ND

        RET
LUN:    DW      1
FORMAT: DB      '(11H RESULT IS=,I5)'
DIMENS: DW      1
NUMBER: DW      9999

        END     TEST
```

4. Loading and Storing Floating Accumulator

In the following definitions, $AC refers to the floating accumulator and $DAC refers to the DOUBLE PRECISION accumulator.

To Load Floating Accumulator:
(H,L points to value to be loaded.)

Name	Function
$L1	Loads into $AC, 4 bytes
$L3	Loads into $DAC, 8 bytes

To Store Floating Accumulator:
(H,L points to memory where value is to be stored)

Name	Function
$T1	Stores 4 bytes from $AC
$T3	Stores 8 bytes from $DAC

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utility software package reference manual

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for 8080 microprocessors

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Contents

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CHAPTER 1

INTRODUCTION

Welcome to the world of Utility Software Package programming. During the course of this manual, we will learn what the Utility Software Package is, why you use it, and how to use it.

1.1 CONTENTS OF THE UTILITY SOFTWARE PACKAGE

One diskette with the following files:

M80.COM - MACRO-80 Macro Assembler program
L80.COM - LINK-80 Linking Loader program
CREF80.COM - Cross-Reference Facility
LIB.COM - Library Manager program
(CP/M versions only)

One Manual

The Utility Software Package Reference Manual

IMPORTANT

> Always make backup copies of your diskettes before using them.

1.2 SYSTEM REQUIREMENTS

MACRO-80 requires about 19K of memory, plus about 4K for buffers. LINK-80 requires about 14K of memory. CREF-80 requires about 6K of memory. LIB-80 requires about 5K of memory. The operating system usually requires about 6K bytes of memory. So a minimum system requirement for the Utility Software Package is 29K bytes of memory. While it is possible to run Utility Software Package programs with only one disk drive, we recommend strongly that you have two disk drives available.

1.3 WHOM IS THE UTILITY SOFTWARE PACKAGE FOR?

The Utility Software Package is a complete assembly language development system with powerful features that support advanced assembly language programming skills. This manual describes the Utility Software Package thoroughly, but the descriptions assume that the reader understands assembly language programming and has experience with an assembler.

If you have never programmed in assembly language, we suggest that you gain some experience on a simpler assembler.

Books on Assembly Language Programming

We can also recommend the following books for basic instruction in assembly language programming:

Leventhal, Lance A. 8080A/8085 Assembly Language Programming. Berkeley: Osborne/McGraw-Hill, 1978.

Leventhal, Lance A. Z80 Assembly Language Programming. Berkeley: Osborne/McGraw-Hill, 1979.

Zaks, Rodnay. Programming the Z80. Second edition. Berkeley: Sybex, 1980.

1.4 A WORD ABOUT THIS MANUAL

Organization

In front of each chapter is a contents page that expands the entries on the contents page at the beginning of the manual. Chapter 1 gives introductory, background, and overview information about the Utility Software Package. Chapters 2-8 describe the use and operation of the Utility Software Package programs. The manual concludes with several appendices which contain some helpful reference information.

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 user entered data. When the angle brackets enclose lower case text, the user must type in an entry defined by the text; for example, <filename>. When the angle brackets enclose upper case text, the user must press the key named by the text; for example, <RETURN>.

{ } Braces indicate that the user has 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.

1.5 OVERVIEW

The Utility Software Package is an assembly language programming system that parallels the design and programming power of assemblers and related software on big computers. Consequently, the design and use of the Utility Software Package involves traits and methods that may be new to you. As explained earlier, we assume that you have some experience in assembly language programming. Your knowledge of when and why to use particular operation codes and pseudo-operations is the base on which you can build your knowledge of the Utility Software Package.

One word of caution: some terms used in this manual may be familiar to you from other sources. Be sure to notice especially how familiar terms are used in the Utility Software Package so that you are not confused or misled.

The Utility Software Package programming relies on two important software programs -- an assembler and a linking loader. To develop an assembly language program that runs on your computer, you must use both the assembler and the linking loader. The whole process is diagrammed on the facing page. The numbers on the diagram correspond to the numbers in the explanations below.

1. You create an assembly language source program using some editor.

2. You assemble your source program using the MACRO-80 macro assembler. The result is a file that contains intermediate object code. This intermediate code is closer to machine code than your source code, but cannot be executed.

3. You link and load separately assembled file(s) into a single program file using the LINK-80 linking loader. LINK-80 converts the file(s) of intermediate code into a single file of true machine code which can be executed from the operating system.

These are only the basics of the whole process. This two step process of converting a source file to an executable program allows you to manipulate your programs to save you time and to extend your programs' usefulness in the following ways:

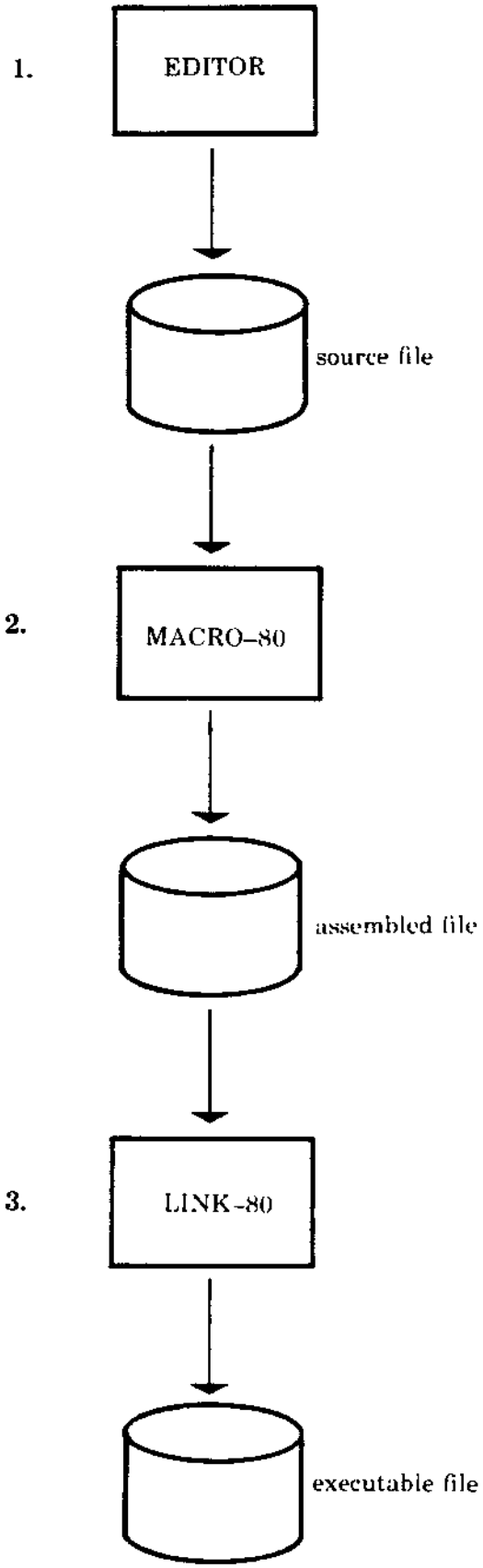


Figure 1.1: Developing Assembly Language Programs

First, you can break your program in convenient parts called modules. You can manipulate these modules at will. You can assemble the modules individually. You fix only those that do not work right and reassemble them. This saves you time.

Second, you can manipulate the placement of modules in memory, subject to certain restrictions; or allow LINK-80 to place modules for you. (This trait is described below under the fourth trait.)

Third, you can use assembled modules in other programs or in variations of the original program because there is no permanent connection among the modules. This saves you recoding time if a part of a program performs some useful, often-repeated task.

Whenever you want to combine assembled modules into an executable program, you use the LINK-80 linking loader. If you simply tell LINK-80 the modules you want combined, it loads them end-to-end in memory. But you have an additional choice. You can set up a direct connection between a statement in one module and a statement inside another module. This direct connection (or "link") means that a value (usually a program address) in one module can be used in another module exactly at the point required.

LINK-80 creates the links between modules. You give LINK-80 the signals it needs to create these links. The signals are called symbols, specifically EXTERNAL symbols and PUBLIC symbols. An EXTERNAL symbol signals LINK-80 that you want it to link a value from another module into this point in the program. The value to be linked-in is defined by a PUBLIC symbol, which is a signal that directs LINK-80 to the correct module and statement line. LINK-80 then links the PUBLIC symbol's value to the EXTERNAL symbol, then continues loading the module with the EXTERNAL symbol. The diagram below suggests this process.

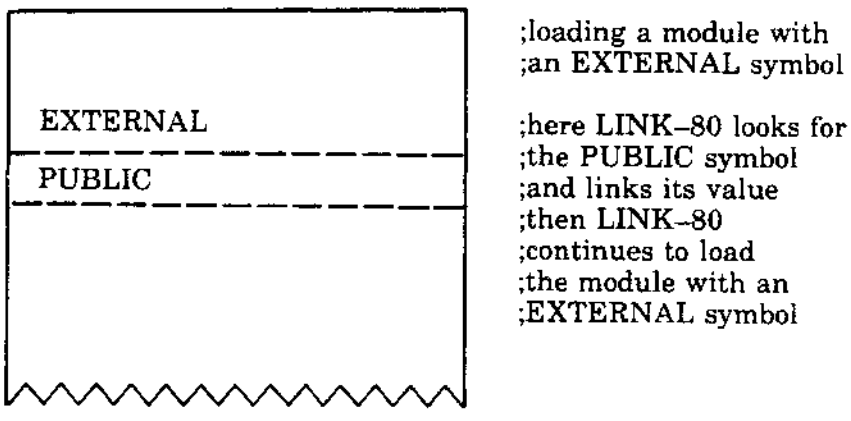


Figure 1.2: PUBLIC symbol linked into module at EXTERNAL

Fourth, modules can be assembled into different modes, even within a single module. The four modes are Absolute, Data-relative, Code-relative, and COMMON-relative. The absolute mode is similar the code produced by most small system assemblers. The code is assembled at fixed addresses in memory. The other three modes are very different and are the reason you can place modules anywhere in memory. Each of the three relative modes assembles to a separate segment. The addresses within each segment are relative addresses. This means the first instruction byte of a segment is given a relative address of 0, the second byte is given relative address 1, and so on. When LINK-80 loads the module, it changes the relative addresses in the segments to fixed addresses in memory. The relative addresses are offsets from some fixed address that LINK-80 uses. For the first module loaded, this address is 103H under the CP/M operating system. Thus, relative addresses in the first module are offsets from 103H. The second module is loaded at the end of the first, and the relative addresses are offsets from the last address in the first module. Subsequent modules are loaded (and offset) similarly. You can change the default start address for the first module at link time. Then, the relative addresses become offsets from the fixed address you specify.

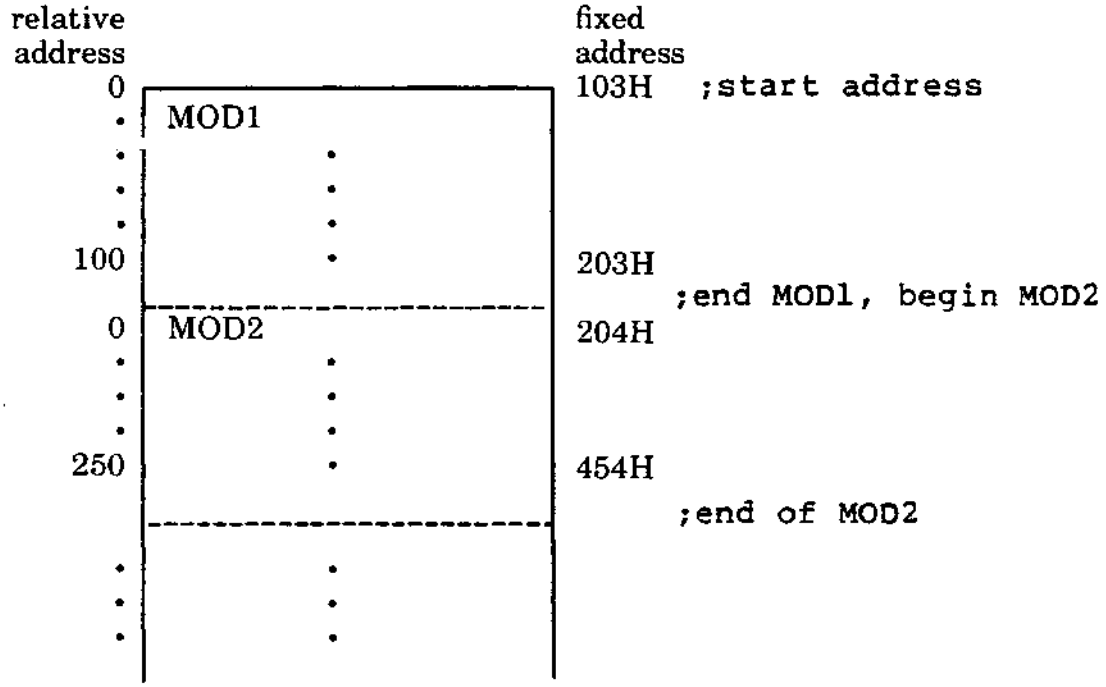
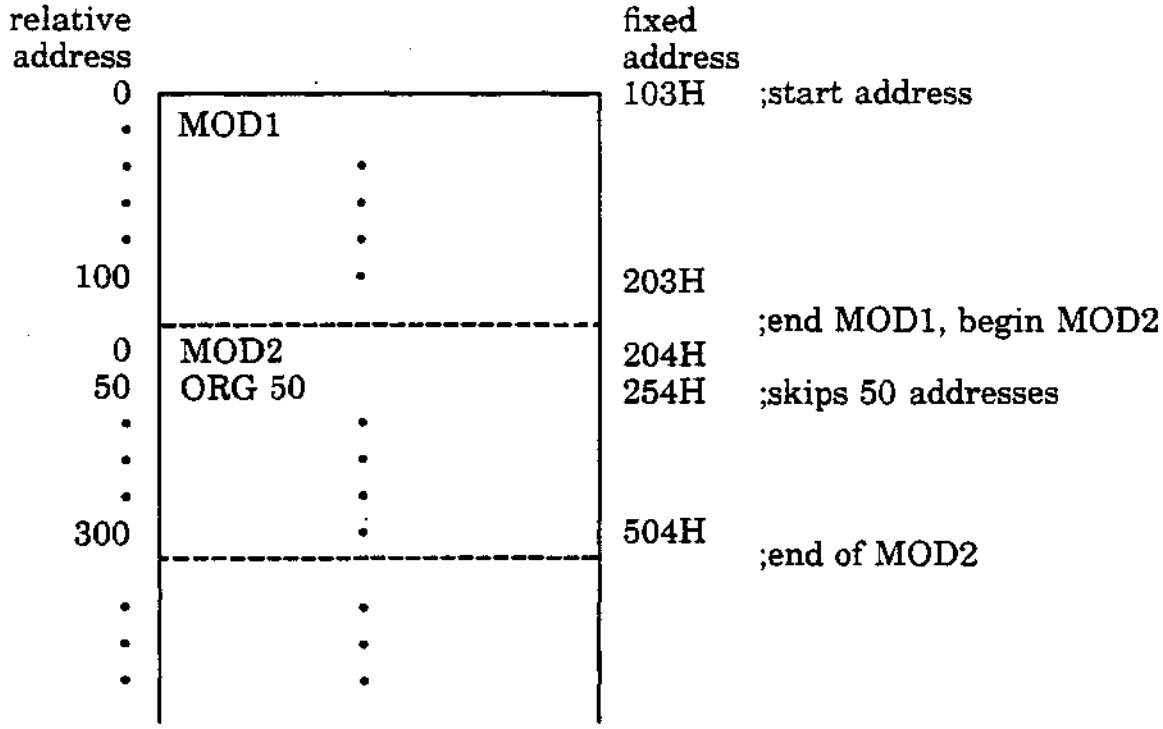


Figure 1.3: Loading Changes Relative Addresses to Fixed

One effect of this relative addressing method is that ORG statements become very different creatures. For the relative segments, the ORG statement specifies an offset rather than a fixed address (as most assemblers do -- ORG specifies a fixed address in the absolute segment). Thus, a relative segment with an ORG statement would skip over a specified number of addresses before beginning to load the rest of the code in that segment.



You should read carefully the description of ORG found in Chapter 4.

The ability to manipulate the placement of modules in memory, with some restrictions (see Chapter 6), derives from the assembler giving relative addresses instead of absolute addresses. This ability to manipulate module placement in memory is called relocatability; the modules are relocatable; the intermediate code produced by the assembler for the three relative segments is called relocatable code. That is why assembled modules are given the filename extension .REL, and these assembled files are called REL files.

Each mode serves a different purpose. The absolute mode contains code you want placed in specific memory addresses. Each relative mode is loaded into memory as a separate segment. The data-relative segment contains data items and any code that may change often and should only be placed in RAM. The code-relative segment contains code that will not change and therefore is suitable for ROM and PROM. The COMMON-relative segment contains data items that can be shared by more than one module.

Source statements in these modes take on the traits of their mode. The symbols and expressions in statements are evaluated by the assembler according to the mode in which they are found and the type of data and other entries that define the symbol or make up the parts of an expression. The mode traits attributed to a symbol or expression are called, appropriately, its Mode; that is, a symbol or expression is absolute, data-relative, code-relative, or COMMON-relative. This concept of mode is important because it is the source of both flexibility and complexity. If all

source statements are assembled in absolute mode, symbols and expressions always have absolute values, and using absolute symbols and expressions is not complex. The problem with absolute mode is that relocatability is possible only through the most complex and time consuming of techniques. Absolute mode effectively reduces your ability to reuse code in a new program.

The relative modes (data, code, and COMMON) are the basis of relocatability and, therefore, of the flexibility to manipulate modules. The complexity is that relative symbols and relative expressions are much more difficult to evaluate. In fact, the assembler must pass through the source statements twice to assemble a module. During the first pass, the assembler evaluates the statements and expands macro call statemnts, calculates the amount of code it will generate, and builds a symbol table where all symbols and macros are assigned values. During the second pass, the assembler fills in the symbol and expression values from the symbol table, expands macro call statements, and emits the intermediate code into a REL file.

When the REL files are given to LINK-80, the segments are linked together and loaded into fixed memory addresses. The relative addresses are converted to absolute addresses. The fixed addresses are assigned to the relative segments in the order: COMMON-relative and data-relative, then code-relative. The relative segments are loaded relative to default address 103H under CP/M. (The addresses 100H-102H are used for a jump to the start address of the first program instruction, which is normally the first address following the COMMON and data area.)

When LINK-80 is finished linking modules together and assigning addresses, the result can be saved in a file that is executable from the operating system. Executing the program is then as simple as entering an operating system command, so these linked and loaded files are called command files.

This short overview should give you a general idea of the workings and processes of the Utility Software Package. Short descriptions of all the Utility Software Package programs are given in the next chapter. Detailed descriptions are given in the rest of this manual. Therefore, the information contained in this overview will be repeated in fuller detail elsewhere in this manual.

As an aid to the description in the next chapter and the rest of this manual, the next page contains an expanded version of the diagram at the beginning of this overview. The expanded diagram shows the relationships among all the programs in the Utility Software Package.

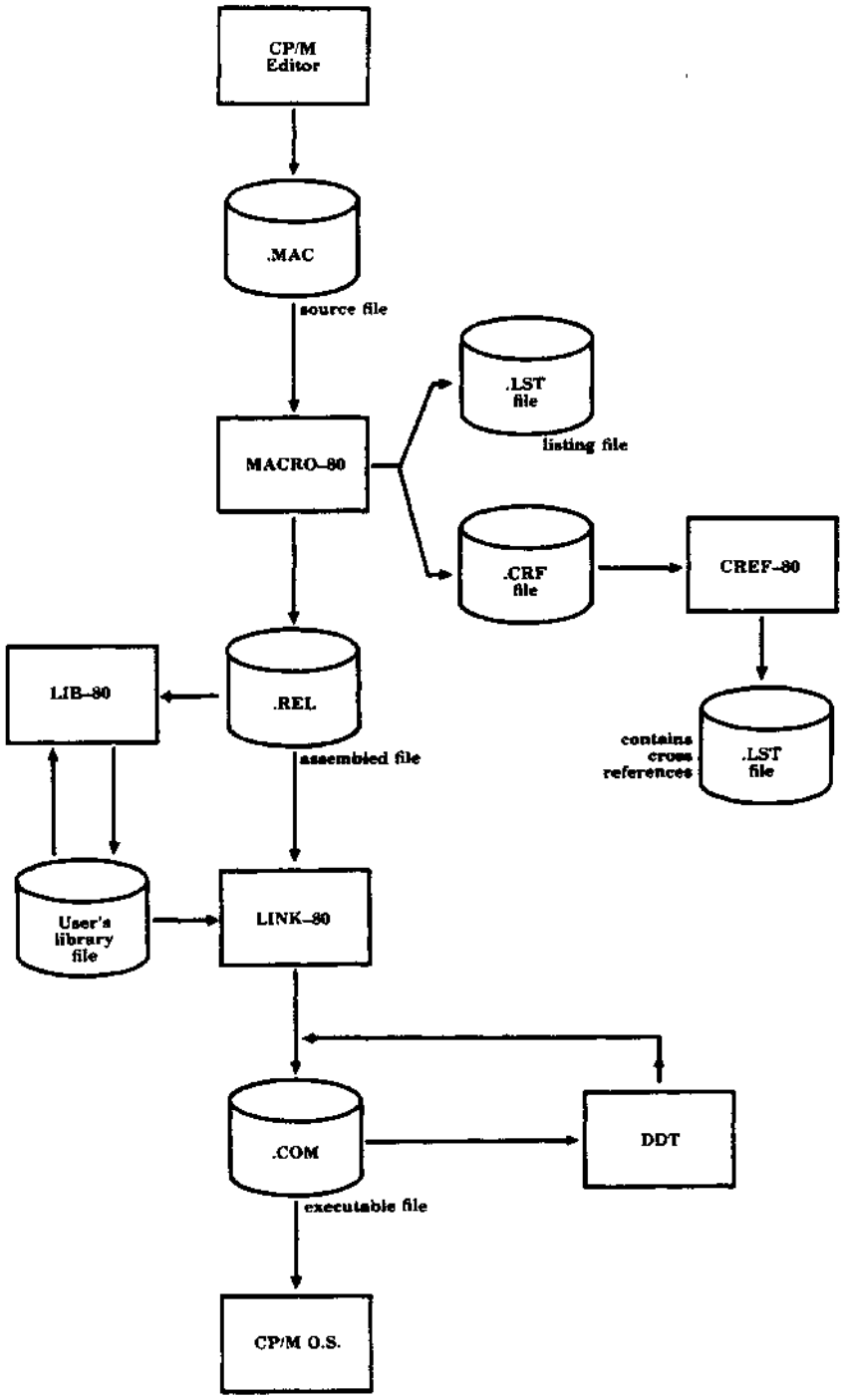


Figure 1.5: Relationships among programs

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CHAPTER 2

FEATURES OF THE UTILITY SOFTWARE PACKAGE

The Utility Software Package is an Assembly Language Development System that assembles relocatable code from two assembly languages, supports a macro facility and conditional assembly, and provides several utility programs that enhance program development.

WHAT IS AN UTILITY SOFTWARE PACKAGE?

An Utility software package is more than an assembler. An Utility Software Package is a series of related utility programming tools:

for assembling an assembly language source file,

for linking several assembled modules into one program,

for creating library files of subroutines (also assembled modules),

for creating cross-reference listings of program symbols,

for testing and debugging binary (machine executable) program files,

Microsoft's Utility Software Package provides versions of these tools that make the Utility Software Package extremely powerful and useful as a program development system. Each tool in the Utility Software Package is described in detail in its own chapter.

2.1 TWO ASSEMBLY LANGUAGES

The assembler in your Utility Software Package supports two assembly languages. Microsoft's MACRO-80 macro assembler supports both 8080 and Z80 mnemonics.

2.2 RELOCATABILITY

MACRO-80 can produce modules of relocatable code. Also, like many assemblers, the MACRO-80 assembler can produce absolute code. The key advantage of relocatability is that programs can be assembled in modules. Then, within certain restrictions described in Chapter 6, the modules can then be located almost anywhere in memory.

Relocatable modules also offer the advantages of easier coding and faster testing, debugging, and modifying. In addition, it is possible to specify segments of assembled code that will later be loaded into RAM or into ROM/PROM.

Relocatability will be discussed further under Section 3.2, Symbols.

2.3 MACRO FACILITY

The MACRO-80 assembler supports a complete, Intel standard macro facility. The macro facility allows a programmer to write blocks of code for a set of instructions used frequently. The need for recoding these instructions is eliminated.

The programmer gives this block of code a name, called a macro. The instructions are the macro definition. Each time the set of instructions is needed, instead of recoding the set of instructions, the programmer simply "calls" the macro. MACRO-80 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 stored in disk files and come into the module only when needed during assembly.

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

2.4 CONDITIONAL ASSEMBLY

MACRO-80 also supports conditional assembly. The programmer can determine a condition under which portions of the program are either assembled or not assembled. Conditional assembly capability is enhanced by a complete set of conditional pseudo operations that include testing of assembly pass, symbol definition, and parameters to macros. Conditionals may be nested up to 255 levels.

2.5 UTILITY PROGRAMS

Three utility programs provide the additional support needed to develop powerful and useful assembly language programs: LINK-80 Linking Loader, LIB-80 Library Manager, and CREF-80 Cross Reference Facility.

LINK-80 Linking Loader

The Microsoft LINK-80 Linking Loader is used to convert the assembled module (.REL file) into an executable module (.COM file). The .REL file is not an executable file.

LINK-80 can also be used to:

load, link, and run one or more modules

load relocatable programs at user-specified locations

load program areas and data areas into separate memory locations

While performing these tasks, LINK-80 resolves external references between modules (that is, any program that calls an external value, something defined in a different program or module, will have the outside references filled at link time by LINK-80), and saves the executable object (.COM) file on disk, so it can be run from the operating system.

These load capabilities mean that the assembled program may be linked with the user's library to add routines to one of the high-level langauge runtime libraries. Assembled programs can be linked to high-level language programs -- COBOL-80 and FORTRAN-80, for example -- as well as to MACRO-80 programs.

CREF-80 Cross Reference Facility

The CREF-80 Cross Reference Facility processes a cross reference file generated by MACRO-80. The result is a cross reference listing that can aid in the debugging of your program.

LIB-80 Library Manager (CP/M versions only)

LIB-80 is designed as a runtime library manager for CP/M versions of the Utility Software Package. LIB-80 may also be used to create your own library of assembly language subroutines.

LIB-80 creates runtime libraries from assembly language programs that are subroutines to COBOL, FORTRAN, and other assembly language programs. The programs collected by LIB-80 may be special modules created by the programmer or modules from an existing library. With LIB-80, you can create specialized runtime libraries for whatever execution requirements you design.

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CHAPTER 3

PROGRAMMING WITH THE UTILITY SOFTWARE PACKAGE

This chapter describes what the user needs to know to create MACRO-80 macro assembler source files. Source files are created using a text editor, such as CP/M ED. The Utility Software Package does not include a text editor program.

Source files are assembled using the procedures described in Chapter 4.

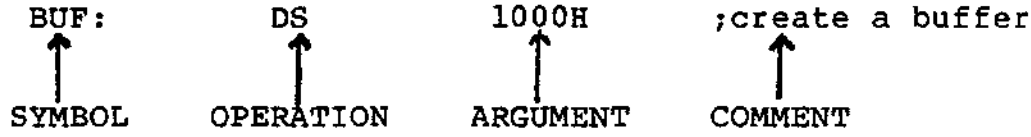
3.1 SOURCE FILE ORGANIZATION

File Organization

A MACRO-80 macro assembler source file is a series of lines written in assembly language. The last line of the file must be an END statement. Matching statements (such as IF...ENDIF) must be entered in the proper sequence. Otherwise, lines may appear in any order the programmer designs.

Statement Line Format

Source files input to the MACRO-80 macro assembler consist of statement lines divided into parts or "fields."



SYMBOL field contains one of the three types of symbol (LABEL, PUBLIC, and EXTERNAL), followed by a colon unless it is part of a SET, EQU, or MACRO statement.

OPERATION field contains an OPCODE, a PSEUDO-OP, a MACRO name, or an expression.

ARGUMENT field contains expressions (specific values, variables, register names, operands and operators).

;COMMENT field contains comment text always preceded by a semicolon.

All fields are optional. You may enter a completely blank line.

Statement lines may begin in any column. Multiple blanks or tabs may be inserted between fields to improve readability, but at least one space or tab is required between each field.

Comments

A MACRO-80 macro assembler source line is basically an Operation and its Argument. Therefore, the MACRO-80 macro assembler requires that a COMMENT always begin with a semicolon. A COMMENT ends with a carriage return.

For long comments, you may want to use the .COMMENT pseudo-op to avoid entering a semicolon for every line. See the File Related Pseudo-ops section of Chapter 4 for the description of .COMMENT.

3.2 SYMBOLS

Symbols are simply names for particular functions or values. Symbol names are created and defined by the programmer.

Symbols in the Utility Software Package belong to one of three types, according to their function. The three types are LABEL, PUBLIC, and EXTERNAL. All three types of symbols have a MODE attribute that corresponds to the segment of memory the symbol represents. Refer to the section on modes following the description of symbol types.

All three types of symbols have the following characteristics:

1. Symbols may be any length, but the number of significant characters passed to the linker varies with the type of symbol:

   a. for LABELs, only the first sixteen characters are significant.

   b. for PUBLIC and EXTERNAL symbols, only the first six characters are passed to the linker.

   Additional characters are truncated internally.

2. A legal symbol name may contain the characters:

   A-Z 0-9 $. ? @ _

3. A symbol may not start with a digit or an underline

4. When a symbol is read, lower case is translated into upper case, so you may enter the name using either case or both.

LABEL:

A LABEL: is a reference point for statements inside the program module where the label appears. A LABEL: sets the value of the symbol LABEL to the address of the data that follows. For example, in the statement:

```
BUF:    DS    1000H
```

BUF: equals the first address of the 1000H byte reserved space.

Once a label is defined, the label can be used as an entry in the ARGUMENT field. A statement with a label in its argument loops to the statement line with that label in its SYMBOL field, which is where the label is defined. The label's definition replaces the label used in an ARGUMENT field. For example,

```
STA    BUF
```

sends the value in the accumulator to the area in memory represented by the label BUF.

A LABEL may be any legal symbol name, up to 16 characters long.

If you want to define a LABEL, it must be the first item in the statement line. 8080 and Z80 labels must be followed immediately by a single colon (no space), unless the LABEL is part of a SET or EQU statement. (If two colons are entered, the "label" becomes a PUBLIC symbol. See PUBLIC Symbols below.)

PUBLIC

A PUBLIC symbol is defined much like a LABEL. The difference is that a PUBLIC symbol is available as a reference point for statements in other program modules, too.

A symbol is declared PUBLIC by:

two colons (::) following the name. For example,

```
FOO::        RET
```

one of the pseduo-ops PUBLIC, ENTRY, or GLOBAL. For example,

```
PUBLIC     FOO
```

See the Data Definition and Symbol Definition Pseudo-ops section in Chapter 4 for descriptions of how to use these pseudo-ops.

The result of both methods of declaration is the same. Therefore,

```
FOO::        RET
```

is equivalent to

```
PUBLIC     FOO
FOO:       RET
```

EXTERNAL

An EXTERNAL symbol is defined outside the program module where it appears. An EXTERNAL symbol is defined as a PUBLIC symbol in another, separate program module. At link time (when the LINK-80 Linking Loader is used), the EXTERNAL symbol is given the value of the PUBLIC symbol in the other program module. For example:

MOD1

```
FOO::     DB      7      ;PUBLIC FOO = 7
```

MOD2

```
          BYTE EXT      FOO      ;EXTERNAL FOO
```

At link time, LINK-80 goes to the address of PUBLIC FOO and uses the value there (7) for EXTERNAL FOO.

A symbol is declared EXTERNAL by:

1. two pound signs (##) following a reference to a symbol name. For example:

   ```
   CALL    FOO##
   ```

   declares FOO as a two-byte symbol defined in another program module.

2. one of the pseudo-ops EXT, EXTRN, or EXTERNAL for two-byte values. For example:

   ```
   EXT    FOO
   ```

   declares FOO as a two-byte value defined in another program module.

3. one of the pseudo-ops BYTE EXT, BYTE EXTERN, or BYTE EXTERNAL for one-byte values. For example:

   ```
   BYTE EXT     FOO
   ```

   declares FOO as a one-byte value defined in another program module.

   See the Symbol Definition Pseudo-ops section in Chapter 4 for descriptions of how to use these pseudo-ops.

As for PUBLIC symbols, the result of both methods of declaration is the same. Therefore,

```
CALL    FOO##
```

is equivalent to

```
EXT     FOO
CALL    FOO
```

MODES

A symbol is referenced by entering its name in the ARGUMENT field of a statement line. When a symbol is referenced, the value of the symbol (derived from the instruction which defines the symbol) is substituted for the symbol name and used in the operation.

The value of a symbol is evaluated according to its program counter (PC) mode. The PC mode determines whether a section of a program will be loaded into memory at addresses predetermined by the programmer (absolute mode), or at relative addresses that change depending on the size and number of programs (code relative mode) and amount of data (data relative mode), or at addresses shared with another program module (COMMON mode). The default mode is Code Relative.

Absolute Mode: Absolute mode assembles non-relocatable code. A programmer selects Absolute mode when a block of program code is to be loaded each time into specific addresses, regardless of what else is loaded concurrently.

Data Relative Mode: Data Relative mode assembles code for a section of a program that may change and therefore must be loaded into RAM. This applies to program data areas especially. Symbols in Data Relative Mode are relocatable.

Code Relative Mode: Code (program) Relative mode assembles code for sections of programs that will not be changed and therefore can be loaded into ROM/PROM. Symbols in Code Relative Mode are relocatable.

COMMON Mode: COMMON mode assembles code that is loaded into a defined common data area. This allows program modules to share a block of memory and common values.

To change mode, use a PC mode pseudo-op in a statement line. The PC mode pseudo-ops are:

```
ASEG    Absolute mode
DSEG    Data Relative mode
CSEG    Code Relative mode--default mode
COMMON  COMMON mode
```

These pseudo-ops are described in detail in the PC Mode Pseudo-ops section of Chapter 4.

This PC mode capability in the MACRO-80 macro assembler allows a programmer to develop assembly language programs that can be relocated. Many assembly language programmers may have learned always to set an Origin statement at the beginning of every module, subroutine, or main assembly language program. Under MACRO-80 this mode of addressing is called Absolute mode because hard (or actual addresses) are specified beginning, especially, with the Origin statement.

MACRO-80 has two other, "relative" modes of addressing available, called Code (Program) relative and Data relative. Segments of code written in these two modes are relocatable. Relocatable means the program module can be loaded starting at any address in available memory, using the /P and /D switches (special commands) in LINK-80.

3.3 OPCODES AND PSEUDO-OPS

Opcodes are the mnemonic names for the machine instructions. Pseudo-ops are directions to the assembler, not the microprocessor.

MACRO-80 supports two instruction sets: 8080 and Z80. A list of the opcodes with brief summaries of their functions is included as Appendix F. To program with the opcodes of the different languages, the user must first enter the pseudo-op which tells the assembler which language is being coded. Refer to the Language Set Selection Pseudo-ops section of Chapter 4 for details.

MACRO-80 also supports a large variety of pseudo-ops that direct the assembler to perform many different functions. The pseudo-ops are described extensively in Chapter 4 and are summarized in Appendix E.

Opcodes and pseudo-ops are (usually) entered in the OPERATION field of a statement line. (A program statement line usually has an entry in the operation field, unless the line is a Comment line only. The Operation field will be the first field filled if no label is entered.) An Operation may be any 8080 or Z80 mnemonic; or a MACRO-80 macro assembler pseudo-op, macro call, or expression.

The OPERATION field entries are evaluated in the following order:

1. Macro call

2. Opcode/Pseudo-op

3. Expressions

MACRO-80 compares the entry in the OPERATION filed to an internal list of macro names. If the entry is found, the macro is expanded. If the entry is not a macro, MACRO-80 tries to evaluate the entry as an opcode. If the entry is not an opcode, MACRO-80 tries to evaluate the entry as a pseudo-op. If the entry is not a pseudo-op, MACRO-80 evaluates the entry as an expression. If an expression is entered as a statement line without an opcode, pseudo-op, or macro name in front of it, the MACRO-80 macro assembler does not return an error. Rather, the assembler assumes that a define byte pseudo-op belongs in front of the expression and assembles the line.

Because of the order of evaluation, a macro name that is the same as an opcode prevents you from using the opcode again, except as a macro call. For example, if you give a block of macro code the name ADD in your program, you cannot use ADD as an opcode in that program.

3.4 ARGUMENTS: EXPRESSIONS

Arguments for the opcodes and pseudo-ops are usually called expressions because they resemble mathematical expressions, such as 5+4*3. The parts of an expression are called operands (5, 4, and 3 in the mathematical expression) and operators (the + and * are examples). Expressions may contain one operand or more than one. One operand expressions are probably the form most commonly used as arguments. If the expression contains more than one operand, the operands are related to each other by an operator. For example:

```
5+4   6-3   7*2   8/7   9>8
```

and so on. In MACRO-80, operands are numeric values represented by numbers, characters, symbols, or 8080 opcodes. Operators may be arithmetic or logical.

You are probably familiar with the various forms of expressions that can be used as arguments, but you may want to review the details given below for characteristics unique to MACRO-80.

The following sections define the forms of operands and operators MACRO-80 supports.

3.4.1 Operands

Operands may be numbers, characters, symbols, or 8080 opcodes.

Numbers

The default base for numbers is decimal. The base may be changed by the .RADIX pseudo-op. Any base from 2 (binary) to 16 (hexadecimal) may be selected. When the radix is greater than 10, A-F are used for the digits following 9. If the first digit of a number is not numeric, the number must be preceded by a zero.

A number is always evaluated in the current radix unless one of the following special notations is used:

nnnnB	Binary
nnnnD	Decimal
nnnnO	Octal
nnnnH	Hexadecimal
X'nnnn'	Hexadecimal

Numbers are 16-bit unsigned binary quantities. Overflow of a number beyond two bytes (16 bits -- that is, 65535 decimal) is ignored, and the result is the low order 16 bits.

ASCII Strings

A string is composed of zero or more characters delimited by quotation marks. Either single (') or double (") quotation marks may be used as string delimiters. When a quoted string is entered as an argument, the values of the characters are stored in memory one after the other. For example:

```
DB      "ABC"
```

stores the ASCII value of A at the first address, B at the second address, and C at the third.

The delimiter quotes may be used as characters if they appear twice for every character occurrence desired. For example, the statement

```
"I am ""great"" today"
```

stores the string

```
I am "great" today
```

If no characters are placed between the quotation marks, the string is evaluated as a null string.

Character Constants

Like strings, character constants are composed of zero, one, or two ASCII characters, delimited by quotation marks. Either single or double quotation marks may be used as delimiters. The delimiter quotes may be used as characters if they appear twice for every character occurrence desired.

The differences are:

1. A character constant is only zero, one, or two characters.

2. Quoted characters are a character constant only if the expression has more than one operand. If the characters are entered as the only operand, they are evaluated and stored as a string. For example:

   'A'+1 is a character constant, but

   'A' is a string.

3. The value of a character constant is calculated, and the result is stored with the low-byte in the first address and the high-byte in the second. For example:

3. The value of a character constant is calculated, and the result is stored with the low-byte in the first address and the high-byte in the second. For example:

```
DW    'AB'+0
```

evaluates to 4142H and stores 42 in the first address and 41 in the second.

A character constant comprised of one character has as its value the ASCII value of that character. That is, the high order byte of the value is zero, and the low order byte is the ASCII value of the character. For example, the value of the constant 'A' is 41H.

A character constant comprised of two characters has as its value the ASCII value of the first character in the high order byte and the ASCII value of the second character in the low order byte. For example, the value of the character constant 'AB'+0 is 41H*256+42H+0.

The ASCII decimal and hexadecimal values for characters are listed in Appendix C.

Symbols in Expressions

A symbol may be used as an operand in an expression. The symbol is evaluated, and the value is substituted for the symbol. The Operation is performed using the symbol's value.

The benefit of using symbols as operands is that the programmer need not remember the exact value each time it is needed; rather, the symbol name can be used. The name is usually easier to remember, especially if the symbol name is made mnemonic. The use of symbols as operands becomes more attractive, of course, as the number of symbols in a program increases.

Rules Governing the Use of EXTERNALS in expressions:

1. EXTERNAL symbols may be used in expressions with the following operators only:

```
+    -    *    /    MOD    HIGH    LOW
```

2. If an EXTERNAL symbol is used in an expression, the result of the expression is always external.

MODE Rules affecting SYMBOLS in expressions:

1. In any operation, except AND, OR, or XOR, the operands may be any mode.

2. For AND, OR, XOR, SHL, and SHR, both operands must be absolute and internal.

3. When an expression contains an Absolute operand and an operand in another mode, the result of the expression will be in the other (not Absolute) mode.

4. When subtracting two operands in different modes, the result will be in Absolute mode. Otherwise, the result will be in the mode of the operands.

5. When adding a data relative symbol and a code relative symbol, the result will be unknown, and MACRO-80 passes the expression to LINK-80 as an unknown, which LINK-80 resolves.

Current Program Counter Symbol

One additional symbol for the Argument field only must be noted: the current program counter symbol. The current program counter is the address of the next instruction to be assembled. The current program counter is often a convenient reference point for calculating new addresses. Instead of remembering or calculating the current program address, the programmer uses a symbol that tells the assembler to use the value of the current program address.

The current program counter symbol is $.

8080 Opcodes as Operands

8080 opcodes are valid one-byte operands in 8080 mode only. During assembly, the opcode is evaluated to its hexadecimal value.

To use 8080 opcodes as operands, first set the .8080 pseudo-op. See the Language Set Selection Pseudo-ops section of Chapter 4 for a description of how to use the .8080 pseudo-op.

Only the first byte is a valid operand. Use parentheses to direct the assembler to generate one byte for opcodes that normally generate more than one. For example:

```
MVI     A,(JMP)
ADI     (CPI)
MVI     B,(RNZ)
CPI     (INX H)
ACI     (LXI B)
MVI     C,MOV A,B
```

The assembler returns an error if more than one byte is included in the operand (inside the parentheses) -- such as (CPI 5), (LXI B,LABEL1), or (JMP LABEL2).

Opcodes that generate one byte normally may be used as operands without being enclosed in parentheses.

3.4.2 Operators

MACRO-80 allows both arithmetic and logical operators. Operators which return true or false conditions return true if the result is any non-zero value and false if the result is zero.

The following arithmetic and logical operators are allowed in expressions.

Operator	Definition
NUL	Returns true if the argument (a parameter) is null. The remainder of the line after NUL is taken as the argument to NUL. The conditional IF NUL <argument> is false if the first character of the argument is anything other than a semicolon or carriage return. Note that IFB and IFNB perform the same functions but are simpler to use. (Refer to the Conditional Assembly Facility section in Chapter 4.)
TYPE	The TYPE operator returns a byte that describes two characteristics of its argument: 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 Relative
2 the mode is Data Relative
3 the mode is Common Relative

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 local (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       SET 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.

LOW — Isolates the low order 8 bits of an absolute 16-bit value.

HIGH — Isolates the high order 8 bits of an absolute 16-bit value.

* — Multiply

/ — Divide

MOD — Modulo. Divide the left operand by the right operand and return the value of the remainder (modulo).

SHR	Shift Right. SHR is followed by an integer which specifies the number of bit positions the value is to be right shifted.
SHL	Shift Left. SHL is followed by an integer which specifies the number of bit positions the value is to be left shifted.
- (Unary Minus)	Indicates that following value is negative, as in a negative integer.
+	Add
-	Subtract the right operand from the left operand.
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.
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.

The order of precedence for the operators is:

NUL, TYPE

LOW, HIGH

*, /, MOD, SHR, SHL

Unary Minus

+, -

EQ, NE, LT, LE, GT, GE

NOT

AND

OR, XOR

Subexpressions involving operators of higher precedence than an expression are computed first. The order of precedence may be altered by using parentheses around portions of an expression you wish to give higher precedence.

All operators except +, -, *, and / must be separated from their operands by at least one space.

The byte isolation operators (HIGH and LOW) isolate the high- or low-order 8 bits of a 16-bit value.

Contents

CHAPTER 4

ASSEMBLER FEATURES

The MACRO-80 macro assembler features three general facilities: single-function pseudo-ops, a macro facility, and a conditional assembly facility.

4.1 SINGLE-FUNCTION PSEUDO-OPS

Single-function pseudo-ops involve only their own statement line and direct the assembler to perform only one function. (Macros and conditionals involve more than one line of code, so they may be thought of as block pseudo-ops.)

The Single-Function Pseudo-ops are divided into five types: Instruction Set Selection, Data Definition and Symbol Definition, PC Mode, File Related, and Listing Control.

INSTRUCTION SET SELECTION

The default instruction set mode is 8080. If the correct instruction set selection pseudo-op is not given, the assembler will return fatal errors for opcodes that are not valid for the current instruction set selection mode. That is, .Z80 assembles Z80 opcodes only; .8080 assembles 8080 opcodes only. Therefore, if you have written any assembly language programs for Z80, you need to insert the .Z80 instruction set pseudo-op at the beginning of the program file.

Note that all the pseudo-ops listed in this chapter will assemble in both instruction set modes.

.Z80

.Z80 takes no arguments. .Z80 directs MACRO-80 to assemble Z80 opcodes.

.8080

.8080 takes no arguments. .8080 directs MACRO-80 to assemble 8080 opcodes. (default)

All opcodes entered following an Instruction Set Selection pseudo-op will be assembled as that type of code until a different Instruction Set Selection pseudo-op is encountered.

If you enter an opcode not belonging to the selected instruction set, MACRO-80 will return an Objectionable Syntax error (letter O).

DATA DEFINITION AND SYMBOL DEFINITION

All of the data definition and symbol definition pseudo-ops are supported in both instruction set modes. (The one notable exception is SET, which is illegal in .Z80 mode. For your information, The following notation has been placed before the pseudo-op syntax to indicate which microprocessor the pseudo-op is usually associated with:

* indicates a Z80 pseudo-op

No asterisk indicates an Intel 8080 pseudo-op

Define Byte

```
    DB <exp>[,<exp>...]
*   DEFB <exp>[,<exp>...]
    DB <string>[<string>...]
*   DEFM <string>[,<string>...]
```

The arguments to DB are either expressions or strings. The arguments to DEFB are expressions. The arguments to DEFM are strings. Strings must be enclosed in quotes, either single or double.

NOTE: DB is used throughout the following explanation to represent all the Define Byte pseudo-ops.

DB is used to store a value (string or numeric) in a memory location, beginning with the current location counter.

Expressions must evaluate to one byte. (If the high byte of the result is 0 or 255, no error is given; otherwise, an A error results.)

Strings of three or more characters may not be used in expressions (i.e., they must be immediately followed by a comma or the end of the line). The characters in a 8080 or Z80 string are stored in the order of appearance, each as a one-byte value with the high order bit set to zero.

EXAMPLE:

```
                        DB      'AB'
                        DB      'AB' AND 0FFH
                        DB      'ABC'
```

assembles as:

```
0000'  41 42            DB      'AB'
0002'  42               DB      'AB' AND 0FFH
0003'  41 42 43         DB      'ABC'
```

Define Character

DC <string>

DC stores the characters in <string> in successive memory locations beginning with the current location counter. As with DB, characters are stored in order of appearance, each as a one-byte value with the high order bit set to zero. However, DC stores the last character of the string with the high order bit set to one. An error will result if the argument to DC is a null string.

EXAMPLE:

```
                    FOO:      DC        "ABC"
```

assembles to:

```
0000'  41 42 C3   FOO:      DC        "ABC"
```

Define Space

```
    DS   <exp>[,<val>]
*   DEFS <exp>[,<val>]
```

The define space pseudo-ops reserve an area of memory. The value of <exp> gives the number of bytes to be reserved.

To initialize the reserved space, set <val> to the value desired. If <val> is nul (that is, omitted), the reserved space is left as is (uninitialized); the reserved block of memory is not automatically initialized to zeros. As an alternative to setting <val> to zero, when you want the define space block initialized to zeros, you may use the /M switch at assembly time. See the Switches section in Chapter 5, Running MACRO-80, for a description of the /M switch.

All names used in <exp> must be previously defined (i.e., all names known at that point on pass 1). Otherwise, a V error is generated during pass 1, and a U error may be generated during pass 2. If a U error is not generated during pass 2, a phase error will probably be generated because the define space pseudo-op generated no code on pass 1.

EXAMPLE:

```
    DS      100H
```

reserves 100H bytes of memory, uninitialized (whatever values were in those bytes before the program was loaded will still be there). Use the /M switch at assembly time to initialized the 100H bytes to zero, if you want. Or, use the following statement to initialize a reserved space to zero or any other value:

```
    DS      100H,2
```

reserves 100H bytes, each initialized to a value of 2.

Define Word

```
    DW <exp>[,<exp>...]
*   DEFW <exp>[,<exp>...]
```

The define word pseudo-ops store the values of the expressions in successive memory locations beginning with the current location counter. Expressions are evaluated as 2-byte (word) values. Values are stored low-order byte first, then high-order byte.

Contrast with DDB.

EXAMPLE:

```
                                FOO:    DW          1234H
```

assembles as:

```
0000' 1234      FOO:        DW      1234H
```

Note: The bytes are shown on the listing in the order entered, not the order stored.

Equate

<name> EQU <exp>

EQU assigns the value of <exp> to <name>. The <name> may be a label, a symbol, or a variable, and may be used subsequently in expressions. <name> may not be followed by colon(s).

If <exp> is External, an error is generated. If <name> already has a value other than <exp>, an M error is generated.

If you will want to redefine <name> later in the program, use the SET or ASET pseudo-op to define <name> instead of EQU.

Contrast with SET.

EXAMPLE:

```
BUF   EQU   0F3H
```

External Symbol

```
    EXT <name>[,<name>...]
    EXTRN <name>[,<name>...]
*   EXTERNAL <name>[,<name>...]
    BYTE EXT <symbol>
    BYTE EXTRN <symbol>
    BYTE EXTERNAL <symbol>
```

The External symbol pseudo-ops declare that the name(s) in the list are External (i.e., defined in a different module). If any item in the list refers to a name that is defined in the current program, an M error results. A reference to a name where the name is followed immediately be two pound signs (e.g., NAME##) also declares the name as External.

Externals may evaluate to either one or two bytes. For all External symbol names, only the first 6 characters are passed to the linker. Additional characters are truncated internally.

EXAMPLE:

```
    EXTRN     ITRAN     ;tranf init rtn
```

MACRO-80 will generate no code for this statement when this module is assembled. When ITRAN is used as an argument to a CALL statement, the CALL ITRAN statement generates the code for CALL but a zero value (0000*) for ITRAN. At link time, LINK-80 will search all modules loaded for a PUBLIC ITRAN statement and use the definition of ITRAN found in that module to define ITRAN in the CALL ITRAN statement.

Public Symbol

```
ENTRY <name>[,<name>...]
GLOBAL <name>[,<name>...]
PUBLIC <name>[,<name>...]
```

The Public symbol pseudo-ops declare each name in the list as internal and therefore available for use by this program and other programs to be loaded concurrently and linked with LINK-80. All of the names in the list must be defined in the current program, or a U error results. An M error is generated if the name is an External name or common block name.

Only the first 6 characters of a Public symbol name are passed to the linker. Additional characters are truncated internally.

EXAMPLE:

```
        PUBLIC  ITRAN   ;tranf init rtn
          .
          .
          .
ITRAN:  LD      HL,PASSA  ;store addr of
                          ;reg pass area
```

MACRO-80 assembles the LD statement as usuall but generates no code for the PUBLIC ITRAN statement. When LINK-80 sees EXTRN ITRAN in another module, it knows to search until it sees this PUBLIC ITRAN statement. Then, LINK-80 links the value of ITRAN: LD HL,PASSA statement to the CALL ITRAN statement in the other module(s).

Set

```
    <name> SET <exp>      (Not in .Z80 mode)
*   <name> DEFL <exp>
    <name> ASET <exp>
```

The Set pseudo-ops assign the value of <exp> to <name>. The <name> may be a label, a symbol, or a variable, and may be used subsequently in expressions. <name> may not be followed by colon(s). If <exp> is External, an error is generated.

The SET pseudo-op may not be used in .Z80 mode because SET is a Z80 opcode. Both ASET and DEFL may be used in both instruction set modes.

Use one of the SET pseudo-ops instead of EQU to define and redefine <name>s you may want to redefine later. <name> may be redefined with any of the Set pseudo-ops, regardless of which pseudo-op was used to define <name> originally (the prohibition against SET in .Z80 mode still applies, however).

Contrast with EQU.

EXAMPLE:

```
    F00 ASET BAZ+1000H
```

Whenever FOO is used as an expression (operand), the ALDS assembler will evaluate BAZ+1000H and substitute the value for FOO. Later, if you want FOO to represent a different value, simply reenter the FOO ASET statement with a different expression.

```
    F00 ASET BAZ+1000H
          .
          .
          .
    F00 ASET 3000H
          .
          .
          .
    F00 DEFL 6CDEH
```

PC MODE

Many of the pseudo-ops operate on or from the current location counter, also known as the program counter or PC. The current PC is the address of the next byte to be generated.

In MACRO-80, the PC has a mode, which gives symbols and expressions their modes. (Refer again to the Overview in Chapter 1 and the Symbols section in Chapter 3, if necessary.) Each mode is given a segment of memory by LINK-80 for the instructions assembled to each mode.

The four modes are Absolute, Data Relative, Code Relative, and COMMON Relative.

If the PC mode is absolute, the PC is an absolute address. If the PC mode is relative, the PC is a relative address and may be considered an offset from the absolute address where the beginning of that relative segment will be loaded by LINK-80.

The PC mode pseudo-ops are used to specify in which PC mode a segment of a program will be assembled.

Absolute Segment

ASEG

ASEG never has operands. ASEG generates non-relocatable code.

ASEG sets the location counter to an absolute segment (actual address) of memory. The ASEG will default to 0, which could cause the module to write over part of the operating system. We recommend that each ASEG be followed with an ORG statement set at 103H or higher.

Code Segment

CSEG

CSEG never has an operand. Code assembled in Code Relative mode can be loaded into ROM/PROM.

CSEG resets the location counter to the code relative segment of memory. The location will be that of the last CSEG (default is 0), unless an ORG is done after the CSEG to change the location.

Note, however, that the ORG statement does not set a hard (absolute) address under CSEG mode. An ORG statement under CSEG causes the assembler to add the number of bytes specified by the <exp> argument in the ORG statement to the last CSEG address loaded. If, for example, ORG 50 is given, MACRO-80 will add 50 bytes to the current CSEG location then begin loading the CSEG. The clearing effect of the ORG statement following CSEG (and DSEG as well) can be used to give the module an offset. The rationale for not allowing ORG to set an absolute address for CSEG is to keep the CSEG relocatable.

To set an absolute address for the CSEG, use the /P switch in LINK-80.

CSEG is the default mode of the assembler. Assembly begins with a CSEG automatically executed, and the location counter in the Code Relative mode, pointing to location 0 in the Code Relative segment of memory. All subsequent instructions will be assembled into the Code Relative segment of memory until an ASEG, DSEG, or COMMON pseudo-op is executed. CSEG is then entered to return the assembler to Code Relative mode, at which point the location counter returns to the next free location in the Code Relative segment.

Data Segment

DSEG

The DSEG pseudo-op never has operands. DSEG specifies segments of assembled relocatable code that will later be loaded into RAM only.

DSEG sets the location counter to the Data Relative segment of memory. The location of the data relative counter will be that of the last DSEG (default is 0), unless an ORG is done after the DSEG to change the location.

Note, however, that the ORG statement does not set a hard (absolute) address under DSEG mode. An ORG statement under DSEG causes the assembler to add the number of bytes specified by the <exp> argument in the ORG statement to the last DSEG address loaded. If, for example, ORG 50 is given, MACRO-80 will add 50 bytes to the last DSEG address loaded then begin loading the DSEG. The clearing effect of the ORG statement following DSEG (and CSEG as well) can be used to give the module an offset. The rationale for not allowing ORG to set an absolute address for DSEG is to keep the DSEG relocatable.

To set an absolute address for the DSEG, use the /D switch in LINK-80.

Common Block

COMMON /<block name>/

The argument to COMMON is the common block name. COMMON creates a common data area for every COMMON block that is named in the program. If <block name> is omitted or consists of spaces, the block is considered to be blank common.

COMMON statements are non-executable, storage allocating statements. .COMMON assigns variables, arrays, and data to a storage area called COMMON storage. This allows various program modules to share the same storage area. Statements entered following the .COMMON statement are assembled to the COMMON area under the <block name>. The length of a COMMON area is the number of bytes required to contain the variables, arrays, and data declared in the COMMON block, which ends when another PC mode pseudo-op is encountered. COMMON blocks of the same name may be different lengths. If the lengths differ, then the program module with the longest COMMON block must be loaded first (that is, must be the first module name given in the LINK-80 command line; see Chapter 6 for the description of LINK-80).

COMMON sets the location counter to the selected common block in memory. The location is always the beginning of the area so that compatibility with the FORTRAN COMMON statement is maintained.

EXAMPLE:

```
          COMMON /DATABIN/
ANVIL     EQU    100H
          DB     0FFH
          DW     1234H
          DCI    'FORGE'
          CSEG
             .
             .
             .
```

Set Origin

ORG <exp>

At any time, the value of a location counter may be changed by use of ORG. Under the ASEG PC mode, the location counter is set to the value of <exp>, and the assembler assigns generated code starting with that value. Under the CSEG, DSEG, and COMMON PC modes, the location counter for the segment is incremented by the value of <exp>, and the assembler assigns generated code starting with the value of that last segment address loaded plus the value of <exp>. All names used in <exp> must be known on pass 1, and the value must either be Absolute or in the same area as the location counter.

EXAMPLE:

```
DSEG
ORG     50
```

sets the Data Relative location counter to 50, relative to the start of the Data Relative segment of memory. This means that the first 50H addresses will be filled with 0. This method provides relocatability. The ORG <exp> statement does not specify a fixed address in CSEG or DSEG mode; rather, LINK-80 loads the segment at a flexible address appropriate to the modules being loaded together.

On the other hand, a program that begins with the statements

```
ASEG
ORG     800H
```

and is assembled entirely in Absolute mode will always load beginning at 800H, unless the ORG statement is changed in the source file. That is, ORG <exp> following ASEG originates the segment at a fixed (i.e., absolute) address specified by <exp>. However, the same program, assembled in Code Relative mode with no ORG statement, may be loaded at any specified address by appending the /P:<address> switch to the LINK-80 command string. (For details, see Section 6.3, Switches.)

Relocate

```
.PHASE <exp>
   .
   .
   .
.DEPHASE
```

.PHASE allows code to be located in one area, but executed only at a different area with a start address specified by <exp>. The <exp> must be an absolute value. .DEPHASE is used to indicate the end of the relocated block of code.

The PC mode within a .PHASE block is absolute, the same as the mode of the <exp> in the .PHASE statement. The code, however, is loaded in the area in effect when the .PHASE statement is encountered. The code within the block is later moved to the address specified by <exp> for execution.

EXAMPLE:

```
                        .PHASE      100H
                FOO:    CALL        BAZ
                        JMP         ZOO
                BAZ:    RET
                        .DEPHASE
                ZOO:    JMP         5
```

assembles as:

```
                        .PHASE      100H
0100    CD 0106 FOO:    CALL        BAZ
0103    C3 0007'        JMP         ZOO
0106    C9      BAZ:    RET
                        .DEPHASE
0007'   C3 0005 ZOO:    JMP         5
                        END
```

.PHASE....DEPHASE blocks are a way to execute a block of code at a specific absolute address.

FILE RELATED

The file related pseudo-ops insert long comments in the program, give the module a name, end the module, or move other files into the current program.

Comment

.COMMENT <delim><text><delim>

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

Use the .COMMENT pseudo-op to make long comments. It is not necessary to enter the semicolon to indicate a COMMENT. Indeed, the main reason for using .COMMENT is to override the need to begin each comment line with a semicolon. During assembly, .COMMENT blocks are ignored and not assembled.

EXAMPLE:

```
.COMMENT * any amount of text
entered here
    .
    .
    .* ;return to normal assembly
```

End of Program

END [<exp>]

The END statement specifies the end of the module. If the END statement is not included, a %No END statement warning error message results.

The <exp> may be a label, symbol, number, or any other legal argument that LINK-80 can load as the starting point into the first address to be loaded. If <exp> is present, LINK-80 will place an 8080 JMP instruction at 0100H to the address of <exp>. If <exp> is not present, then no start address is passed to LINK-80 for that program, and execution begins at the first module loaded. (Also, if <exp> is not specified, the LINK-80 /G switch will not work for the module.)

The <exp> tells LINK-80 that the program is a main program. Without <exp>, LINK-80 takes assembly language programs as subroutines. If you link only assembly language programs and none contains an END statement with <exp>, LINK-80 will ask for a main program. If you link two or more programs with END <exp> statements, LINK-80 cannot distinguish which should be the main program.

If you want to link two or more main programs, use the /G:Name or /E:Name switches in LINK-80 (see Section 6.2.2, Switches). The "Name" will be the <exp> of the END statement for the program you want to serve as the main program.

If any high-level language program is loaded with assembly language modules, LINK-80 takes the high-level language program as the main program automatically. Therefore, if you want an assembly language module executed before the high-level language program, use the /G:Name or /E:Name switch in LINK-80 to set the assembly language module as the beginning of the program.

As an alternative, we recommend that you place a CALL or INCLUDE statement at the beginning of the high-level language program, and call in the assembly language program for execution prior to execution of the high-level language program.

Include

```
INCLUDE <filename>
$INCLUDE <filename>
MACLIB <filename>
```

All three pseudo-ops are synonomous.

These Include pseudo-ops insert source code from an alternate assembly language source file into the current source file during assembly. Use of an Include pseudo-op 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 filename extension and/or device designation are other than the default, source filename specifications must include them. The default filename extension for source files is .MAC. 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 pseudo-op statement. When end-of-file is reached, assembly resumes with the next statement following Include pseudo-op.

Nested Includes are not allowed. If encountered, they will result in an objectionable syntax error, O.

The file specified in the operand field must exist. If the file is not found, the error V (value error) is returned, and the Include is ignored. The V error is also returned if the Include filename extension is not .MAC.

On a MACRO-80 listing, the letter C is printed between the assembled code and the source line on each line assembled from an included file. See the Listing Control Pseudo-op section below for a description of listing file formats.

Name Module

NAME ('modname')

Name defines a name for the module. The parentheses and quotation marks around modname are required. Only the first six characters are significant in a module name.

A module name may also be defined with the TITLE pseudo-op. In the absence of both the NAME and TITLE pseudo-ops, the module name is created from the source filename.

Radix

.RADIX <exp>

The <exp> in a .RADIX statement is always a decimal numeric constant, regardless of the current radix.

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

.RADIX does not change the radix of the listing; rather, it allows you to input numeric values in the radix you choose without special notation. (Values in other radixes still require the special notations described in Section 3.4.1.) Values in the generated code remain in hexadecimal radix.

EXAMPLE:

```
                    DEC:    DB      20
                            .RADIX  2
                    BIN:    DB      00011110
                            .RADIX  16
                    HEX:    DB      0CF
                            .RADIX  8
                    OCT:    DB      73
                            .RADIX  10
                    DECI:   DB      16
                    HEXA:   DB      OCH
```

assembles as:

```
0000'  14           DEC:    DB      20
0002                        .RADIX  2
0001'  1E           BIN:    DB      00011110
0010                        .RADIX  16
0002'  CF           HEX:    DB      0CF
0008                        .RADIX  8
0003'  3B           OCT:    DB      73
000A                        .RADIX  10
0004'  10           DECI:   DB      16
0005'  0C           HEXA:   DB      OCH
```

Request

.REQUEST <filename>[,<filename>...]

When you run LINK-80, .REQUEST sends a request to the LINK-80 linking loader to search the filenames in the list for undefined external symbols. If LINK-80 finds any undefined external symbols (external symbols for which a corresponding PUBLIC symbol is not currently loaded), you will know that you need to load one or more additional modules to complete linking.

The filenames in the list should be in the form of legal symbols. <filename> should not include a filename extension or device designation. LINK-80 assumes the default extension (.REL) and the currently logged disk drive.

EXAMPLE:

```
        .
        .
        .
    .REQUEST   SUBR1
        .
        .
        .
```

LINK-80 will search SUBR1 for external symbols which do not have corresonding PUBLIC symbol definitions declared among the currently loaded modules.

LISTING

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

Format Control

These pseudo-ops allow you to direct page breaks, titles, and subtitles on your program listings.

Form Feed

```
*  *EJECT [<exp>]
   PAGE <exp>
   $EJECT
```

The form feed pseudo-ops cause 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 value of <exp>, if included, becomes the new page size (measured in lines per page) and must be in the range 10 to 255. The default page size is 50 lines per page.

EXAMPLE:

```
        .
        .
        .
    *EJECT 58
        .
        .
        .
```

The assembler causes the printer to start a new page every time 58 lines of program have been printed.

Title

TITLE <text>

TITLE specifies a title to be listed on the first line of each page. If more than one TITLE is given, a Q error results. The first six characters of the title are used as the module name, unless a NAME pseudo-op is used. (If neither a TITLE nor a NAME pseudo-op is used, the module name is created from the source filename.)

EXAMPLE:

```
TITLE PROG1
   .
   .
   .
```

The module name is now PROG1. The module may be called by this name, which will be printed at the top of every listing page.

Subtitle

```
SUBTTL <text>
$TITLE ('<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).

General Listing Control

.LIST - List all lines with their code
.XLIST - Suppress all listing

.LIST is the default condition. If you specify a listing file in the command line, the file will be listed.

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 control pseudo-ops. So, nothing will be listed, even if another listing pseudo-op (other than .LIST) is encountered.

EXAMPLE:

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

Print At Terminal

.PRINTX <delim><text><delim>

The first non-blank character encountered after .PRINTX is the delimiter. The following text is listed on the terminal during assembly until another occurrence of the delimiter is encountered. .PRINTX is useful for displaying progress through a long assembly or for displaying the value of conditional assembly switches.

.PRINTX will output on both passes. If only one printout is desired, use the IF1 or IF2 pseudo-op, depending on which pass you want displayed. See the Conditional pseudo-ops for IF1 and IF2.

EXAMPLE:

```
    .PRINTX *Assembly half done*
```

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

```
IF1
.PRINTX *Pass 1 done*   ;pass 1 message only
ENDIF

IF2
.PRINTX *Pass 2 done*   ;pass 2 message only
ENDIF
```

Conditional Listing Control

The three conditional listing control pseudo-ops are used to specify whether or not you wish statements contained within a false conditional block to appear on the listing. See also the description of the /X switch in Chapter 5.

Suppress False Conditionals

.SFCOND

.SFCOND suppresses the portion of the listing that contains conditional expressions that evaluate as false.

List False Conditionals

.LFCOND

.LFCOND assures the listing of conditional expressions that evaluate false.

Toggle False Listing Conditional

.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 in the assembler command line. When /X is present, .TFCOND will cause false conditionals to list. When /X is not given, .TFCOND will suppress false conditionals.

Macro Expansion Listing Control

Expansion listing pseudo-ops control the listing of lines inside macro and repeat pseudo-op (REPT, IRP, IRPC) blocks, and may be used only inside a macro or repeat block.

Exclude Non-code Macro Lines

.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.

List Macro Text

.LALL

.LALL lists the complete macro text for all expansions, including lines that do not generate code.

Suppress Macro Listing

.SALL

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

CREF Listing Control Pseudo-ops

You may want the option of generating a cross reference listing for part of a program but not all of it. To control the listing or suppressing of cross references, use the cross reference listing control pseudo-ops, .CREF and .XCREF, in the source file for MACRO-80. These two pseudo-ops may be entered at any point in the program in the OPERATOR field. Like the other listing control pseudo-ops, .CREF and .XCREF support no ARGUMENTs.

Suppress Cross References

.XCREF

.XCREF turns of the .CREF (default) pseudo-op. .XCREF remains in effect until MACRO-80 encounters .CREF. Use .XCREF to suppress the creation of cross references in selected portions of the file. Because neither .CREF nor .XCREF takes effect until the /C switch is set in the MACRO-80 command line, there is no need to use .XCREF if you want the usual List file (one without cross references); simply omit /C from the ALDS assembler command line.

List Cross References

.CREF

.CREF is the default condition. Use .CREF to restart the creation of a cross reference file after using the .XCREF pseudo-op. .CREF remains in effect until MACRO-80 encounters .XCREF. Note, however, that .CREF has no effect until the /C switch is set in the MACRO-80 command line.

4.2 MACRO FACILITY

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

The macro facility of the MACRO-80 macro assembler includes pseudo-ops for:

macro definition:
    MACRO

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

termination:
    ENDM
    EXITM

unique symbols within macro blocks:
    LOCAL

The macro facility also supports some special macro operators:

&
;;
!
%

Macro Definition

```
<name> MACRO <dummy>[,<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. Note that <name> may be any length, but only the first 16 characters are passed to the linker. After the macro has been defined, <name> is used to invoke the macro.

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. Each <dummy> may be up to 32 characters long. The number of dummys is limited only by the length of a line. If you specify more than one dummy, they must be separated by commas. MACRO-80 interprets all characters between commas as a single dummy.

NOTE

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

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.

If you want to use the TITLE, SUBTTL, or NAME pseudo-ops 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-80 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>[,<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. 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 dummys in the MACRO definition. If there are more parameters than dummys, the extras are ignored. If there are fewer, the extra dummys will be made null. The assembled code will include the macro block after each macro call statement.

EXAMPLE:

```
EXCHNG    MACRO    X,Y
          PUSH     X
          PUSH     Y
          POP      X
          POP      Y
          ENDM
```

If you then enter as part of a program some code and a macro call statement:

```
          LDA      2FH
          MOV      HL,A
          LDA      3FH
          MOV      DE,A
          EXCHNG   HL,DE
```

assembly generates the code:

```
0000'  3A 002F             LDA      2FH
0003'  67                  MOV      HL,A
0004'  3A 003F             LDA      3FH
0007'  57                  MOV      DE,A
                           EXCHNG   HL,DE
0008'  E5          +       PUSH     HL
0009'  D5          +       PUSH     DE
000A'  E1          +       POP      HL
000B'  D1          +       POP      DE
```

Repeat Pseudo-ops

The pseudo-ops 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 pseudo-ops and MACRO pseudo-op 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 pseudo-op 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 pseudo-ops are convenient. With the MACRO pseudo-op, you must call in the MACRO each time it is needed.

Note that each Repeat pseudo-op must be matched with the ENDM pseudo-op 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   SET   0
                REPT  10     ;generates DB 1 - DB 10
            X   SET   X+1
                DB    X
                ENDM
```

assembles as:

```
0000        X   SET   0
                REPT  10     ;generates DB 1 - DB 10
            X   SET   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 - 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 are 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 - DB 10) as the two previous examples.

Termination

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 pseudo-op. Otherwise, the 'Unterminated REPT/IRP/IRPC/MACRO' message is generated at the end of each pass. An unmatched ENDM causes an O 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 pseudo-op 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 pseudo-op.

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
Y       SET       0
        REPT      X
Y       SET       Y+1
        IFE       Y-0FFH  ;test Y
        EXITM     ;if true, exit REPT
        ENDIF
        DB        Y
        ENDM
        ENDM
```

Macro Symbol

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

The LOCAL pseudo-op is allowed only inside a MACRO definition block. 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 ..0001 to ..FFFF. Users should avoid the form ..nnnn for their own symbols. A LOCAL statement must precede all other types of statements in the macro definition.

EXAMPLE:

```
                FOO     MACRO   NUM,Y
                        LOCAL   A,B,C,D,E
                A:      DB      7
                B:      DB      8
                C:      DB      Y
                D:      DB      Y+1
                E:      DW      NUM+1
                        JMP     A
                        ENDM
                        FOO     0C00H,0BEH
                        END
```

generates the following code (notice that MACRO-80 has substituted LABEL names in the form ..nnnn for the instances of the dummy symbols):

```
                FOO     MACRO   NUM,Y
                        LOCAL   A,B,C,D,E
                A:      DB      7
                B:      DB      8
                C:      DB      Y
                D:      DB      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' BF        +..0003:DB      0BEH+1
0004' 0C01      +..0004:DW      0C00H+1
0006' C3 0000'  +       JMP     ..0000
                        END
```

Special Macro Operators

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

& Ampersand concatenates text or symbols. (The & 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 &. To form a symbol from text and a dummy, put & between them.

For example:

```
ERRGEN      MACRO    X
ERROR&X:    PUSH     B
            MVI      B,'&X'
            JMP      ERROR
            ENDM
```

The call ERRGEN A will then generate:

```
ERRORA:     PUSH     B
            MVI      B,'A'
            JMP      ERROR
```

;; In a block operation, a comment preceded by two semicolons is not saved as a part of the expansion (i.e., it will not appear on the listing even under .LALL). A comment preceded by only one semicolon, however, will be preserved and appear in the expansion.

! 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 (set by the .RADIX pseudo-op). 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 conform to the same rules as expressions for the DS (Define Space) pseudo-op. That is, a valid expression that evaluates to an absolute (non-relocatable) constant is required.

EXAMPLE:

```
PRINTE    MACRO     MSG,N
           .PRINTX  * 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:

```
    .PRINTX   * SYM1 + SYM2 = (SYM1 + SYM2)
```

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

```
    .PRINTX   * SYM1 + SYM2 = 300 *
```

4.3 CONDITIONAL ASSEMBLY FACILITY

Conditional pseudo-ops allow users to design blocks of code which test for specific conditions then proceed accordingly.

All conditionals follow the format:

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

Each IFxxxx must have a matching ENDIF to terminate the conditional. Each COND must have a matching ENDC to terminate the conditional. Otherwise, an 'Unterminated conditional' message is generated at the end of each pass. An ENDIF without a matching IF or an ENDC without a matching COND causes a C error.

The assembler evaluates the conditional statement to TRUE (which equals FFFFH, or -1, or any non-zero value), or to FALSE (which equals 0000H). The code in the conditional block is assembled if the evaluation matches the condition defined in the conditional statement. If the evaluation does not match, the assembler either ignores the conditional block completely or, if the conditional block contains the optional ELSE statement, assembles only the ELSE portion.

Conditionals may be nested up to 255 levels. Any argument to a conditional must be known on pass 1 to avoid V errors and incorrect evaluation. For IF/IFT/COND and IFF/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.

Each conditional block may include the optional ELSE pseudo-op, which allows alternate code to be generated when the opposite condition exists. Only one ELSE is permitted for a given IFxxxx/COND. 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 C error.

Conditional Pseudo-ops

```
    IF <exp>
    IFT <exp>
 *  COND <exp>
```

If <exp> evaluates to not-0, the statements within the conditional block are assembled.

```
IFE <exp>
IFF <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.

IF2 Pass 2 Conditional

If the assembler is in pass 2, the statements in the conditional block are assembled.

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.

IFNB <arg>

The angle brackets around <arg> are required.

If <arg> is not blank, the statements in the conditional block are assembled. Used for testing for dummy parameters.

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.

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.

ELSE

The ELSE pseudo-op allows you to generate alternate code when the opposite condition exists. May be used with any of the conditional pseudo-ops.

ENDIF
* ENDC

These pseudo-ops terminate conditional blocks. A terminate pseudo-op must be given for every conditional pseudo-op used. ENDIF must be matched with an IFxxxx pseudo-op. ENDC must be matched with the COND pseudo-op.

Contents

CHAPTER 5

RUNNING MACRO-80

When you have completed creating the assembly language source file, you are ready to assemble it. MACRO-80 assembles the source file statements, including expanding macros and repeat pseudo-ops. The result of assembly will be relocatable object code which is ready to link and load with LINK-80. The relocatable object code can be saved in a disk file, which the assembler gives the filename extension .REL. The assembled (REL) file is not an executable file. The file will be executable only after it is processed through LINK-80.

MACRO-80 resides in approximately 19K of memory and has an assembly rate of over 1000 lines per minute. MACRO-80 runs under the CP/M operating system.

MACRO-80 assembles your source file in two passes. During pass 1, MACRO-80 evaluates the program statements, calculates how much code it will generate, builds a symbol table where all symbols are assigned values, and expands macro call statements. During pass 2, MACRO-80 fills in the symbol and expression values from the symbol table, again expands macro call statements, and emits the relocatable code. MACRO-80 checks the values of symbols, expressions, and macros during both passes. If a value during pass 2 is different from the value during pass 1, MACRO-80 returns a phase error code.

Before MACRO-80 can be run, the diskette which contains MACRO-80 must be inserted in the appropriate disk drive. The diskette on which you created the source file must also be in a disk drive.

5.1 INVOKING MACRO-80

To invoke MACRO-80, enter:

```
M80
```

The program file M80.COM will be loaded. MACRO-80 will display an asterisk (*) to indicate that the assembler is ready to accept a command line.

5.2 MACRO-80 COMMAND LINE

The command line for MACRO-80 consists of four fields, labeled:

```
Object,List=Source/Switch
```

The command line may be entered on its own line, or it may be entered at the same time as the M80 command. (If M80 and the command line are entered on one line, MACRO-80 will not return the asterisk prompt.) Entering the command line on its own line allows single drive configurations to use MACRO-80. In addition, by entering M80 and the command line separately, you are able to perform another assembly without reinvoking MACRO-80. When assembly is finished, MACRO-80 will return the asterisk (*) prompt and wait for another command line. To exit MACRO-80 when you have entered M80 and the command line separately, type <CTRL-C>.

If you are performing only one assembly, entering the command line on the same line as M80 is convenient; it requires less typing and allows the assembly operation to be part of a SUBMIT command. When you enter M80 and the command line together, MACRO-80 exits automatically to the operating system.

NOTE

If you enter M80 and the command line separately, you must enter the command line in upper case only. If you do not, MACRO-80 will return a ?Command Error message. If you enter M80 and the command line on one line, the entries may be in either upper or lower case (or mixed) because CP/M converts all entries to upper case before passing the entries.

Source (=filename)

To assemble your source program, you must enter at least an equal sign (=) and the source filename.

The =filename indicates which source file you want to assemble. If the source file disk is not in the currently logged drive, you must include the drive designation as part of the filename. If the source filename is entered without an extension, MACRO-80 assumes that the extension is .MAC. If the extension is not .MAC, you must include the extension as part of the filename. For other possibilities for drive/device designations and filename extensions, see the Additional Command Line Entries section, below.)

The Source entry is the only entry required besides M80.

The simplest command is:

```
M80 =Source
```

This command directs MACRO-80 to assemble the source file and save the result in a relocatable object file (called a REL file) with the same name as the source file. If the source file is NEIL.MAC, the command line:

```
M80 =NEIL
```

generates an assembled file named NEIL.REL.

An additional option is to enter only a comma (,) to the left of the equal sign. When MACRO-80 sees a comma as the first entry after the M80 entry, it suppresses all output files (Object and List). The command line

```
M80 ,=NEIL
```

causes MACRO-80 to assemble the file NEIL.MAC, but no output files are created. Programmers use this command line to check syntax in the source program before saving the assembled program. Because no files are generated, the assembly is completed faster and errors are known sooner.

Object (filename)

An Object entry is always optional. However, certain circumstances will compel you to make some entry for the Object.

The Object file saves the assembled program in a disk file. LINK-80 uses the Object file to create an executable program. If both Object and List entries are omitted from a command line (as in =Source), MACRO-80 will generate an Object file with the same filename as the Source, but with the default extension .REL.

If you want your Object file to have a name different from the source file, you must enter a filename in the Object field. MACRO-80 will still append the filename extension .REL, unless you also enter an extension.

Also, if you want both a List file and a REL file generated, you must enter a filename for the Object, even if you want the REL file named after the source file. If you enter a filename for the List but omit the Object, no REL file will be generated. Programmers do use this feature for checking the program for errors before final assembly. The program listing aids debugging.

The name for the Object file may be the same as the source filename or any other legal filename you choose. Since it is practical to have all files which relate to a program carry some mutual indication of their relationship, most often you will want to give your object file the same name as your source file.

List (,filename)

A List entry is always optional. The comma is required in front of all List entries. If you want a List file, enter a ,filename for the List. (There is an alternative to this rule. See the Switches section below for discussion of the /L switch.)

MACRO-80 appends the default extension .PRN to the List file unless you specify a different extension in the List entry.

The command line:

```
M80 ,NEIL=NEIL
```

assembles the file NEIL.MAC (source file) and creates the List file NEIL.PRN. An Object (REL) file is not created.

The name may be the same as the source filename or any other legal filename you choose. Since it is practical to have all files which relate to a program carry some mutual indication of their relationship, most often you will want to give your listing file the same name as your source file.

Avoid entering only a comma for the List after entering a filename for the Object. For example:

```
M80 NEIL,=NEIL
```

MACRO-80 will probably ignore the comma and assemble the source file into a REL file. It is possible that MACRO-80 might return a COMMAND ERROR message.

If you enter only a comma for the List and nothing for the Object, MACRO-80 will assemble the source file, but will generate no output files. This command

```
M80 ,=Source
```

allows you to check the source program for syntax errors before saving the assembled program in a disk file. While MACRO-80 always checks for errors, this command form provides much faster assembly because the output files do not have to be created.

At the end of assembly, MACRO-80 will print the message:

```
[xx][No] Fatal errors [,xx warnings]
```

This message reports the number of fatal errors and warning errors encountered in the program. The message is listed at the end of every assembly on the terminal screen and in the listing file. When the message appears, the assembler has finished. When the message No Fatal Errors appears, the assembly is complete and successful.

Switches (/Switch)

You can command MACRO-80 to perform some additional functions besides assembling and creating object and listing files. These additional commands are given to MACRO-80 as entries at the end of the command line. A Switch entry directs MACRO-80 to "switch on" some additional or alternate function; hence, these entries are called switches. Switches are letters preceded by slash marks (/). Any number of switches may be entered, but each switch must be preceded by a slash. For example:

```
M80 ,=NEIL/L/R
```

The available switches for MACRO-80 are:

Switch	Action
/O	Octal listing. MACRO-80 generates List file addresses in octal radix.
/H	Hexadecimal listing. MACRO-80 generates List file addresses in hexadecimal. This is the default.

/R	Force generation of an Object file with the same name as the source file. May be used instead of giving a filename in the Object field of the command line.
	
	This switch is convenient when you want a REL file but forgot to enter a filename in the Object field and entered a comma and filename or a comma only in the List field. (Remember: if no filenames or comma is entered before the equal sign, a REL file is generated.) Thus, if you enter
	
	`M80 ,NEIL=NEIL`
	`or M80 ,=NEIL`
	
	then decide, before pressing <ENTER>, that you want a REL file, simply add /R. The command line would then be:
	
	`M80 ,NEIL=NEIL/R`
	`or M80 ,=NEIL/R`

/L Force generation of a listing file with the same name as the source file. May be used instead of giving a filename in the List field of the command line.

This switch is convenient when you want a List file but forgot to enter a filename in the List field. If you enter the command line:

```
    M80 =NEIL
 or M80 ,=NEIL
 or M80 NEIL=NEIL
```

then decide, before pressing <ENTER>, that you do want a List file, simply add /L. The command would then be:

```
    M80 =NEIL/L
 or M80 ,=NEIL/L
 or M80 NEIL=NEIL/L
```

/C Causes MACRO-80 to generate a special List file (with the same name as the Source file) for use with CREF-80 Cross Reference Facility. If you want to use CREF-80, you must assemble your file with this switch set. See Chapter 8, CREF-80 Cross Reference Facility, for further details.

/Z Directs MACRO-80 to assemble Z80 opcodes. If your source file contains Z80 opcodes and if you do not include the .Z80 pseudo-op in your source file, then you must use the /Z switch at assembly time so that MACRO-80 will assemble the Z80 opcodes.

/I Directs MACRO-80 to assemble 8080 opcodes. If your source file contains 8080 opcodes and if you do not include the .8080 pseudo-op in your source file, then you must use the /I switch at assembly time so that MACRO-80 will assemble the 8080 opcodes. (Default)

/P Each /P allocates an extra 256 bytes of stack space for use during assembly. Use /P if stack overflow errors occur during assembly. Otherwise, /P is not needed.

/M The /M switch initializes Block data areas. If you want the area that is defined by the DS (Define Space) pseudo-op initialized to zeros, then you should use the /M switch in the command line. Otherwise, the space is not guaranteed to contain zeros. That is, DS does not automatically initialize the space to zeros, in which case you may not know what is stored in the DS space or how the program will be affected.

/X The /X switch sets the default and current setting to suppress the listing of false conditionals. Absence of /X in the command line sets the default and current setting to list conditional blocks which evaluate false. /X is often used in conjunction with the conditional listing pseudo-op .TFCOND. Refer to the Listing Pseudo-ops section in Chapter 4 for details.

Additional Command Line Entries

Each command line field supports two additional types of entries--filename extensions and device designations. These two types of entries are actually part of a "file specification." A file specification includes the device where a file is located, the name of the file, and the filename extension.

Usually, filename extensions and device designations are handled by defaults--the MACRO-80 program "inserts" these entries if their positions are left blank in a command line. The default assignments in no way prevent you from entering either filename extensions or device designations, including entries that match the default entries. The programmer may enter or omit these additional entries in any combination.

The format for a file specification under MACRO-80 is:

```
dev:filename.ext
```

where: dev: is a 1-3 letter device designation followed by a (required) colon.

filename is a 1-8 letter filename.

.ext is a 1-3 character filename extension preceded by a (required) period.

Filename Extensions (.ext)

To distinguish between Source file, Object file, and List file, MACRO-80 appends an extension to each filename. Filename extensions are three-letter mnemonics appended to the filename with a period (.) between the filename and the extension. The extension which MACRO-80 appends reflects the type of file. Since the extensions are supplied by MACRO-80, they are called default extensions. The default extensions which MACRO-80 supplies are:

.REL	Relocatable object file
.PRN	Listing file
.COM	Absolute (executable object) file

Also, MACRO-80 assumes that, if no filename extension is entered, a source file carries the filename extension .MAC.

You may supply your own extensions, if you find this necessary or desirable. The disadvantage is that whenever you call the file, you must always remember to include your extension. Also, you must remember what type of file it is--relocatable, source, absolute, etc. The advantage of allowing MACRO-80 to assign default extensions is that you always have a mnemonic indication of the type of file, and you can call the filename without appending the extension, in most cases.

Device Designations (dev:)

Each of the fields in a command line (except Invocation) also may include a device designation.

When a device designation is specified in the Source field, the designation tells MACRO-80 where to find the source file. When a device designation is specified in the Object or List fields, the designation tells MACRO-80 where to output the object or list file. If the device designation is omitted from any of these fields, MACRO-80 assumes (defaults to) the currently logged drive. Thus, any time the device designation is the currently logged drive or device, the device designation need not be specified.

It is important to include device designations if several devices or drives will be used during an assembly. For example, if your ALDS diskette is in drive A and your program diskette is in drive B, and you want your REL file output to drive B, you need to give the command line:

```
M80 =B:NEIL
```

When the REL file is output, the currently logged drive is drive B. (However, when MACRO-80 is finished, drive A will be the currently logged drive again.) In contrast, if you saved your source program on the MACRO-80 diskette in drive A and want the REL file output to a diskette in drive B, then you need to enter the command line:

```
M80 B:=A:NEIL
```

As a rule of thumb, if you are not sure if you need to include the device designation (especially the drive designation), enter a designation; it is the one sure way to get the right files in the right places.

The available device designations for MACRO-80 are:

A:, B:, C:,...	Disk drives
LST:	Line Printer
TTY:	Terminal Screen or Keyboard
HSR:	High Speed Reader

Device Designations as Filenames

As an option, you may enter a device designation only in the command line fields in place of a filename. The use of this option gives various results depending on which device is specified and in which field the device is specified. For example:

```
M80 ,TTY:=TTY:
```

allows you to assemble a line immediately on input to check for syntax or other errors. A modification of this command (that is, M80 ,LST:=TTY:), provides the same result but printed on a line printer instead of the terminal screen.

If you use either of these commands (,TTY:=TTY: or ,LST:=TTY:), your first entry should be an END statement. You need to put the assembler into pass 2 before it will emit the code. If you simply start entering statement lines without first entering END, you will receive no response until an END statement is entered. Then you will have to reenter all your statements before you see any code generated.

The following table illustrates the results of the various choices. The table is meant to indicate the possibilities rather than provide an exhaustive list of the combinations.

dev:	Object	,List	=Source
A:, B:, C:, D:	write file to drive specified	write file to drive specified	N/A (a filename must be specified)
HSR:	N/A (input only)	N/A (input only)	reads source program from high-speed reader
LST:	N/A (unreadable file format)	writes listing to line printer	N/A (output only)
TTY:	N/A (unreadable file format)	"writes" listing to screen	"reads" source program from keyboard

Figure 5.1: Effects of Device Designations without Filenames

5.3 MACRO-80 LISTING FILE FORMATS

A listing of a MACRO-80 file displays the two parts of the file in two different formats. One format displays the file lines. The second format displays symbol table listings.

File Format

Each page of a MACRO-80 listing prints header data in the first two lines. If no header data were commanded in the source file (neither the TITLE nor SUBTTL pseudo-op was given), those portions of the header lines are left blank.

The format is:

```
[TITLE text]      M80 z.zz        PAGE x
[SUBTTL text]
```

where: TITLE text is the text supplied with the .TITLE pseudo-op, if .TITLE was included in the source file. If no .TITLE pseudo-op was given in the source file, this space is left blank.

z.zz is the version number of your MACRO-80 program.

x is the page number, which is shown and incremented only when a .PAGE pseudo-op is encountered in the source file, or whenever the current page size has been filled.

SUBTTL text is the text supplied with the .SUBTTL pseudo-op, if .SUBTTL was included in the source file. If no .SUBTTL was given in the source file, this space is left blank.

A blank line follows the header data. The text of the listing file begins on the next line.

The format of a listing line is:

```
[error] ####m xx xxxxm[w]     text
```

where: error represents a one-letter error code. An error code is printed only if the line contains an error. Otherwise, the space is left blank.

represents the location counter. The number is a 4-digit hexadecimal number or a 6-digit octal number. The radix of the location counter number is determined by the use of the /O or /H switch in the MACRO-80 command line Switch field. If no radix switch was given, the default radix is hexadecimal (4-digit).

m represents the PC mode indicator character. The possible symbols are:

'	Code Relative
"	Data Relative
!	COMMON Relative
<space>	Absolute
*	External

xx and xxxx represent the assembled code. xx represents a one-byte value. One-byte values are always followed immediately by a space. xxxx represents a two-byte value, with the high-order byte printed first (this is the opposite of the order in which they are stored). Two-byte values are followed by one of the mode indicators discussed above (indicated by the second m).

[w] represents a line in the MACRO-80 file that came from another file through an INCLUDE pseudo-op; or a line that is part of an expansion (MACRO, REPT, IRP, IRPC). For lines from an INCLUDE statement, a C is printed following the assembled code; for lines in an expansion, a plus sign (+) is printed following the assembled code. Otherwise, this space is blank.

text represents the rest of the line, including labels, operations, arguments, and comments.

Symbol Table Format

The symbol table listing page follows the same header data format as the file line pages. However, instead of a page number, the symbol table page shows PAGE S.

Then, in a symbol table listing, all macro names in a program are listed alphabetically. Next, all symbols are listed, also alphabetically. A tab follows each symbol, then the value of the symbol is printed. Each symbol value is followed by one of the following characters:

I	PUBLIC symbol
U	Undefined symbol
C	COMMON block name. The value shown for the COMMON block name is its length in bytes in hexadecimal or octal radix.
*	External symbol
<space>	Absolute value

' Program relative value

" Data relative value

! COMMON relative value

5.4 ERROR CODES AND MESSAGES

Errors encountered during assembly cause MACRO-80 to return either an error code or an error message. Error codes are one-character flags printed in column one of the listing file. If a listing file is not being printed on the terminal screen, the lines containing errors will nevertheless be printed on the terminal screen. Error messages are printed at the end of the listing file, or, if the listing file is not being displayed on the terminal screen, any error messages will be displayed at the end of the error code lines.

ERROR CODE	MEANING
A	Argument error. The argument to a pseudo-op is not in correct format or is out of range.
C	Conditional nesting error. ELSE without IF, ENDIF without IF, two ELSEs for one IF, ENDC without COND.
D	Double defined symbol. Reference to a symbol which has more than one definition.
E	External error. Use of an External is illegal in the flagged context. For example, FOO SET NAME or LXI B,2-NAME.
M	Multiply defined symbol. The definition is for a symbol that already has a definition.
N	Number error. An error in a number, usually a bad digit. For example, 8Q.

O Bad opcode or objectionable syntax.
ENDM, LOCAL outside a block; SET, EQU, or MACRO without a name; bad syntax in an opcode; or bad syntax in an expression (for example, mismatched parentheses, quotes, consecutive operators).

P Phase error.
The value of a label or EQU name is different during pass 2 from its value during pass 1.

Q Questionable.
Usually, a line is not terminated properly. For example, MOV AX,BX,. This is a warning error.

R Relocation.
Illegal use of relocation in an expression, such as abs-rel. Data, code, and COMMON areas are relocatable.

U Undefined symbol.
A symbol referenced in an expression is not defined. For some pseudo-ops, a V error is printed for pass 1 then a U error for pass 2. Compare with V error code definition below.

V Value error.
On pass 1 a pseudo-op which must have its value known on pass 1 (for example, .RADIX, .PAGE, DS, IF, IFE) has a value which is undefined. If the symbol is defined later in the program, a U error will not appear on the pass 2 listing.

ERROR MESSAGES

%No END statement

No END statement: either it is missing or it is not parsed because it is in a false conditional, unterminated IRP/IRPC/REPT block, or terminated macro.

Unterminated conditional

At least one conditional is unterminated at the end of the file.

Unterminated REPT/IRP/IRPC/MACRO

At least one block is unterminated.

Symbol table full

As MACRO-80 was building the symbol table, the memory available was exhausted. The most usual cause is a large number of macro blocks which also contain statements for many of the statement lines. Macro blocks are stored in the symbol table verbatim, including the comments appended to the lines inside the macro block. You should check all macro blocks in the source program. To exclude comments inside macro blocks from the symbol table, precede these comments by double semicolons (;;). This method should free enough space to assemble your program.

[xx][No] Fatal errors [,xx warnings]

The number of fatal errors and warning errors encountered in the program. The message is listed at the end of every assembly on the terminal screen and in the listing file. When the message appears, the assembler has finished. When the message No Fatal Errors appears, the assembly is complete and successful.

Contents

CHAPTER 6

LINK-80 LINKING LOADER

The .REL files which MACRO-80 creates are not executable. To make a REL file executable, you need to load and link the REL file with the LINK-80 linking loader. The result is an executable object file.

Loading means physically placing the file in memory and assigning absolute addresses to the code and data in place of the relative addresses assigned by the assembler. This is one of the required steps for converting a relocatable (REL) file into an executable (COM) file.

Linking means that each loaded file (or module) that directs program flow outside itself (by a CALL, an EXTERNAL symbol, or an Include) will be "linked" to the module that contains the corresponding code.

LINK-80 can also save the assembled-and-linked program as an executable object program on disk in a file with the extension .COM. Consequently, any time you wish to run your program, you need only insert the disk which contains your COM file into an appropriate disk drive and "call" your program -- a simple process of typing in the filename you used to save the program, followed by a carriage return.

6.1 INVOKING LINK-80

To invoke LINK-80, enter:

```
L80
```

The program file L80.COM will be loaded. LINK-80 will display an asterisk (*) to indicate that the linking loader is ready to accept a command. The REL file(s) you want link-loaded must be available in a disk drive. If you have only one drive, you will need to swap diskettes in the drive at each step of the link-loading process.

6.2 LINK-80 COMMANDS

LINK-80 commands are filenames and switches.

You can enter your commands to LINK-80 one at a time; or, you can enter all of your commands (including L80) on one line.

A command line has a flexible format, allowing you a number of options for loading and linking files and for performing other operations. The basic rule for LINK-80 commands is that files are loaded in the order they are named, beginning at the (default) address 103H under CP/M. Even though the files will be loaded in the order entered, you do not have to enter the files in the order of execution. LINK-80 places a jump instruction at address 100H-102H which jumps to the start address of the first instruction to be executed, regardless of its location in memory.

LINK-80 can perform about eleven different tasks. Even though you could use them all, you will rarely use more than three or four at a time.

When you enter a command to LINK-80, LINK-80 returns an asterisk (*) prompt that tells you to enter another command. For example:

```
A>L80<RETURN>
*/switch<RETURN>
*filename<RETURN>
*/switch<RETURN>
*filename/switch<RETURN>
*/E<RETURN>      (to exit LINK-80)
```

Note that all of the above lines may be entered as one line. For example:

```
L80 /switch,filename/switch,filename/switch/E<RETURN>
```

This shows further the flexibility of the LINK-80 command line.

Although entering each command on a separate line is slow and tedious, the advantage is, especially if you are new to a linking loader, that you know at all times what function LINK-80 is performing.

6.2.1 Filenames

Files processed by LINK-80 are REL files. A filename commands LINK-80 to load the named file (also called a module). If any file has been loaded already, a filename also commands LINK-80 to link the loaded files as required.

Normally each linking session requires at least two filenames. One filename directs LINK-80 which REL file to load and link; the other commands LINK-80 to save the executable code in a file with the specified name.

If you enter only one filename during the link session, either the COM file will not be saved (in which case you may have wasted your time), or LINK-80 will return the error message

```
?NOTHING LOADED
```

Note, however, that if you enter only one filename followed by the /G switch, the COM file will not be saved, but the program will execute as soon as LINK-80 is finished loading and linking. (Refer to the description of the switches in the next section.)

You may enter as many filenames as will fit on one line. The files named may be REL files in different languages (BASIC, COBOL, FORTRAN, or assembly) or runtime library REL files for any of the high-level programming languages. (For exact procedures for high-level language REL files, see the product manual included with the high-level language compiler.)

When LINK-80 is finished, the results are saved in the file named by the programmer in the command line (the filename followed by a /N -- see below, Section 6.2.2, Switches). LINK-80 gives this filename the extension .COM.

A filename command in LINK-80 actually means a file specification. A file specification includes a device designation, a filename, and a filename extension. The format of a file specification is:

```
dev:filename.ext
```

LINK-80 defaults the dev: to the default or currently logged disk drive. LINK-80 defaults the input filename extension to .REL and the output filename extension to .COM. You can alter the device designation to any applicable output device supported by MACRO-80 and/or the filename extension to any three characters by specifying a device or a filename extension when you enter a filename command.

6.2.2 Switches

Switches command LINK-80 to perform functions besides loading and linking. Switches are letters preceded by slash marks (/). You can place as many switches as you need in a single command line, but each switch letter must be preceded by a slash mark (/). For example, if you want to link and load a program named NEIL, save an image of it on diskette, then execute the program, you need two filenames and two switches, so you would enter the commands:

```
NEIL,NEIL/N/G<RETURN>
```

LINK-80 saves a memory image on diskette (the /N switch), then runs the NEIL program (the /G switch).

Some switches can be entered by themselves (/E, /G, /R, /P, /D, /U, /M, /O, /H). Some switches must be appended to the filename they affect (/N, /S). Some switches work only if other switches are also entered during the LINK-80 session (/X, /Y). Some switches must precede any filenames you want affected (/P, /D). Some switches command actions that are deferred until the end of the LINK-80 session (/N, /X, /Y). Some switches command actions that take place when entered (/S, /R -- a filename entered without a switch appended acts this way, too). These "rules of behavior" should be kept in mind when entering LINK-80 commands. See the descriptions for each switch for full details of its action.

The chart below summarizes the switches by function. Full descriptions of the switches by function follow the chart.

BE CAREFUL: Do not confuse the LINK-80 switches with the MACRO-80 switches.

FUNCTION	SWITCH	ACTION
Execute	/G	Execute .COM file then exit to operating system.
	/G:Name	Set .COM file start address equal to value of Name, execute .COM file, then exit to operating system.
Exit	/E	Exit to operating system.
	/E:Name	Set .COM file start address equal to value of Name, then exit to operating system.
Save	/N	Save all previously loaded programs and subroutines using filename immediately preceding /N.
	/N:P	Alternate form of /N; save only program area.
Address Setting	/P	Set start address for programs and data. If used with /D, /P sets only the program start.
	/D	Set start address for data area only.
	/R	Reset LINK-80.
Library Search	/S	Search the library named immediately preceding /S.
Global Listing	/U	List undefined globals.
	/M	List complete global reference map.
Radix Setting	/O	Octal radix.
	/H	Hexadecimal radix (default).
Special Code	/X	Save "COM" file in Intel ASCII Hex format. Requires /N switch. Gives "COM" file the extension .HEX.
	/Y	Creates a special file for use with SID/ZSID debugger. Requires /N and /E switches. Gives special file the extension .SYM.

Figure 6.1: Table of LINK-80 Switches

At least two switches will probably be used in every linking session. These switches belong to the first three functions -- Execute, Exit, and Save.

EXECUTE

Switch Action

/G The /G switch causes LINK-80 to load the filename(s) entered in the command line, to link the program(s) together, then to execute the link-loaded program. After the program run, your computer returns to operating system command level. For example,

```
L80 NEIL,NEIL/N/G
```

links NEIL.REL, saves the result in a disk file named NEIL.COM, then exits to the operating system.

Execution takes place as soon as the command line has been interpreted. Just before execution begins, LINK-80 prints three numbers and a BEGIN EXECUTION message. These three numbers can be very useful to you in developing future assembly language programs. The first number is the start address of the program. The second number is the address of the next available byte; that is, the end address plus one byte. The third number is the number of 256-byte pages taken up by the program (the difference between the start address and the end address converted to 256-byte pages).

If you do not want to save the .COM file, use the /G switch and enter only one filename on the command line. For example:

```
L80 NEIL/G
```

But Remember: No COM file is created (since you did not include /N). To run the program again, you will have to run LINK-80 again.

/G:<name> The /G:<name> switch performs exactly like the plain /G switch but with one additional feature. <name> is a global symbol which was defined previously in one of the modules which is being linked and loaded. When LINK-80 sees <name>, it uses <name> as the start of the program and loads the address of the line with <name> as its LABEL into the jump instruction at 100H-102H.

The value of this switch (and of /E:<name> below) is the ability to tell LINK-80 where to start execution when the assembled modules do not make this clear. Usually this is no problem because you link in a high-level language program (which LINK-80 takes as the main program by default), or you link only assembly language modules and only one has an END <name> statement to signal LINK-80 which assembly language program to execute first. But if two or more assembly language modules contain an END <name> statement, or if none of the assembly language modules contain an END <name> statement, then /G:<name> tells LINK-80 to use this module as the starting point for execution.

Programmers who want to execute an assembly language module before a high-level language program should use a CALL or INCLUDE statement at the beginning of the high-level language program to cause execution of the assembly language module before execution of the high-level language program.

EXIT

Switch	Action
/E	Use /E to link and load a program and perform some other functions on the files (for example, save it on a diskette) when you do not want to run the program at this time. When LINK-80 has finished the tasks, it will exit to the operating system. (The /G switch is the only other switch which exits LINK-80.) When linking is finished, LINK-80 outputs three numbers: start address, next available byte, number of 256-byte pages.
/E:<name>	The /E:<name> switch performs exactly like the plain /E switch but with one additional feature. <name> is a global symbol which was defined previously in one of the modules which is being linked and loaded. When LINK-80 sees <name>, it uses <name> as the start of the program and loads the address of the line with <name> as the LABEL into the jump instruction at 100H-102H. The value of this switch (and of /G:<name> above) is the ability to tell LINK-80 where to start execution when the assembled modules do not make this clear. Usually this is no problem because you link in a high-level language program (which LINK-80 takes as the main program by default), or you link only assembly language modules and only one has an END <name> statement to signal LINK-80 which assembly language program to execute first. But if two or more assembly language modules contain an END <name> statement, or if none of the assembly language modules contain an END <name> statement, then /E:<name> tells LINK-80 to use this module as the starting point for execution. Programmers who want to execute an assembly language module before a high-level language program should use a CALL or INCLUDE statement at the beginning of the high-level language program to cause this order of execution.

SAVE

Switch Action

/N The /N switch causes the assembled-linked program to be saved in a disk file. It is important that a filename always be specified for the /N switch. If you do not specify an extension, the default extension for the saved file is .COM. The COM filename will be the name the programmer appends the /N switch to. The /N switch must immediately follow the filename under which you wish to save the results of the link-load session.

The /N switch does not take effect unless a /E or /G switch follows it.

The most common error programmers make with the /N switch is to forget that they must specify at least two filenames; one as the file to be linked and another one as the name for the file to be saved. Therefore, at a minimum the command line should include:

```
L80 NEIL,NEIL/N/G
```

The first filename NEIL is the file to be loaded and linked; the second filename NEIL is the name for the COM file that will save the result of the link-loading session.

It is, of course, possible to specify filenames in any order. For example:

```
L80 NEIL/N,ASMSUB1,ASMSUB2,BASPROG/G
```

Here LINK-80 will load and link the files BASPROG, ASMSUB1, and ASMSUB2; then save the result in the file named NEIL.

From these two examples, it is possible to see that the filename followed by the /N save switch is not loaded; it is only a specification for an output file; you must also always name at least one input file, too.

You will use this switch almost every time you link a REL file because there is no other way to save the result of a link-load session and because not saving the result means you would have to link load again to run your program.

Once saved on disk, you need only type the COM filename at operating system command level to run the program.

/N:P By default, LINK-80 saves both the program and data areas in the COM file. If you wish to save only the program area to make your disk files smaller, use the /N switch in the form /N:P. With this switch set, only the program code will be saved.

Two of these switches (/N plus either a /G or a /E type) are all the switches required for most LINK-80 operations. Some additional functions are available through the use of other switches which allow programmers to manipulate the LINK-80 processes in more detail. The switches which turn on these additional functions are arranged in categories according to type of function. The function of each category is defined by the category name.

ADDRESS SETTING

Switch Action

/P The /P switch is used to set both the program and data origin. If you do not enter the /P switch, LINK-80 performs this task automatically, using a default address for both program and data. (103H for CP/M)

The format of the /P switch is:

/P:<address>,

The address value must be expressed in the current radix. The default radix is hexadecimal.

The /P switch is designed to allow you to place program (or code) segments at addresses other than the default. The default value for the /P switch is 103H.

REMEMBER: The /P switch takes effect as soon as it is seen, but it does not affect files already loaded. So be sure to place the /P switch before any files you want to load starting at the specified address. The /P switch and /D switch, when used, must be separated from the REL filename by a comma. For example,

L80 /P:103,NEIL,NEIL/N/E

The /P switch affects primarily the CSEG code in your assembly language program. If /P is given but not /D, both data and program (CSEG and DSEG) areas will be loaded starting at the /P:<address>. DSEG (and any COMMON areas) will be loaded first. If both /P and /D switches are given, /P sets the start of the CSEG area only. Normally, unless your programs are all CSEG, you will use /P and /D together.

Note especially that ASEG areas are not affected by the /P switch. So be careful to set the /P address outside any ASEG areas unless you want the program or data areas to write over the ASEG areas.

You may enter more than one /P switch during a single link session to place different program (code) segments at addresses which are not end to end. LINK-80 will automatically place one program segment (CSEG) after the next. You can cause space to be left between modules. However, some

restrictions one the placement of modules apply:

1. Be sure that program areas do not overlay one another. LINK-80 returns a warning error message if they do.

2. Be sure that the program areas are not split by data or COMMON areas; that is, a CSEG at 200H, a DSEG at 300H, and another CSEG at 400H is illegal. LINK-80 returns a fatal error in this case.

When the loading session is all done, LINK-80 wants to see a segment of memory loaded with data and COMMON and another segment loaded with program code. The code segments may have gaps between the modules as long as a data segment is not loaded between the start of the first code segment module and the end of the last code segment module, and vice versa. So, placing DSEG modules at 103H-115H, 150H-165H, 170H-175H, and CSEG modules at 200H-250H, 300H-350H, 400H-450H is acceptable. LINK and 80 will show Data between 103H and 175H and Program between 200H and 450H.

Note that any gaps you leave may contain data or program code from a previous program. LINK-80 does not initialize gaps to zero or null. This could cause unpredictable results.

/D The /D switch sets the origin for DSEG and COMMON areas. If you do not enter the /D switch, LINK-80 performs this task automatically, using a default address for both data and program. (103H for CP/M)

The format for the /D switch is:

```
/D:<address>,
```

The address for the /D switch must be in the current radix. The default radix is hexadecimal.

The /D switch is designed to allow you to place data and COMMON segments at addresses other than the default. The default value for the /D switch is 103H. The /D switch must be separated from the REL filenames by a comma. For example,

```
L80 /D:103,NEIL,NEIL/N/E
```

When the /P switch is used with the /D switch, data and common areas load starting at the address given with the /D switch. (The program will be

loaded beginning at the program origin given with the /P switch.) This is the only occasion when the address given in /P: is the start address for the actual program code.

REMEMBER: The /D switch takes effect as soon as LINK-80 "sees" the switch, so the /D switch has no effect on programs or data already loaded. Therefore, it is important to place the /D switch (as well as the /P switch) before the files you want to load starting at the address specified.

You may enter more than one /D switch during a single link session to place different program (code) segments at addresses which are not end to end. LINK-80 will automatically place one data segment (DSEG) after the next. You can cause space to be left between modules. However, some restrictions on the placement of modules apply:

1. Be sure that data areas do not overlay one another. LINK-80 returns a warning error message if they do.

2. Be sure that the data areas are not split by program areas; that is, a DSEG at 200H, a CSEG at 300H, and another DSEG at 400H is illegal. LINK-80 returns a fatal error in this case.

When the loading session is all done, LINK-80 wants to see a segment of memory loaded with data and COMMON and another segment loaded with program code. The data segments may have gaps between the modules as long as a program segment is not loaded between the start of the first data segment module and the end of the last data segment module, and vice versa. So, placing DSEG modules at 103H-115H, 150H-165H, 170H-175H, and CSEG modules at 200H-250H, 300H-350H, 400H-450H is acceptable. LINK and 80 will show Data between 103H and 175H and Program between 200H and 450H.

Note that any gaps you leave may contain data or program code from a previous program. LINK-80 does not initialize gaps to zero or null. This could cause unpredictable results.

ADDITIONAL NOTE FOR /P AND /D SWITCHES

If your program is too large for the loader, you will sometimes be able to load it anyway if you use /D and /P together. This way you will be able to load programs and data of a larger combined total. While LINK-80 is loading and linking, it builds a table consisting of five bytes for each program relative reference. By setting both /D and /P, you eliminate the need for LINK-80 to build this table, thus giving you some extra memory to work with.

To set the two switches, look to the end of the List file. Take the address you decided for the /D switch (where you want the DSEG to start loading), add the number for the total of data, add that number to 103H, add another 100H+1, and the result should be the /P: address for the start of the program area. The /D switch should be set at 103H or higher (D:103).

/R The /R switch "resets" LINK-80 to its initialized condition. LINK-80 scans the command line before it begins the functions commanded. As soon as LINK-80 sees the /R switch, all files loaded are ignored, LINK-80 resets itself, and the asterisk (*) prompt is returned showing that LINK-80 is running and waiting for you to enter a command line.

LIBRARY SEARCH

Switch	Action
/S	The /S switch causes LINK-80 to search the file named immediately prior to the switch for routines, subroutines, definitions for globals, and so on. In a command line, the filename with the /S switch appended must be separated from the rest of the command line by commas. For example:

```
L80 NEIL/N,MYLIB/S,NEIL/G
```

The /S switch is used to search library files only, including a library you constructed, using the LIB-80 Library Manager (see Chapter 8).

GLOBAL LISTING

Switch Action

/U The /U switch tells LINK-80 to list all undefined globals. The /U works only in command lines that do not include either a /G or a /E switch. Note that if your program contains any undefined globals, LINK-80 lists them automatically, unless the command line also contains a /S (library search) switch. In these cases, enter only the /U switch, and the list of undefined globals will be listed. Use CTRL-S to suspend the listing if you want to study a portion of the list that would scroll off the screen. Use CTRL-Q to restart the listing.

The various runtime libraries provide definitions for the globals you need to run your high-level language programs.

In addition to listing undefined globals, the /U switch directs LINK-80 to list the origin, end, and size of the program and data areas. These areas are listed as one lump area unless both the /P and /D switches are set. If both /P and /D are set, the start, end, and size of both areas are listed separately.

/M The /M switch directs LINK-80 to list all globals, both defined and undefined, on the screen. The listing cannot be sent to a printer. In the listing, defined globals are followed by their values, and undefined globals are followed by an asterisk (*).

In addition to listing all globals, the /M switch directs LINK-80 to list the origin, end, and size of the program and data areas. These areas are listed as one lump area unless both the /P and /D switches are set. If both /P and /D are set, the start, end, and size of both areas are listed separately.

RADIX SETTING

Switch	Action
/O	The /O switch sets the current radix to Octal. If you have a reason to use octal values in your program, give the /O switch in the command line. If you can think of no reason to switch to octal radix, then there is no reason to use this switch.
/H	The /H switch resets the current radix to Hexadecimal. Hexadecimal is the default radix. You do not need to give this switch in the command line unless you previously gave the /O switch and now want to return to hexadecimal.

SPECIAL CODE

Switch Action

/X The /X switch saves the "COM" file in Intel ASCII HEX format. The /X switch requires the /N switch appended to the same filename as the /X. For example:

```
L80 NEIL,NEIL/X/N/E
```

The file that is saved with the /X switch set is given the filename extension .HEX.

The primary use of the /X switch is to prepare programs to be burned into PROMs. The hex format was originally developed to facilitate the movement of programs from one machine to another. The hex format provides more code checking than object code does. Also, a HEX file can be edited with some sophisticated line editors.

/Y The /Y switch saves a file in a special format for use with Digital Research's Symbolic Debuggers, SID and ZSID. The /Y switch requires the /N and the /E (not /G) switches be given in the command line. For example:

```
L80 NEIL,NEIL/Y/N/E
```

The file that is saved with the /Y switch set is given the filename extension .SYM. A COM file will also be saved. So the sample command line above creates both NEIL.COM and NEIL.SYM.

The SYM file contains the names and addresses of all globals, which allows you to use Digital Research's Symbolic Debuggers SID and ZSID with the SYM file.

6.3 ERROR MESSAGES

Errors encountered during the running of LINK-80 will return messages, most preceded by either the symbol ? or the symbol %. No error codes are returned, so once you understand the meaning of the message, error recognition should be easy.

?No Start Address

The /G switch was issued, but no main program has been loaded.

?Loading Error

The last file given for input was not a properly formatted LINK-80 object file.

?Out of Memory

Not enough memory to load the module.

?Command Error

Unrecognizable LINK-80 command.

?<filename> Not Found

<filename>, as given in the command string, did not exist.

?Start Symbol - <name> - Undefined

The /E:Name or /G:Name switch was given, but the Name specified was not defined.

?Nothing Loaded

A <filename>/S or /E or /G was given, but no object file was loaded. That is, an attempt was made to search a library, to exit LINK-80, or to execute a program, when in fact nothing had been loaded. For example:

```
TEST/N/E
```

Results in "?Nothing Loaded" because TEST/N names TEST.COM, but does not load TEST.REL.

To load a file, enter the filename. To save a file, enter a filename followed by the /N switch and either a /E or a /G switch. For example, any of the following sets of commands should work:

```
L80 NEIL,NEIL/N/E
```

or

```
L80
*NEIL
*NEIL/N/E
```

or

```
L80 NEIL/N,NEIL/E
```

?Can't Save Object File

A disk error occurred when the file was being saved. Usually, this means that the disk is full or that it is write-protected.

%2nd COMMON larger /XXXXXX/

When loading modules which include COMMON blocks, LINK-80 takes the size of the first COMMON block loaded to set the amount of memory needed before program code is loaded. If a subsequent module contains a COMMON block larger than the first one loaded, LINK-80 returns this error message. It means that the first definition of the COMMON block /XXXXXX/ encountered in the modules loaded was not the largest block defined with that name. Reorder module loading sequence or change COMMON block definitions so that all blocks are the same size.

%Mult. Def. Global YYYYYY

You have one global (PUBLIC) symbol name YYYYYY with more than one definition. Usually, two or more of the modules being loaded have declared the same symbol name as PUBLIC.

%Overlaying Program Area ,Start = xxxx
,Public = <symbol name> (xxxx)
,External = <symbol name> (xxxx)

Usually this occurs when either /D or /P is set to an address inside the area taken by LINK-80. You should reset the switch address above 102H. It may also occur if you set addresses for programs loaded after some initial programs were loaded and the addresses were not set high enough. For example, if MYPROG is larger than 147 bytes and you enter the commands:

```
MYPROG,/P:150,SUBR1,FUNNY/N/E
```

you will receive the %Overlaying Program Area error message.

%Overlaying Data Area ,Start = xxxx
,Public = <symbol name> (xxxx)
,External = <symbol name> (xxxx)

The /D and /P switches were set too close together. For example, if /D was given a higher address than /P but not high enough to be beyond the end of the program area, when the program is loaded, the top end will be laid over the data area. Or, if /D is lower than /P, /P was not high enough to prevent the beginning of the program from starting in the area already loaded with data.

?Intersecting Program Area
or
?Intersecting Data Area

The program and data areas intersect and an address or external chain entry is in this intersection. The final value cannot be converted to a current value since it is in the area intersection.

Origin Above Loader Memory, Move Anyway (Y or N)?
or
Origin Below Loader Memory, Move Anyway (Y or N)?

This message will appear only after either the /E or the /G switch command was given to LINK-80. If LINK-80 has not enough memory to load a module but a /E or /G has not been entered, you will receive the ?Out of Memory message.

LINK-80 can load modules only between its first address in memory and the top of available memory. If the program is too large for this space or if you set a /D and/or /P switch too high for the size of your program, LINK-80 runs out of memory and returns the Origin Above Loader Memory message.

If you set a /D and/or /P switch below the first address of LINK-80 (100H for CP/M), LINK-80 returns the Origin Below Loader Memory message. This prevents you from loading your program into memory designated for the operating system.

If a Y<CR> is given, LINK-80 will move the area and continue. If anything else is given, LINK-80 will exit. In either case, if the /N switch was given, the image will already have been saved.

Contents

CHAPTER 7

CREF-80 CROSS REFERENCE FACILITY

A cross reference facility processes a specially assembled listing file to list the locations of all intermodule references and the locations of their definitions. The result is a cross reference listing. This cross reference listing can be used to aid debugging your program.

The CREF-80 Cross Reference Facility allows a programmer to process the cross reference file generated by MACRO-80. This cross reference file contains embedded control characters, set up during MACRO-80 assembly. CREF-80 interprets the control characters and generates a file that lists cross references among variables.

CREF-80 produces a listing, resembling the PRN listing of MACRO-80, with two additional features:

1. Each source statement is numbered with a cross reference number.

2. At the end of the listing, variable names appear in alphabetic order. Each name is followed by the line number where the variable is defined (flagged with #) followed by the numbers of other lines where the variable is referenced.

The CREF listing file replaces the MACRO-80 PRN List file and receives the filename extension .LST instead of .PRN.

7.1 CREATING A CREF LISTING

Creating a CREF listing involves two steps: (1) creating a cross reference file (.CRF), and (2) generating a cross reference listing (.LST). The first step occurs in the MACRO-80 macro assembler; the second in the CREF-80 Cross Reference Facility.

Creating a Cross Reference File

To create a cross reference file, set the /C switch in the MACRO-80 command line. For example:

```
M80 =NEIL/C
```

This command line assembles the file NEIL.MAC, generating the output files NEIL.REL (object file) and NEIL.CRF (cross reference file).

Generating a Cross Reference Listing

The cross reference listing is generated by running the .CRF file through CREF-80.

To invoke the cross reference facility, enter:

```
CREF80
```

CREF-80 will return an asterisk (*) prompt.

To create the cross reference listing file, enter:

```
=filename
```

where filename is the name of your .CRF file. For example:

```
CREF80 =NEIL
```

will generate a .LST file (NEIL.LST) containing the cross reference information.

This .LST file can be printed or sent to the terminal screen using operating system commands. Additionally, CREF-80 supports the same output device designations as MACRO-80. Simply enter the device designation in front of the filename. For example:

```
CREF80 LST:=NEIL
```

sends the .LST listing to the printer only (no disk file is generated).

```
CREF80 TTY:=NEIL
```

sends the .LST listing to the CRT only (no disk file is generated).

You will need to give a drive designation if you want the .LST file saved elsewhere than the currently logged drive (where the .CRF file resides). For example:

```
CREF80 B:=A:NEIL
```

saves NEIL.LST on drive B.

When finished, CREF-80 prompts with an asterisk. You may enter another =filename, or exit from CREF-80 to the operating system.

To exit CREF-80, enter:

```
CTRL-C
```

If you want the .LST file named differently from the default (.CRF filename and extension .LST), enter the name in front of the equal sign. For example:

```
CREF80 NEIL.CRL=NEIL
or CREF80 NEILCREF=NEIL
```

The former command line generates a cross reference list file named NEIL.CRL; the latter generates a file named NEILCREF.LST.

Look at the filename extensions to distinguish a cross reference listing file from the listing file MACRO-80 normally generates. The listing file MACRO-80 normally generates (without the /C switch set in the command line) receives the default filename extension .PRN. The cross reference listing file generated by CREF-80 receives the default filename extension .LST.

7.2 CREF LISTING CONTROL PSEUDO-OPS

You may want the option of generating a cross reference listing for part of a program but not all of it. To control the listing or suppressing of cross references, use the cross reference listing control pseudo-ops, .CREF and .XCREF, in the source file for MACRO-80. These two pseudo-ops may be entered at any point in the program in the OPERATOR field. Like the other listing control pseudo-ops, .CREF and .XCREF support no ARGUMENTs.

Pseudo-op	Definition
.CREF	Create cross references. .CREF is the default condition. Use .CREF to restart the creation of a cross reference file after using the .XCREF pseudo-op. .CREF remains in effect until MACRO-80 encounters .XCREF. Note, however, that .CREF has no effect until the /C switch is set in the MACRO-80 command line.
.XCREF	Suppress cross references. .XCREF turns off the .CREF (default) pseudo-op. .XCREF remains in effect until MACRO-80 encounters .CREF. Use .XCREF to suppress the creation of cross references in selected portions of the file. Because neither .CREF nor .XCREF takes effect until the /C switch is set in the MACRO-80 command line, there is no need to use .XCREF if you want the usual List file (one without cross references); simply omit /C from the MACRO-80 command line.

CHAPTER 8

LIB-80 LIBRARY MANAGER

WARNING

> Read this chapter carefully and make a back-up copy of your libraries before using LIB-80. LIB-80 is very powerful and thus can be very destructive. It is easy to destroy a library with LIB-80.

LIB-80 is designed as a runtime library manager for CP/M versions of Microsoft FORTRAN-80 and COBOL-80. LIB-80 may also be used to create your own library of assembly language subroutines.

LIB-80 creates runtime libraries from assembly language programs that are subroutines to COBOL, FORTRAN, and other assembly language programs. The programs collected by LIB-80 may be special modules created by the programmer or modules from an existing library (FORLIB, for example). With LIB-80, you can build specialized runtime libraries for whatever execution requirements you design.

The value of building a library is that all the routines needed to execute a program can be linked with it into an executable object (COM) file by entering the library name followed by /S in a LINK-80 command line. For example:

```
L80 MAIN,NEWLIB/S,NEIL/N/G
```

This is much more convenient than entering the necessary subroutines individually, especially if there are many modules. With a library file you can be sure all the necessary modules will be linked into the COM file, plus there is no danger of running out of space on the LINK-80

command line. Additionally, the library makes this special collection of subroutines available for easy linking into any program.

8.1 SAMPLE LIB-80 SESSION

The two most common uses you will have for LIB-80 are building a library and listing a library. The following sample sessions illustrate the basic commands for these two uses.

BUILDING A LIBRARY:

```
A>LIB
*TRANLIB=SIN,COS,TAN,ATAN,ACOG
*EXP
*/E
A>
```

In this sample session, LIB invokes LIB-80, which returns an asterisk (*) prompt. TRANLIB is the name of the library being created. SIN,COS,TAN,ATAN,ACOG are filenames to be concatenated into TRANLIB. EXP is another filename to be concatenated into TRANLIB. (EXP could be listed on the previous command line; this example shows files entered singly and multiply.) /E causes LIB-80 to rename TRANLIB.LIB to TRANLIB.REL then to exit to CP/M.

LISTING A LIBRARY:

```
A>LIB
*TRANLIB.LIB/U
*TRANLIB.LIB/L
    .
    .
    .

(List of symbols in TRANLIB.LIB)
    .
    .
    .

*CTRL-C
A>
```

In this sample session, LIB invokes LIB-80. TRANLIB.LIB/U tells LIB-80 to search TRANLIB.LIB for any intermodule references that would not be defined during a single pass through the library

(that is, any "backward" referencing symbols). TRANLIB.LIB/L directs LIB-80 to list the modules in TRANLIB.LIB and the symbol definitions the modules contain. CTRL-C exits to CP/M without destroying any files.

WARNING

/E will destroy your current library if there is no new library under construction. This is a special danger to your FORTRAN runtime library FORLIB.REL. IF YOU ARE ONLY LISTING THE LIBRARY AND NOT REVISING IT, EXIT LIB-80 USING CTRL-C.

8.2 LIB-80 COMMANDS

Invoking LIB-80

To invoke LIB-80, enter:

```
LIB
```

LIB-80 will return an asterisk (*) prompt, indicating ready to accept commands. Each command in LIB-80 adds modules to the library under construction.

Commands to LIB-80 consist of an optional Destination field, a Source field, and an optional Switch field.

The format of a LIB-80 command is:

```
Destination=Source/Switch
```

Each field is described below. The general format for each field is shown in parentheses after the field name.

Destination field (filename=)

This field is optional. The equal sign is required if any entry is made in this field.

Enter in this field the filename (and extension, if you choose) for the library file you want to create.

If this field is omitted, LIB-80 defaults to the filename FORLIB. The default filename extension is .REL.

WARNING

Do not confuse this default filename FORLIB.LIB with FORLIB.REL, the runtime library supplied with FORTRAN-80. These two libraries will not be the same unless you command LIB-80 to copy all the files from the FORTRAN runtime library to the new library. Furthermore, when you exit LIB-80, the default library name will be given the filename extension .REL, which means that it replaces the FORLIB.REL supplied with FORTRAN-80. For this reason, unless you want your FORTRAN-80 runtime library destroyed, we recommend emphatically that you always specify a Destination filename when creating a new library.

Source field (filename<module>)

Some entry is required in this field. All Source files must be REL files.

Source field entries tell LIB-80 which files or parts of files (modules) you want added to the destination library file. You have two choices for entries:

1. Filename(s) only

2. Any combination of filename(s) and module name(s)

The following syntax rules apply:

1. If a command consists of filenames only, the entries are separated by commas only. For example:

   FILE1,FILE2,FILE3

2. If a command consists of filenames and module names, the module names must be enclosed in angle brackets (<>). Modules follow the filename where they are found. Each filename<module name> combination is separated from other command line entries by commas. For example:

   FILE1,FILE2<MODZ>,FILE3<MODR>,FILE4

3. If more than one module is named from the same file, the module names, enclosed in angle brackets (<>), must be separated from each other by commas. For example:

   FILE1,FILE2<MODZ,MODR>,FILE3

   See Additional Details about Source Modules, option 2, below.

Files and modules are typically FORTRAN or COBOL subprograms or main programs, or ALDS assembly language programs that contain ENTRY, GLOBAL, or PUBLIC statements. (These statements are called entry points.) LIB-80 recognizes a module by its program name, which may be a filename, or a name given by either the .TITLE or the NAME pseudo-op in MACRO-80. All Source files must be REL files.

LIB-80 concatenates REL files and modules of REL files; that is, LIB-80 strings one file or module after the other.

So there is no difference between the command under syntax rule 2 above and

```
FILE1
FILE2<MODZ>
FILE3<MODR>
FILE4
```

Also, because the library file is built by concatenation, it is important to order the modules so that all intermodule references are "forward." That is, the module containing the external reference should physically appear ahead of the module containing the ENTRY point (the definition). Otherwise, when you direct LINK-80 to search the library, LINK-80 may not satisfy all references on a single pass through the library.

Additional Details about Source Modules

To extract modules from previous libraries and other REL files, LIB-80 uses a powerful syntax to specify ranges of modules within a REL file.

These ranges may be from one module to the entire file (in which case no module specification is given).

The basic principle of specifying a range of modules is, generally, that any module named in a command will be included. (There is an exception, when specifying a relative offset range--item 6, below.)

The options for specifying modules are:

1. One module only
   Enter the module name. For example:

   ```
   FILE1<MODZ>
   ```

   includes only module MODZ of FILE1.

2. Several discontiguous modules from one file
   Enter the module names separated by commas. For example:

   ```
   FILE1<MODZ,MODR,MODK>
   ```

   includes modules MODZ, MODR, and MODK. Note that these modules may be given in any order you need them concantenated for a proper one-pass search, regardless of their order in the original file.

3. From the first module through the named module
   Enter two periods (..) and the name of the last module to be included. For example:

   ```
   FILE1<..MODK>
   ```

   includes all modules from the first module in FILE1 through module MODK.

4. From a named module through the last module
   Enter the name of the module that starts the range followed by two periods (..). For example:

   ```
   FILE1<MODR..>
   ```

   includes all the modules, beginning with module MODR, through the last module in FILE1.

5. From one named module through another named module
   Enter the name of the module that starts the range followed by two periods (..) followed by the name of the module that ends the range. For example:

   ```
   FILE1<MODZ..MODK>
   ```

   includes all modules, beginning with module MODZ, through module MODK.

6. Relative offset range
   Enter the module name followed by a + or - and the number of modules to be included. + means following the named module. - means preceding the named module. The named module is not included in the library. The offset number must be an integer in the range 1 to 255. For example:

   ```
   FILE1<MODZ+2>
   ```

   includes the two modules immediately following module MODZ. While

   ```
   FILE1<MODK-3>
   ```

   includes the three modules immediately preceding module MODK.

Additionally, ranges and offsets may be used together. For example:

```
FILE1<MODR+1..MODK-1>
```

includes all the modules between module MODR and module MODK (but neither MODR nor MODK is included).

7. All modules in a file
   Enter the filename only. For example:

```
FILE1
```

includes the entire file (all modules in FILE1).

Switch field (/switch)

An entry in the Switch field commands LIB-80 to perform additional functions. A Switch field entry is a letter preceded by a slash mark (/).

WARNING

/E will destroy your current library if there is no new library under construction. This is a special danger to your FORTRAN runtime library FORLIB.REL because FORLIB is the default filename used if you do not specify a destination filename. Therefore, unless you want to delete your complete FORTRAN runtime library, give LIB-80 a destination filename for the new library. If you are only listing the library and not revising it, exit LIB-80 using CTRL-C.

Switch Action

/E Exit to CP/M. If you are not creating a new library or revising an existing library, use CTRL-C instead of /E.

The library under construction (.LIB) is renamed to .REL and any previous copy of the library file is deleted. This is why /E is so dangerous and not to be used unless you are constructing a new library. Again, we recommend emphatically that you always enter a filename in the Destination field of the LIB-80 command line.

/R Rename the library currently being built (.LIB) to .REL. The same warnings and cautions apply to /R as apply to /E.

The previous copy of the library is deleted. Use /R only if you are building a new library. /R performs the same functions as /E, but does not exit to CP/M on completion. Use /R instead of /E when you want to exit the current library but want to continue using LIB-80 for other library managing.

/L List the modules in the file specified and the symbol definitions the modules contain. The contents of a file are listed in cross reference format.

Listings are currently always sent to the terminal; use CTRL-P before running LIB-80 to send the listing to the printer.

/U Use /U to list the symbols which could be undefined in a single pass through a library. If a symbol in a library module refers "backward" (to a preceding module), /U will list that symbol.

/C Use /C to clear commands from LIB-80 without exiting the LIB-80 program. The library under construction is deleted and the LIB-80 session starts over. The asterisk (*) prompt will appear.

Use /C if you specified the wrong module(s) or the wrong order and want to start over with new LIB-80 commands.

/O Use /O to set typeout mode to Octal radix. /O will be given together with the /L switch, which commands LIB-80 to list. REMEMBER: When switches are given together, a slash must precede each switch. For example:

```
NEWLIB/L/O
```

/H Use /H to set typeout mode to Hexadecimal radix. Hexadecimal is the default radix.

APPENDIX A

Compatibility with Other Assemblers

The $EJECT and $TITLE controls are provided for compatability with Intel's ISIS assembler. The dollar sign must appear in column 1 only if spaces or tabs separate the dollar sign from the control word. The control word

```
$EJECT
```

is the same as the MACRO-80 PAGE pseudo-op.

The control word

```
$TITLE('text')
```

is the same as the MACRO-80 SUBTTL <text> pseudo-op.

The Intel operands PAGE and INPAGE generate Q errors when used with the MACRO-80 CSEG or DSEG pseudo-ops. These errors are warnings; the assembler ignores the operands.

When MACRO-80 is invoked, the default for the origin is Code Relative 0. With the Intel ISIS assembler, the default is Absolute 0.

With MACRO-80, the dollar sign ($) is a defined constant that indicates the value of the location counter at the start of the statement. Other assemblers may use a decimal point or an asterisk. Other constants are defined by MACRO-80 to have the following values:

```
A=7     B=0     C=1     D=2     E=3
H=4     L=5     M=6     SP=6    PSW=6
```

APPENDIX B

The Utility Software Package with TEKDOS

The command formats for MACRO-80, LINK-80, and CREF-80 differ slightly under the TEKDOS operating system.

B.1 TEKDOS COMMAND FILES

The files M80, L80, and C80 are actually TEKDOS command files for the assembler, loader, and cross reference programs, respectively. These command files set the emulation mode to 0 and select the Z-80 assembler processor (see TEKDOS documentation), then execute the appropriate program file. You will note that all of these command files are set up to execute the Microsoft programs from drive #1. LINK-80 will also look for the library on drive #1. If you wish to execute any of this software from drive #0, the command file must be edited. Then, LINK-80 should be given an explicit library search directive, such as MYLIB-S. See the Switches section in Chapter 6, LINK-80 Linking Loader.

Filenames under TEKDOS do not use the Utility Software Package default filename extensions.

B.2 MACRO-80

The MACRO-80 assembler accepts command lines only (the invoke command, M80, and all filenames and switches must be on one line). No prompt is displayed, and the interactive commands (,TTY:=TTY: and ,LPT:=TTY:) are not accepted. Commands have the same format as TEKDOS assembler commands; that is, up to three filenames or device names plus optional switches.

M80 [object] [list] source [switch [switch [...]]]

The object and list file entries are optional. These files will not be created if the parameters are omitted. Any

error messages will still be displayed on the console. The available switches are described in Chapter 5 of this manual. All command line entries may be delimited by commas or spaces. If you do not want to request an object file, you must enter a <space comma space> between the M80 entry and the name of the list file. For example:

```
M80 , LIST SOURCE
```

B.3 CREF-80

The form of commands to CREF-80 is:

```
C80 list source
```

Both filenames are required. The source file is always the name of a CREF-80 file created during assembly by the C switch.

Example:

To create a CREF-80 file from the source TSTMAC using MACRO-80, enter:

```
M80 , TSTCRF TSTMAC C
```

To create a cross reference listing from the CREF-80 file TSTCRF, enter:

```
C80 TSTLST TSTCRF
```

B.4 LINK-80

With TEKDOS, the LINK-80 loader accepts interactive commands only. Command lines are not supported.

When LINK-80 is invoked, and whenever it is waiting for input, it will prompt with an asterisk. Commands are lists of filenames and/or devices separated by commas or spaces and optionally interspersed with switches. The input to LINK-80 must be Microsoft relocatable object code (not the same as TEKDOS loader format).

Switches to LINK-80 are delimited by hyphens under TEKDOS, instead of slashes. All LINK-80 switches (as documented in Chapter 6) are supported, except -G and -N, which are not implemented at this time.

EXAMPLE:

1. Assemble a MACRO-80 program named XTEST, creating an object file called XREL and a listing file called XLST:

```
>M80 XREL XLST XTEST
```

2. Load XTEST and save the loaded module:

```
>L80
*XREL-E
[04AD  22B8]
*DOS*ERROR 46
L80 TERMINATED
>M XMOD 400 22B8 04AD
```

Note that -E exits via an error message due to execution of a Halt instruction. The memory image is intact, however, and the TEKDOS Module command may be used to save it. Once a program is saved in module format, it may then be executed directly without going through LINK-80 again.

The bracketed numbers printed by LINK-80 before exiting are the entry point address and the highest address loaded, respectively. The loader default is to begin loading at 400H. However, the loader also places a jump to the start address in location 0, which allows execution to begin at 0. The memory locations between 0003 and 0400H are reserved for SRB's and I/O buffers at runtime.

APPENDIX C

ASCII CHARACTER CODES

Dec	Hex	CHR	Dec	Hex	CHR	Dec	Hex	CHR
000	00H	NUL	043	2BH	+	086	56H	V
001	01H	SOH	044	2CH	,	087	57H	W
002	02H	STX	045	2DH	-	088	58H	X
003	03H	ETX	046	2EH	.	089	59H	Y
004	04H	EOT	047	2FH	/	090	5AH	Z
005	05H	ENQ	048	30H	0	091	5BH	[
006	06H	ACK	049	31H	1	092	5CH	\
007	07H	BEL	050	32H	2	093	5DH	]
008	08H	BS	051	33H	3	094	5EH	^
009	09H	HT	052	34H	4	095	5FH	
010	0AH	LF	053	35H	5	096	60H	`
011	0BH	VT	054	36H	6	097	61H	a
012	0CH	FF	055	37H	7	098	62H	b
013	0DH	CR	056	38H	8	099	63H	c
014	0EH	SO	057	39H	9	100	64H	d
015	0FH	SI	058	3AH	:	101	65H	e
016	10H	DLE	059	3BH	;	102	66H	f
017	11H	DC1	060	3CH	<	103	67H	g
018	12H	DC2	061	3DH	=	104	68H	h
019	13H	DC3	062	3EH	>	105	69H	i
020	14H	DC4	063	3FH	?	106	6AH	j
021	15H	NAK	064	40H	@	107	6BH	k
022	16H	SYN	065	41H	A	108	6CH	l
023	17H	ETB	066	42H	B	109	6DH	m
024	18H	CAN	067	43H	C	110	6EH	n
025	19H	EM	068	44H	D	111	6FH	o
026	1AH	SUB	069	45H	E	112	70H	p
027	1BH	ESCAPE	070	46H	F	113	71H	q
028	1CH	FS	071	47H	G	114	72H	r
029	1DH	GS	072	48H	H	115	73H	s
030	1EH	RS	073	49H	I	116	74H	t
031	1FH	US	074	4AH	J	117	75H	u
032	20H	SPACE	075	4BH	K	118	76H	v
033	21H	!	076	4CH	L	119	77H	w
034	22H	"	077	4DH	M	120	78H	x
035	23H	#	078	4EH	N	121	79H	y
036	24H	$	079	4FH	O	122	7AH	z
037	25H	%	080	50H	P	123	7BH	{
038	26H	&	081	51H	Q	124	7CH	|
039	27H	'	082	52H	R	125	7DH	}
040	28H	(	083	53H	S	126	7EH	~
041	29H	)	084	54H	T	127	7FH	DEL
042	2AH	*	085	55H	U			

Dec=decimal, Hex=hexadecimal (H), CHR=character.
LF=Line Feed, FF=Form Feed, CR=Carriage Return, DEL=Rubout

APPENDIX D

FORMAT OF LINK COMPATIBLE OBJECT FILES

This appendix contains reference material for users who wish to know the load format of LINK-80 relocatable object files. None of this material is necessary to the operation of ALDS. There is nothing in the format material presented here which can be manipulated by the user. The material is highly technical, and it is not presented in any tutorial manner.

LINK-compatible object files consist of a bit stream. Individual fields within the bit stream are not aligned on byte boundaries, except as noted below. Use of a bit stream for relocatable object files keeps the size of object files to a minimum, thereby decreasing the number of disk reads/writes.

There are two basic types of load items: Absolute and Relocatable. The first bit of an item indicates one of these two types. If the first bit is a 0, the following 8 bits are loaded as an absolute byte. If the first bit is a 1, the next 2 bits are used to indicate one of four types of relocatable items:

00	Special LINK item (see below).
01	Program Relative. Load the following 16 bits after adding the current Program base.
10	Data Relative. Load the following 16 bits after adding the current Data base.
11	Common Relative. Load the following 16 bits after adding the current Common base.

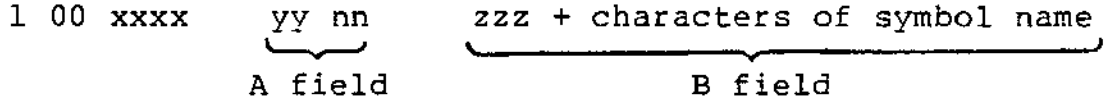
Special LINK items consist of the bit stream 100 (read one-zero-zero) followed by:

a four-bit control field

an optional A field consisting of a two-bit address type that is the same as the two-bit field described above, except 00 specifies absolute address

an optional B field consisting of 3 bits that give a symbol length and up to 8 bits for each character of the symbol

A general representation of a special LINK item is:



where: xxxx is four-bit control field (0-15 below)
yy is two-bit address type field
nn is sixteen-bit value
zzz is three-bit symbol length field

The following special types have a B-field only:

0 Entry symbol (name for search)
1 Select COMMON block
2 Program name
3 Request library search
4 Extension LINK items (see below)

The following special LINK items have both an A field and a B field:

5 Define COMMON size
6 Chain external (A is head of address chain, B is name of external symbol)
7 Define entry point (A is address, B is name)

The following special LINK items have an A field only:

8	External - offset. Used for JMP and CALL to externals
9	External + offset. The A value will be added to the two bytes starting at the current location counter immediately before execution.
10	Define size of Data area (A is size)
11	Set loading location counter to A
12	Chain address. A is head of chain. Replace all entries in chain with current location counter. The last entry in the chain has an address field of absolute zero.
13	Define program size (A is size)
14	End program (forces to byte boundary)

The following special LINK item has neither an A nor a B field:

15	End file

An Extension LINK item follows the general format of a B-field-only special LINK item, but the contents of the B-field are not a symbol name. Instead, the symbol area contains one character to identify the type of extension LINK item, followed by from 1 to 7 characters of additional information.

Thus, every extension LINK item has the format:

1 00 0100 111 s bbbbbb

where:	111	is 3 bits containing the length of the field bbbbbb (0 implys 1 since F80 emits entry length of 0 for Blank Common),
	s	is an eight bit extension LINK item sub-type identifier, and
	bbbbbb	are 1 to 6 bytes for additional information. If used as B field for name, bbbbbb may be only 6 characters.

The present extension LINK item sub-types are:

5	X'35'	COBOL overlay segment sentinel
A	X'41'	Arithmetic Fixup (Arithmetic Operator)
B	X'42'	Arithmetic Fixup (External Reference)
C	X'43'	Arithmetic Fixup (Area Base + Offset)

Descriptions of Sub-types

Sub-type 5

When the overlay segment sentinel is encountered by LINK-80, lll receives the value 010 (binary), and the current overlay segment number is set to the value b+49. If the previously existing segment number was non-zero and the /N switch is in effect, the data area is written to disk in a file whose name is the current program name and whose extension is Vnn, where nn are the two hexadecimal digits representing the number b+49 (decimal).

Sub-types A,B,C

Sub-types A, B, and C allow the processing of Polish Arithmetic text. Items must be read as Reverse Polish Expression. One or more Value items (sub-type B or C) are followed by one or more Arithmetic Operators (sub-type A) and end with a Store-Result Arithmetic Operator (B.STBT or B.STWD).

All Items are put in the Fixup Table afer any offset entries have been converted to final addresses. The Polish expression is executed out of the Fixup Table at the end of link. The result is stored at the PC given when the Items were read.

APPENDIX E

Table of MACRO-80 Pseudo-ops

Notation: * means Z80 pseudo-op
no stars means 8080 pseudo-op

SINGLE-FUNCTION PSEUDO-OPS

Instruction Set Selection

```
        .Z80
        .8080
```

Data Definition and Symbol Definition

```
        <name> ASET <exp>
        BYTE EXT <symbol>
        BYTE EXTRN <symbol>
        BYTE EXTERNAL <symbol>
        DB <exp>[,<exp>...]
        DB <string>[<string>...]
        DC <string>
        DDB <exp>[,<exp>...]
    *   DEFB <exp>[,<exp>...]
    *   <name> DEFL <exp>
    *   DEFM <string>[,<string>...]
    *   DEFS <exp>[,<val>]
    *   DEFW <exp>[,<exp>...]
        DS  <exp>[,<val>]
        DW <exp>[,<exp>...]
        ENTRY <name>[,<name>...]
        <name> EQU <exp>
        EXT <name>[,<name>...]
        EXTRN <name>[,<name>...]
    *   EXTERNAL <name>[,<name>...]
        GLOBAL <name>[,<name>...]
        PUBLIC <name>[,<name>...]
        <name> SET <exp> (not in .Z80 mode)
```

PC Mode Pseudo-ops

```
ASEG
CSEG
DSEG
COMMON /<block name>/
ORG <exp>
.PHASE <exp>/.DEPHASE
```

File Related Pseudo-ops

```
.COMMENT <delim><text><delim>
END [<exp>]
INCLUDE <filename>
$INCLUDE <filename>
MACLIB <filename>
.RADIX <exp>
.REQUEST <filename>[,<filename>...]
```

Listing Pseudo-ops

Format Control Pseudo-ops

```
*  *EJECT [<exp>] (one star is part of *EJECT)
   PAGE <exp>
   SUBTTL <text>
   TITLE <text>
   $TITLE
```

General Listing Control Pseudo-ops

```
.LIST
.XLIST
.PRINTX <delim><text><delim>
```

Conditional Listing Control Pseudo-ops

```
.SFCOND
.LFCOND
.TFCOND
```

Expansion Listing Control Pseudo-ops

```
.LALL
.SALL
.XALL
```

Cross-Reference Listing Control Pseudo-ops

```
.XCREF
.CREF
```

MACRO FACILITY PSEUDO-OPS

Macro Pseudo-ops

```
<name> MACRO <parameter>[,<parameter>...]
ENDM
EXITM
LOCAL <parameter>[,<parameter>...]
```

Repeat Pseudo-ops

```
REPT <exp>
IRP <dummy>,<parameters in angle brackets>
IRPC <dummy>,string
```

Conditional Assembly Facility

```
*  COND <exp>
   ELSE
*  ENDC
   ENDIF
   IF <exp>
   IFB <arg>
   IFDEF <symbol>
   IFDIF <arg1>,<arg2>
   IFE <exp>
   IFF <exp>
   IFIDN <arg1>,<arg2>
   IFNB <arg>
   IFNDEF <symbol>
   IFT <exp>
   IF1
   IF2
```

APPENDIX F

Table of Opcodes

The opcodes are listed alphabetically by instruction set. For details, refer to the reference books listed in Chapter 1.

F.1 Z80 OPCODES

Opcode		Function
ADC	A	Add with Carry to Accumulator
ADC	HL,rp	Add Register Pair with Carry to HL
ADD		Add
AND		Logical AND
BIT		Test Bit
CALL	addr	Call Subroutine
CALL	cond,addr	Call Conditional
CCF		Complement Carry Flag
CP		Compare
CPD		Compare, Decrement
CPDR		Compare, Decrement, Repeat
CPI		Compare, Increment
CPIR		Compare, Increment, Repeat
CPL		Complement Accumulator
DAA		Decimal Adjust Accumulator
DEC		Decrement
DI		Disable Interrupts
DJNZ		Decrement and Jump if Not Zero
EI		Enable Interrupts
EX		Exchange
EXX		Exchange Register Pairs and Alternatives
HALT		Halt
IM	x	Set Interrupt Mode
IN		Input
INC		Increment
IND		Input, Decrement
INDR		Input, Decrement, Repeat
INI		Input, Increment
INIR		Input, Increment, Repeat
JP	addr	Jump
JP	cond,addr	Jump Conditional
JR		Jump Relative

```
JR     cond,addr      Jump Relative Conditional
LD       A,(addr)     Load Accumulator Direct
LD   A,(BC) or (DE)   Load Accumulator Secondary
LD       A,I          Load Accumulator from Interrupt Vector Register
LD       A,R          Load Accumulator from Refresh Register
LD   HL,(addr)        Load HL Direct
LD       data         Load Immediate
LD   xy,(addr)        Load Index Register Direct
LD       reg,(HL)     Load Register
LD   reg,(xy+disp)    Load Register Indexed
LD   rp,(addr)        Load Register Pair Direct
LD       SP,HL        Move HL to Stack Pointer
LD       SP,xy        Move Index Register to Stack Pointer
LD       dst,scr      Move Register-to-Register
LD       (addr),A     Store Accumulator Direct
LD   (BC) or (DE),A   Store Accumulator Secondary
LD       I,A          Store Accumulator to Interrupt Vector Register
LD       R,A          Store Accumulator to Refresh Register
LD   (addr),HL        Store HL Direct
LD   (HL),data        Store Immediate to Memory
LD   (xy+disp),data   Store Immediate to Memory Indexed
LD   (addr),xy        Store Index Register Direct
LD       (HL),reg     Store Register
LD   (xy+disp),reg    Store Register Indexed
LD   (addr),rp        Store Register Pair Direct
LDD                   Load, Decrement
LDDR                  Load, Decrement, Repeat
LDI                   Load, Increment
LDIR                  Load, Increment, Repeat
NEG                   Negate (Two's Complement) Accumulator
NOP                   No Operation
OR                    Logical OR
OUT                   Output
OUTD                  Output, Decrement
OTDR                  Output, Decrement, Repeat
OUTI                  Output, Increment
OTIR                  Output, Increment, Repeat
POP                   Pop from Stack
PUSH                  Push to Stack
RES                   Reset Bit
RET                   Return from Subroutine
RET    cond           Return Conditional
RETI                  Return from Interrupt
RETN                  Return from Non-Maskable Interrupt
RL                    Rotate Left Through Carry
RLA                   Rotate Accumulator Left Through Carry
RLC                   Rotate Left Circular
RLCA                  Rotate Accumulator Left Circular
RLD                   Rotate Accumulator and Memory Left Decimal
RR                    Rotate Right Through Carry
RRA                   Rotate Accumulator Right Through Carry
RRC                   Rotate Right Circular
RRCA                  Rotate Accumulator Right Circular
RRD                   Rotate Accumulator and Memory Right Decimal
RST                   Restart
```

SET	Set Bit
SBC	Subtract with Carry (Borrow)
SCF	Set Carry Flag
SLA	Shift Left Arithmetic
SRA	Shift Right Arithmetic
SRL	Shift Right Logical
SUB	Subtract
XOR	Logical Exclusive OR

F.2 8080 OPCODES

Opcode	Function
ADC,ACI	Add with Carry
ADD,ADI	Add
ANA,ANI	Logical AND
CALL	Call Subroutine
CC	Call on Carry
CM	Call on Minus
CMA	Complement Accumulator
CMC	Complement Carry
CMP,CPI	Compare
CNC	Call on No Carry
CNZ	Call on Not Zero
CP	Call on Positive
CPE	Call on Parity Even
CPO	Call on Parity Odd
CZ	Call on Zero
DAA	Decimal Adjust
DAD	16-bit Add
DCR	Decrement
DCX	16-bit Decrement
DI	Disable Interrupts
EI	Enable Interrupts
HLT	Halt
IN	Input
INR	Increment
INX	Increment 16 bits
JC	Jump on Carry
JM	Jump on Minus
JMP	Jump
JNC	Jump on Not Carry
JNZ	Jump on Not Zero
JP	Jump on Positive
JPE	Jump on Parity Even
JPO	Jump on Parity Odd
JZ	Jump on Zero
LDA	Load Accumulator
LDAX	Load Accumulator Indirect
LHLD	Load HL Direct
LXI	Load 16 bits

MOV	Move
MVI	Move Immediate
NOP	No Operation
ORA,ORI	Logical OR
OUT	Output
PCHL	HL to Program Counter
POP	Pop from Stack
PUSH	Push to Stack
RAL	Rotate with Carry Left
RAR	Rotate with Carry Right
RC	Return on Carry
RET	Return from Subroutine
RLC	Rotate Left
RM	Return on Minus
RNC	Return on No Carry
RNZ	Return on Not Zero
RP	Return on Positive
RPE	Return on Parity Even
RPO	Return on Parity Odd
RRC	Rotate Right
RST	Restart
RZ	Return on Zero
SBB,SBI	Subtract with Borrow
SHLD	Store HL Direct
SPHL	HL to Stack Pointer
STA	Store Accumulator
STAX	Store Accumulator Indirect
STC	Set Carry
SUB,SUI	Subtract
XCHG	Exchange D and E, H and L
XRA,XRI	Logical Exclusive OR
XTHL	Exchange Top of Stack, HL

Microsoft
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Report only one problem per form.

Describe your hardware and operating system: _____

Please supply a concise description of the problem and the circumstances surrounding its occurrence. If possible, reduce the problem to a simple test case. Otherwise, include all programs and data in machine readable form (preferably on a diskette). If a patch or interim solution is being used, please describe it.

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