HP 64000 Logic Development System

HP-UX Hosted Cross Assembler/ Linker User Definable

Operating Manual

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Using This Manual

This manual describes how to use the HP 64851S User Definable Assembler in a HP-UX environment. Create your custom assembler on an HP 64000 development station. After it has been created, upload the assembler to the host mainframe. At this point, the assembler can be used in the same way as any other assembler in the HP-UX environment. Follow the instructions in the first eight chapters to create the custom assembler and linker, then follow the uploading instructions in Chapter 9.

Note

Be certain to read the CAUTION on page 7-1 and "Sample Code Defining 8080 Processor" on page 7

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General Information (User Definable Assembler/Linker)

Introduction

An assembler translates mnemonic source code into object code that will execute on a specific processor. The user definable assembler/linker permits the instruction set and instruction format of any processor to be defined in a source program by the user. In addition, it can be used to modify source type HP Model 64000 Assemblers by adding or changing instructions. Assembler code for the Model 64000 is modular and changes can also be made by merging code in appropriate places.

Note

The user definable assembler/linker cannot be used to modify existing ABSOLUTE assembler files.

The assembler and linker both have two modules:

1. The basic assembler module that is part of the Model 64000 operating system and cannot be modified by the user.
2. The user definable assembler module.
3. The basic linker module, which is also part of the Model 64000 operating system and cannot be modified by the user.
4. The user definable linker module.

Figure 1-1 illustrates how the user definable assembler and linker are created and then used with target system programs for the user processor.

Note

Refer to the *Assembler/Linker Reference Manual* for details on the basic assembler and linker modules. This manual supplement will only describe the user definable assembler and linker modules.

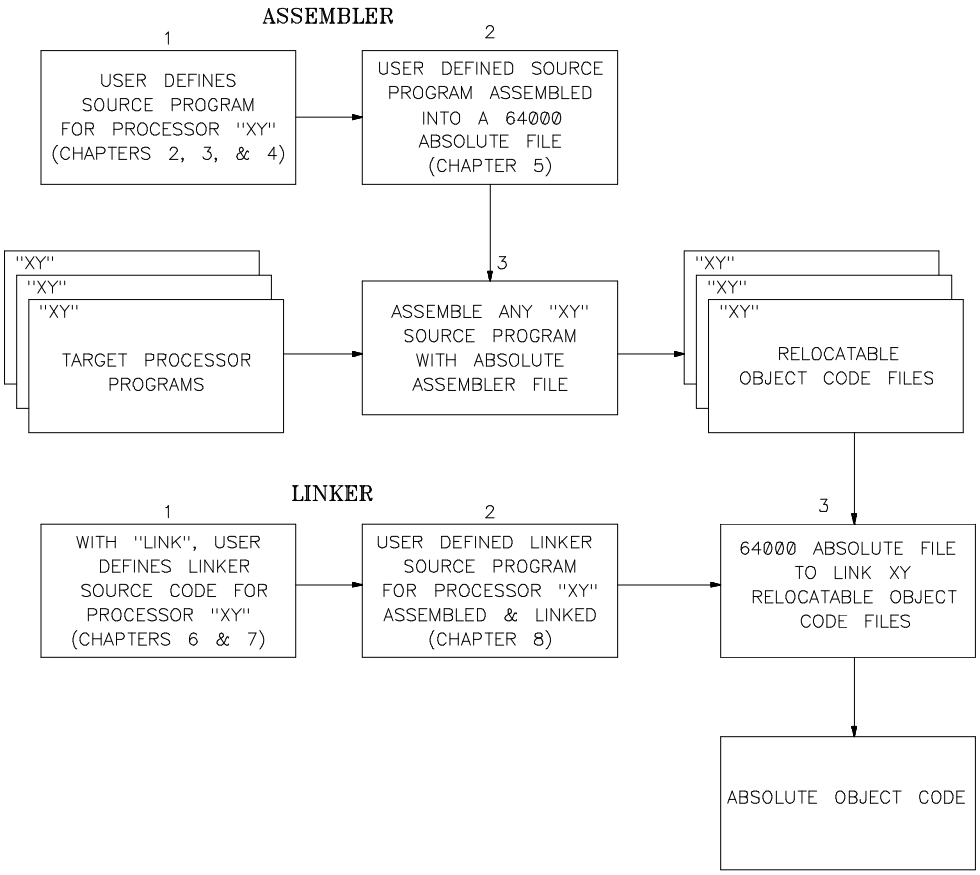


Figure 1-1. User Definable Assembler/Linker Overview

Assembler Operation

HP 64000 Assemblers include a pass 1 and a pass 2. The same code is used to generate both passes. Primary functions in pass 1 are building the symbol table and updating the program counter. To build the symbol table, labels and operands are identified and stored by names and addresses or labels. Object code is generated in pass 2, based on the symbol table.

The programmer implements the functions the user definable assembler must perform with a set of subroutines. These subroutines will be explained in Chapter 4 of this supplement. The functions performed by the basic assembler module and user definable assembler module are shown in figure 1-2.

The user defines the instruction set and predefined registers and symbols. The standard set of pseudo instructions can be used as is, redefined, or extra pseudo instructions peculiar to the user's assembly language can be added. The assembler also includes a symbol table building method that is mostly transparent to the user.

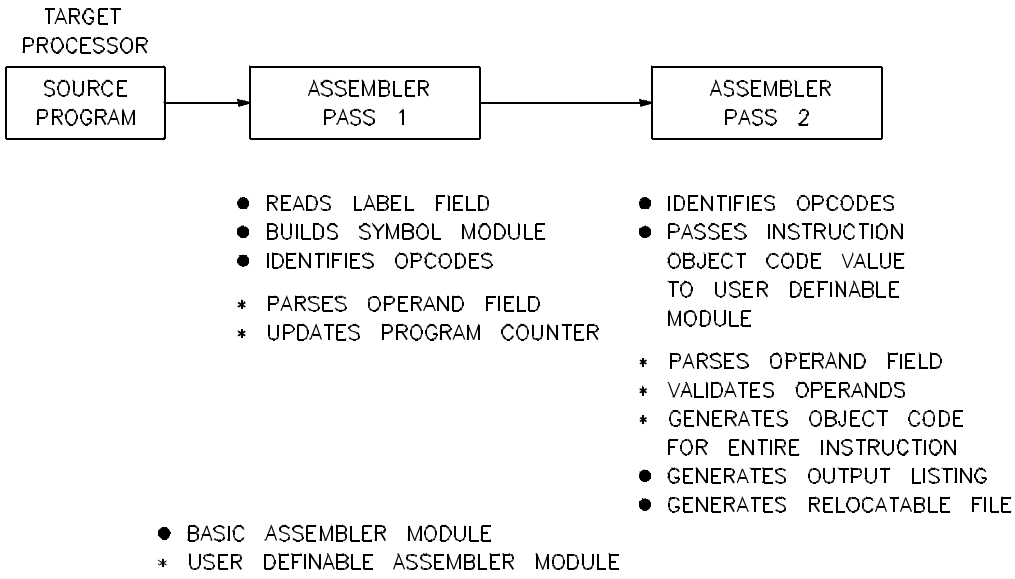


Figure 1-2. Assembler Functions

What The User Must Define

To define an assembler program, the user must provide the following information.

1. Identify all predefined symbols for registers, stack pointers, condition codes, etc. for the target processor.

2. Divide the instruction set into separate groups of instructions that are parsed in the same way.

3. Identify the machine code corresponding to the "unalterable" part of each instruction (opcode).

4. Define the parsing rules for each instruction group.

2

Programming Rules

Introduction

This chapter will explain the tasks that must be completed before user definable assembler code can be written. The functional block diagram in figure 2-1 illustrates the assembler building process. Each block corresponds to a paragraph title.

1. The user processor must be defined, including all predefined symbols for its language.

2. Instructions must be divided in groups that can be parsed in the same way and then defined in machine code (INSTR_DEF).

3. The parsing rules for each instruction group in step b must be specified. This defines how to handle the instruction set (INSTR_SET).

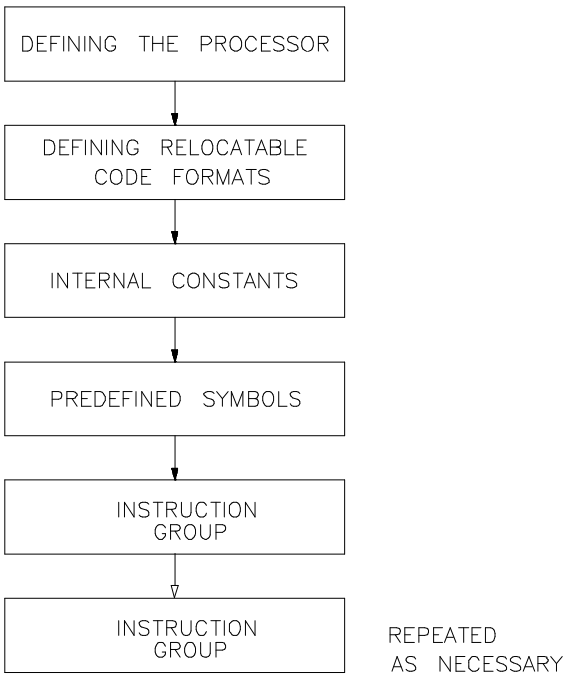


Figure 2-1. Assembler Building Process

User Definable Assembler Structure

Defining the Processor

In this first section of user definable code, setup commands define the basic parameters of the user processor. For example, assembler directive, word size, address size, assembler list title, print field size, linker file identifier, constants, registers, status words, and stack pointers. The 8080 processor will be used in the examples shown in this manual. Some information about the processor is included here. For more details, refer to the *8080/8085 Assembler Supplement*.

In the following examples, some of the user definable assembler setup commands are illustrated. Chapter 3 discusses all the setup

commands. The setup commands can be in any order desired by the programmer, except for the assembler directive, which must be the FIRST setup command.

Example:

```
ASSEMBLER "8080"            ;Defines the processor.
WORDSIZE = 8                ;Defines the word size.
ADDRESS_BASE = 8            ;Specifies the program counter increment.
TITLE = "8080"              ;Title for the assembler list.
LOC_SIZE = 4                ;Four characters in the print field for the location
                            ;counter.
LINK_FILE L8080 : XX        ;Specifies linker file. XX is the USERID
                            ;(1 to 6 characters).
PC_16                       ;Only the lower 16 bits of the program counter are used.
```

Defining Relocatable Code Generation Formats

The relocatable code formats must also be defined at this time with the RELOC_FMT setup command. This command can be located anywhere in the group of setup commands. The command is used as follows.

RELOC_FMT < name> , SIZE = < n>

where:

< name>	is used in conjunction with GEN_CODE to identify the relocatable addressing mode. GEN_CODE will be explained in a later paragraph, Parsing the Instruction Set.
SIZE = < n>	defines the variable size being parsed (n= 1 to 32 bits).

Examples:

```
RELOC_FMT HIGH_LOW, SIZE = 16     ;Relocate 16 bits.
RELOC_FMT LOW_HIGH, SIZE = 16     ;Relocate and swap bytes.
RELOC_FMT LOW_BYTE, SIZE = 8      ;Low byte, no error check.
RELOC_FMT HIGH_BYTE, SIZE = 8     ;High byte, no error check.
RELOC_FMT LOW_CHECK, SIZE = 8     ;Low byte, check for >256.
RELOC_FMT REL_8, SIZE = 8         ;Plus minus 128.
RELOC_FMT PC_REL, SIZE = 8        ;-126, +129
```

Internal Constants

Assembler internal constants are used for the programmers convenience. In the examples below, the temporary registers TEMP1, TEMP2, and TEMP3 are assigned a new name under CONSTANTS to aid in program documentation. There are 40 temporary registers available to the programmer (TEMP1 to 40).

Examples:

```
CONSTANTS
HIGH_FLAG = TEMP 1              ;Used as a flag if HIGH keyword is found.
COUNT = TEMP2                   ;Used as a temporary count.
MEM_CHECK = TEMP3               ;Used to check memory reference on MOV instructions
END
```

Predefined Symbols

Predefined symbols can be defined to represent registers, status words, stack pointers, etc.

Examples:

```
OBJ.
CODE
0006          SYMBOLS = REGISTER        ;Defines the TYPE and
                                        ;VALUE assigned to the
0007               A  =  7              ;symbols. REGISTER is
0000               B  =  0              ;TYPE 6. Symbol C has
0001               C  =  1              ;a VALUE of 1.
.                  D  =  2
.                  E  =  3
.                  H  =  4
.                  L  =  5
.                  M  =  6
END

SYMBOLS = STATUS
    PSW  =  6
END
SYMBOLS = STACK
    SP  =  6
END
SYMBOLS = ADDR_OPER
    HIGH  =  1
     LOW  =  0
END
```

During assembler operation, values assigned to the symbols will be used by the assembler subroutines.

Instruction Group

Defining the Instruction Set (INSTR_DEF)

The user must now divide the instruction set into separate groups of instructions that are parsed in the same way. Depending on the processor being defined, common parsing rules could include instruction format, data format, addressing modes, etc. This allows all instructions within a group to be handled in the same manner, which simplifies assembler operation.

The definition of each group must start with INSTR_DEF. This is followed by each instruction and its object code format. It is used as follows:

INSTR_DEF [OPERAND = X] [SPACES]

initiates section of code where the instruction mnemonics are equated to their respective machine codes. OPERAND= X and SPACES are optional parameters and are specified on the same line. X is the number of operands in a source statement to be cross referenced. OPERAND= 0 turns off cross referencing for the instruction group. DEFAULT: if OPERAND is not specified, all operands in the source statement are cross referenced.

SPACES is a key word used by the cross-reference generator to develop cross-reference tables. The key word "SPACES" indicates to the cross-reference generator that spaces are permitted in the operand field for the target processor. Note that SPACES must be used if it applies to the target processor. Each INSTR_DEF section is followed by an INSTR_SET section.

Example:

```
INSTR_DEF  OPERAND=0            ;Starts instruction set
                                ;definition section for
                                ;no operand instructions.

    CMC = 3FH
    RIM = 20H
        .
        .
        .
    HLT = 76H
```

Parsing the Instruction Set (INSTR_SET)

This next section defines the parsing rules that will perform the object code conversion for the user processor. It must start with INSTR_SET and terminate with the DONE instruction. The following example illustrates the basic structure. Each instruction group made up of INSTR_DEF and INSTR_SET must terminate with an END instruction. An example assembler source program with details on exactly how code is written is provided in Chapter 5. Chapter 4 explains the user definable assembler subroutines.

Example:

```
INSTR_DEF OPERAND=0

  CMC = 03FH
   ..
   ..
INSTR_SET                      ;Starts source code parsing section.

  GEN_CODE ABS 8, OBJECT_CODE
  DONE                         ;Return to basic assembler module.
END                            ;Must terminate instruction group.

INSTR_DEF                      ;Starts next instruction group definition section.
   ..
   ..
   Code
   ..
   DONE
END
```

This continues until each instruction group for the processor is defined.

The print formats and code generating rules are defined with the GEN_CODE subroutine. For absolute code this is accomplished by setting up GEN_CODE parameters that define the size of the generated code in bits (8 or 16) and the predefined operand that contains the binary code to be generated. The GEN_CODE subroutine is explained in detail in Chapter 4.

Example:

```
GEN_CODE ABS 8, OBJECT_CODE    ;The code size is 8 bits.
                               ;The predefined symbol
                               ;OBJECT_CODE will contain
                               ;the bit pattern to be
                               ;generated.
```

For relocatable code, the GEN_CODE subroutine has a different format and is used with the RELOC_FMT setup command described earlier. It has the following form.

GEN_CODE < name> , VALUE[SPACE]

or (either VALUE or BOTH must be specified)

GEN_CODE < name> , BOTH[SPACE]

where:

< name>	is used in conjunction with GEN_CODE to identify the relocatable addressing mode.
VALUE	uses the contents of the predefined symbols VALUE and relocation TYPE to generate code.
[SPACE]	inserts a space in the object code field of the assembler listing.
BOTH	uses the contents of the predefined symbols VALUE, relocation TYPE, and OBJECT_CODE to generate code.

Notes

3

Assembler Commands, Symbols, Instructions, and Conventions

Introduction

This chapter first explains the assembler directive and the setup commands needed to define the user processor. Predefined symbols are identified next, followed by pseudo and assembler instructions. An explanation of the conventions used completes the chapter.

Assembler Directive

In Chapter 2, under "Defining the Processor", brief examples show how a processor is defined. In defining a processor, the first statement must be the assembler setup command ASSEMBLER, followed by the assembler directive in quotes.

Example:

```
ASSEMBLER "8080"
```

After the processor is defined, target system source programs must always begin with the assembler directive.

```
"8080"
source code
 "
 "
END
```

Assembler Setup Commands

Use the setup commands to define basic parameters such as assembler directive, word size, address size, constants, registers, status words, and stack pointers. Except for the assembler directive, which must be first, the order of the setup commands is left to the programmer's discretion.

ADDRESS_BASE = nn	defines the process address mode; i.e., word or byte. Defaults to eight bits.
ASSEMBLER "< name> "	defines the assembler directive for the user processor.
LINK_FILE	allows the user to define the linker module to be used during a target system source program link operation. If an HP system linker absolute module exists on the Model 64000, it can be used, providing no additional formats or no system linker is available, a user definable linker module must be defined. An example of the LINK_FILE setup command for the system linker module and the user definable linker module follows:

(system absolute linker module) LINK_FILE I8085_Z80 : HP
(user defined absolute linker module) LINK_FILE L8080 : USERID

Note

The user linker name (L8080 here) can be any legal file name. The system linker module uses a lower case I identifier and is stored under USERID HP.

LOC_SIZE = n	sets up the size of the print field for the location counter (n= 1 to 8 characters). DEFAULT: four characters.

DOUBLE_ADDRESS	defines 32-bit addresses to be passed to the linker.
PC_16	indicates only the lower 16 bits of the program counter will be incremented.

RELOC_FMT < name> , SIZE = < n>

< name>	is used in conjunction with GEN_CODE to identify the relocatable addressing mode. The GEN_CODE subroutine is explained in Chapter 4.
SIZE = < n>	defines the variable size being parsed (n= 1 to 32 bits).
RENAME_PSEUDO	allows the user to rename the pseudo provided by the Model 64000 system. It has the following format:
RENAME_PSEUDO	< new name of pseudo> = < pseudo number>

Example:

RENAME_PSEUDO ORIGIN = 1

The list of pseudos and their associated pseudo number follow:

Note 

The IF pseudo cannot be renamed.

PSEUDO	PSEUDO NUMBER
ORG	1
PROG	2
DATA	3
COMN	4
EQU	5
EXT, EXTERNAL	6
GLB, GLOBAL	7
LIST	8
SPC	9
NAME	10
REPT	11
SKIP	12
TITLE	13
MASK	14
END	15
WARN	16
NOWARN	17
NOLIST	18
EXPAND	19
HEX	20
DEC, DECIMAL	21
OCT, OCTAL	22
BIN, BINARY	23
ASC, ASCII	24
INCLUDE	25
TRACE	26
REAL	27
SET	28

SYMBOLS = < name> defines user definable types. See TYPE under Predefined Symbols.

TITLE = "< string> " defines the header line on the assembler list output.

WORD_SIZE = nnn defines the processor word size. Allowable range is 8 to 128 bits. DEFAULT: eight bits.

Predefined Symbols

The following symbols are reserved. They have special meaning to the basic assembler module and cannot be redefined by the user.

Note 

All variables and registers are 32 bits long.

ACCUMULATOR	working register.
AUTO_DEC_COUNT	set by CHECK_AUTO_DEC and used by EXPRESSION.
AUTO_INC_COUNT	set by CHECK_AUTO_INC and used by EXPRESSION.
CHARACTER	used by CHECK_DELIMITER, GET_START_CHAR and GET_STOP_CHAR to return the character found.
CLASS	returned by GET_TOKEN with an indicator of the token type found: 0= Numeric constant 1= Undefined 2= String constant 3= Operator 4= Delimiter 5= Upper case variable 6= Undefined 7= Lower case variable 8= Undefined 9= End of line-no tokens in string 10= Decimal constant with E notation

*EXT_ID_NUMB	variable returned EXPRESSION and GET_SYMBOL with an external variable identification number assigned by the assembler.
*EXT_OFFSET	variable returned by EXPRESSION and GET_SYMBOL with the value of the offset to be added to an external operand at link time.

*For more information, refer to EXPRESSION and GET_SYMBOL subroutines in Chapter 4.

INSTR_RESET	variable reset to 0 at the beginning of each instruction.
OBJECT_CODE	register used to pass the object code to the code generating routine.
PROGRAM_ COUNTER	variable identifying the current TYPE of code. See TYPE 0 through 3.
RESULT	variable containing the value of the TOKEN returned by GET_TOKEN.
SAVE_PTR	pointer set by EXPRESSION to save the position of the STOP pointer at the time EXPRESSION was invoked.
START	pointer used by subroutines to control the scanning function.
STOP	pointer used by subroutines to control the scanning function.
TOKEN_ERROR	set by GET_TOKEN when an error is found.
TYPE	variable containing the type of an evaluated expression.

0= absolute
1= program relocatable
2= data relocatable
3= common relocatable
4= external reference
5= equated to external
6> user definable types (see SYMBOLS).

VALUE	variable containing the value of an expression.

Pseudo Instructions

Pseudo instructions are used by most assemblers to provide for special functions that are not part of the basic instruction set. They are used to define storage space, equate variable names to specific values, identify labels to variable names, etc. In some cases nonexecutable code is generated for assembler pseudo instructions, while in other cases, such as listing control and constant definition, no code is generated.

All of the standard pseudo instructions explained in the *Assembler/Linker Reference Manual* are available to the user. In addition, these standard instructions can be renamed as explained earlier in this chapter, under "Assembler Setup Commands", RENAME_PSEUDO.

The TRACE pseudo enables the user to examine execution of user definable assembler code. For more details and an example, refer to" Tracing the User Definable Assembler", in Chapter 5.

Assembler Instructions

Use the following assembler instructions in the INSTR-SET section to implement the instruction group parsing rules. All arithmetic is performed in two's complement, 32 bits wide. Be certain to read the next section," Conventions".

ADD operand	add the contents of "operand" to the contents of the ACCUMULATOR. The result remains in the ACCUMULATOR.
AND operand	logically ANDs the "operand" with the contents of the ACCUMULATOR. The result remains in the ACCUMULATOR. ACCUMULATOR < -- ACCUMULATOR AND operand
CALL label	transfers program execution to the subroutine at the address specified by label.
DECREMENT operand	decrements the "operand" by one.
DONE	terminates INSTR_SET code and transfers control to the basic assembler module.
END	indicates the end of an assembler module. Each module must be terminated by and END instruction.
GOTO label	transfers program execution to the address specified by label.
IF operand1 "condition" operand2 THEN instruction	compares operand1 with operand2 according to the specified "condition." If "condition" is true, instruction is executed. If not, control is transferred to

the instruction immediately after the IF instruction.

"condition" can be:

> greater than
> equal to or greater than
< less than
< less than or equal to
= equal to
< > not equal to

Note 

All comparisons are unsigned.

INCREMENT operand	increments the contents of "operand" by one. operand < -- operand + 1
LOAD operand	loads the ACCUMULATOR with the contents of "operand." ACCUMULATOR < -- operand
NOP	no operation.
OR operand	logically ORs the contents of "operand" with the contents of the ACCUMULATOR. The result remains in the ACCUMULATOR. ACCUMULATOR < -- ACCUMULATOR OR operand
RETURN n	transfers program control to the "nth" instruction after the CALL instruction. If n is omitted, a return 1 is executed by default.

SHIFT_LEFT n	shifts the ACCUMULATOR contents n bits to the left. Zeros are filled in. 0 < = n < = 32.
SHIFT_RIGHT n	shifts the ACCUMULATOR contents n bits to the right. Zeros are filled in. 0 < = n < = 32.
STORE operand	stores the contents of the ACCUMULATOR in "operand." operand < -- ACCUMULATOR
STORE_0 operand	clears the contents of "operand." operand < -- 0
STORE_1 operand	sets bit 0 of "operand" and clears all other bits. operand < -- 1
SUBTRACT operand	subtracts "operand" contents from ACCUMULATOR contents and stores results in ACCUMULATOR. ACCUMULATOR < -- ACCUMULATOR - operand
TWOS_ COMPLEMENT	calculates the two's complement of ACCUMULATOR contents. ACCUMULATOR < -- ACCUMULATOR + 1

Conventions

Observe the following conventions when programming.

Auto decrement	automatic decrement function is represented by a trailing minus sign; e.g., An-.
Auto increment	automatic increment function is represented by a trailing plus sign; e.g., An+ .
Blank line	blank lines are ignored by the assembler modules.
Comment field	begins with a semicolon.
Comment line	if a semicolon is in the first column, the entire line is treated as a comment.
Delimiters	legal delimiters are: space ; , $: @ ! % # ' & ? . \ / ~ { } or end of line.
End of line	a blank, semicolon, or actual end of line are valid end of line indicators.
Hex notation	the first digit in hexadecimal notation must be a numeral 0 through 9. The suffix H must also be present. For example, F8 in hexadecimal is 0F8H.
Indexing	specified by brackets, [ ]; e.g., [Rn].
Label	identifies a statement. Every label is unique within a source program. A label can be up to 110 characters long, but only the first 15 are used for identification.

Notes

4

Assembler Subroutines

Introduction

This chapter explains all the assembler subroutines and illustrates their operation with one or more examples where appropriate. The assembler subroutines are arranged alphabetically. For quick reference, an alphabetical summary of all the subroutines appears in Appendix C.

Back in Chapter 2, how to define and implement a user instruction set was briefly described (see INSTR_DEF and INSTR_SET). By the end of this current chapter, the user will have seen all the assembler subroutines. At this point, the building process has been explained. Chapter 5 shows how to create the assembler program; it also lists a sample 8080 program if further clarification is needed.

Subroutines And Examples

Note

When program control passes from the basic assembler module to the user definable module, the START and STOP pointers are positioned at the first character in the operand field if the delimiter is a blank. If another delimiter is present, both pointers will be at the delimiter.

Column Pointers

There are two column pointers (START and STOP) not visible to the programmer. Their column location can be identified with the

TRACE pseudo instruction. Refer to "Tracing the User Definable Assembler" in Chapter 5 for an example. These column pointers are initialized to the start of the operand field by the user definable assembler and are used by the subroutines. In most cases, the subroutines called will move the pointers as required; however, they can be moved by the programmer using the assembler instructions. In the subroutine examples that follow, the pointer positions are shown to clarify the subroutine explanation. There is an additional pointer, SAVE_PTR, used with the EXPRESSION subroutine. SAVE_PTR saves the initial position of the STOP pointer. It is useful for flagging errors in expression VALUES and/or TYPES. An example of how the pointers are moved follows.

Example:

There are two operands in the source line. The first operand has been evaluated by the EXPRESSION subroutine and the second operand is to be evaluated next. The STOP pointer is at the first space after operand 1 and there are one or more spaces between the operands.

```
operand1      operand2
       ^
       | STOP pointer
```

The subroutine GET_TOKEN is used to get the next token in the source statement (operand 2). GET_TOKEN begins at the STOP pointer and skips to the first nonblank column. The START pointer is placed at the beginning of the token and the STOP pointer is placed at the first column past the token.

```
            | START pointer
            v.
operand1    operand2
                   ^
                   | STOP pointer
```

To use the subroutine EXPRESSION on operand 2, the STOP pointer must be at the beginning of operand 2. The STOP pointer is moved with the LOAD and STORE instructions. LOAD START loads the column value of the START pointer into the accumulator. STORE STOP stores the contents of the accumulator in the STOP pointer.

```
LOAD START      operand1      operand2
STORE STOP                    ^
                              | START pointer
                              ^
                              | STOP pointer

EXPRESSION can now evaluate operand 2.
```

ADD_LABEL

Puts a label found in the operand field in the symbol table during pass 1. Stores VALUE and TYPE. A return 1 is executed if there is no label. A return 2 is executed if a label is found. This allows the user to insert symbols in the symbol table in addition to the standard symbol table building performed by the assembler.

CHECK_AUTO_DEC

Checks for auto decrement in the form of a trailing operator(s). For example, A- or A--; the - sign(s) represents the auto decrement operator(s). AUTO_DEC_COUNT is set to the number of trailing operators found. In the example A--, it is set to 2. If no operators are found, it is set to 0.

Both CHECK_AUTO_DEC and the next subroutine, CHECK_AUTO_INC, are used in conjunction with the EXPRESSION subroutine. If an expression can legally end in - or + , then these subroutines should be used.

Example:

```
CHECK_AUTO_DEC     R10-
EXPRESSION              ^
                        | STOP pointer after EXPRESSION
    R10-                is invoked
```

Note, if the subroutine is not called before EXPRESSION, then EXPRESSION will flag the - sign as an error.

CHECK_AUTO_INC

Checks for auto increment in the form of a trailing operator(s). For example, B+ or B+ + ; the + sign represents the auto increment operator(s). AUTO_INC_COUNT is set to the number of trailing operators found. If no operators are found, it is set to 0.

CHECK_COMMA

Checks the token at the STOP pointer for a comma. If a comma is not present, a return 1 is executed and the STOP pointer is not changed. If a comma is found, a return 2 is executed and the STOP pointer is incremented by one.

Examples:

```
     | STOP pointer before CHECK_COMMA is invoked.
     v
MVI A:LABEL
     ^
     | STOP pointer after return 1.

     | STOP pointer before CHECK_COMMA is invoked.
     v
MVI A,LABEL
     ^
     | STOP pointer after return 2.
```

CHECK_DELIMITER

Checks for a delimiter at the position indicated by the STOP pointer. If an end of line is found (blank, semicolon, or actual end of line), a return 1 is executed. If the character found is not a legal delimiter, a return 2 is executed and the STOP pointer is not altered. If a legal delimiter is found, the STOP pointer is incremented, the delimiter is stored in CHARACTER, and a return 3 is executed. Legal delimiters were listed under "Conventions", in Chapter 3.

Examples:

```
   | STOP pointer before CHECK_DELIMITER is invoked.
   v
MVI
   ^
   | STOP pointer after return 1.

     | STOP pointer before CHECK_DELIMITER is invoked.
     v
MVI A>LABEL
     ^
     | STOP pointer after return 2.

     | STOP pointer before CHECK_DELIMITER is invoked.
     v
MVI A,LABEL
      ^
      | STOP pointer after return 3.

CHARACTER now contains ","
```

CHECK_EOL

Checks for a valid end of line; i.e., a blank, a semicolon, or the actual end of line. A return 1 is executed if a valid end of line is found. A return 2 is executed if no valid end of line is found. The STOP pointer is not incremented after return 1 or return 2. Example:

```
          ↓ STOP pointer before CHECK_EOL in invoked.
          v
MVI A,LABEL
          ^
          ↑ STOP pointer after return 1 or return 2.
```

CHECK_EXPR_ERROR

After the EXPRESSION handler is called, CHECK_EXPR_ERROR can determine if an error has been flagged by EXPRESSION. If an error is found, a return 1 is executed. If no error is found, a return 2 is executed.

Example:

```
EXPRESSION                ;Evaluate expression.
CHECK_EXPR_ERROR          ;Check for error.
GOTO ERROR_EX             ;Error subroutine.
LOAD VALUE
..
..
..
ETC
```

CHECK_PASS1 _ERROR

A problem arises when a symbol is used in the operand field before it is defined in the symbol table (forward reference). The missing information can introduce an error in the program counter. For example, if the subroutine EXPRESSION is used in pass 1 and a symbol is not defined, the quantities in VALUE and TYPE will not be defined. If the same symbol is defined later, the subroutine EXPRESSION will return the appropriate VALUE and TYPE in pass 2, but the program counter will differ between the two passes, and a different number of bytes of code will be generated. Two error checking routines are included in the user definable assembler to warn the programmer of these oversights.

In either pass 1 or pass 2, if a symbol was not defined when the routine is invoked, the CHECK_PASS1_ERROR routine returns program control to the instruction immediately following the routine call. If the symbol was defined in pass 1, program control is passed to the second instruction following the routine call.

Whan a syntax error is found by the EXPRESSION subroutine, the CHECK_EXPR_ERROR subroutine allows the assembler to stop parsing. Using both error subroutines differentiates between pass 1 errors and syntax errors. The usual sequence of steps and associated code is shown in the next example.

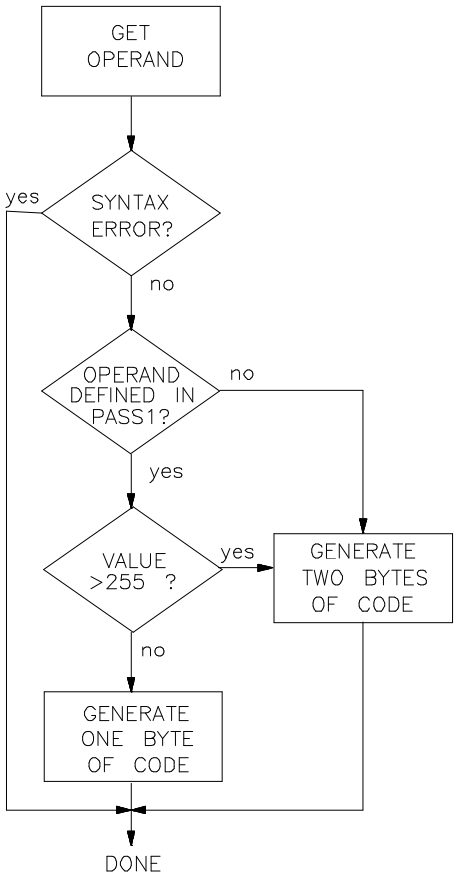


Figure 4-1. Forward Referenced Symbol Code Gen. Chart

Example:

```
EXPRESSION                          ;Get operand.
CHECK_EXPR_ERROR                    ;Was there a syntax error?
DONE                                ;Yes, terminate
CHECK_PASS1_ERROR                   ;Was there a pass 1 error?
GOTO OUTPUT_TWO                     ;Yes- two bytes address.
IF VALUE >255 GOTO OUTPUT_TWO
GEN_CODE ABS 8 VALUE                ;Generate one byte of code.
DONE
OUTPUT_TWO
GEN_CODE ABS 16 VALUE               ;Generate two bytes of code.
DONE
ERROR_ROUTINE
ERROR DE_ERR                        ;Definition error.
DONE
```

COUNTER_UPDATE Increments the program counter by the amount contained in VALUE.

```
program_counter <-- program_counter + VALUE
```

ERROR An error message is displayed from the following list. For example, ERROR IO_ERR.

AS_ERR	ASCII string
CL_ERR	Conditional label
DE_ERR	Definition error
DS_ERR	Duplicate symbol
DZ_ERR	Division by zero
EE_ERR	Expected end of line
EG_ERR	External global
EO_ERR	External overflow
ES_ERR	Expanded source
ET_ERR	Expression type
IC_ERR	Illegal constant
ID_ERR	Invalid delimiter
IE_ERR	Illegal expression
IO_ERR	Invalid operand
IS_ERR	Illegal symbol
IP_ERR	Illegal parameter
LR_ERR	Legal range
MC_ERR	Macro conditional
MD_ERR	Macro definition
ML_ERR	Macro label
MM_ERR	Missing MEND
MO_ERR	Missing operator
MP_ERR	Mismatched parenthesis
MS_ERR	Macro symbol
NI_ERR	Nested includes
OS_ERR	Operand syntax
PC_ERR	Parameter call
PE_ERR	Parameter error
RC_ERR	Repeat call
RM_ERR	Repeat macro
SE_ERR	Stack error
TR_ERR	Text replacement
UC_ERR	Undefined conditional
UE_ERR	Unexpected end of line
UO_ERR	Undefined opcode
UP_ERR	Undefined parameter
US_ERR	Undefined symbol

EVEN n Increments the program counter to an even word boundary if it is set to an odd value. "n" sets the program counter to the next value with "n" trailing zeros.

EXECUTE_OPCODE

Assumes that the STOP pointer is positioned at the start of a user defined opcode. The subroutine looks up the opcode, initializes OBJECT_CODE, and branches to the proper format in the user defined machine code. This occurs just as if the opcode was the first one encountered in the source statement.

Examples:

```
         |STOP pointer before EXECUTE_OPCODE is invoked.
         V
OPCODE   MVI A,LABEL
            ^
            | STOP pointer after EXECUTE_OPCODE is invoked.

    | STOP pointer before EXECUTIVE_OPCODE is invoked.
    V
MVI A,LABEL   ;Error, not a valid user defined opcode.
    ^
    | STOP pointer after EXECUTE_OPCODE is invoked.
```

EXPRESSION Evaluates expressions in the operand field and flags syntax errors in these expressions. Before the subroutine is invoked, the STOP pointer is at the beginning of the expression. After EXPRESSION is invoked, the STOP pointer moves to the next delimiter. The initial position of the STOP pointer is saved in SAVE_PTR as shown in the following example. The SAVE_PTR pointer is useful for flagging errors in expression VALUES and/or TYPES.

Example:

```
    | STOP pointer before EXPRESSION is invoked.
    V
MVI A,LABEL   ;Error, not a valid user defined opcode.
     ^
     | STOP pointer after EXPRESSION is invoked.
    ^
    | SAVE_PTR after EXPRESSION is invoked.
```

EXPRESSION returns two predefined variables: VALUE, which contains the value of the expression and TYPE, which contains the type of the expression. A list of the various expression types follows.

```
TYPE

0     Absolute
1     Program relocatable
2     Data relocatable
3     Common relocatable
4     External reference
5     Equated to external
>6     User definable
```

The EXPRESSION subroutine sets up the following parameters used by the linker.

EXT_OFFSET - value of the offset to an external variable such as in: EXT SAM, SAM1 EQU SAM+ 10. SAM1 is external and has an offset of 10.

EXT_ID_NUMB- identification number assigned to each external symbol.

EXPRESSION_2

Performs exactly like EXPRESSION except for the following two cases:

1. When an open parenthesis is encountered immediately following an operand token in an expression, the evaluation will be cleanly terminated and the VALUE (and other parameters) of the expression up to that point will be returned. The STOP pointer will be left pointing at the open parenthesis.

2. An initial '*' in an expression is considered to be identical with '$' (current location counter). Note that while '$' can occur anywhere in the expression, '*' must occur as the first token in the expression in order not to be mistaken for its use as the multiplication operator.

This version of EXPRESSION is primarily useful in evaluating operand fields where an index register can be enclosed in parenthesis.

FIND_DELIMITER

Finds the next delimiter in the current operand field.

Example:

```
    | STOP pointer before FIND_DELIMITER is invoked.
    v

MVI A,LABEL
     ^
     |STOP pointer after FIND_DELIMITER is invoked.
```

GEN_CODE

Generates absolute or relocatable object code according to the parameters chosen. The program counter is incremented after the code is generated by the amount specified in the GEN_CODE instruction.

Absolute code is generated with:

GEN_CODE ABS < n> , < operand> [SPACE]

where:

```
<n>          is the code size in bits (8 or 16)

<operand>    contains the bit pattern to be generated; e.g.,
             VALUE, OBJECT_CODE, etc.

[SPACE]      inserts a space in the object code field of the
             assembler listing.
```

Relocatable code is generated with:

```
GEN_CODE <name>, VALUE [SPACE]

or (either VALUE or BOTH must be specified)

GEN_CODE <name>, BOTH [SPACE]
```

where:

```
<name>       is used in conjunction with GEN_CODE to identify
             the relocatable addressing mode.

VALUE        uses the contents of the predefined symbols VALUE
             and relocation TYPE to generate code.

BOTH         uses the contents of the predefined symbols VALUE,
             relocation TYPE, and OBJECT_CODE to generate code.
```

The default instruction is GEN_CODE < name> , VALUE.

GET_ASCII_BYTE

Retrieves one ASCII character from an ASCII string within quotation marks. The START pointer must be at the left quote and the STOP pointer must be at the character after the right quote. A return 1 is executed if an end-of-string is found. A return 2 is executed when a valid character is found. The character is stored in the ACCUMULATOR.

Note

The number of characters in the string is equal to: STOP pointer minus START pointer, minus 2. GET_TOKEN should be called prior to GET_ASCII_BYTE. Then the START and STOP pointers will be set so this subroutine will operate properly.

Example:

```
   | START pointer before GET_ASCII_BYTE is invoked.
   v

DB "ASCII string"
                ^
...             | STOP pointer before GET_ASCII BYTE is invoked.
...
LOOP_BACK
       GET_ASCII_BYTE                    ;Get character.
       GOTO END_OF_STRING                ;End-of-string found
       GEN_CODE ABS 8 ACCUMULATOR SPACE  ;Generate one byte.
       GOTO LOOP_BACK                    ;Get another character.
END_OF_STRING
...
...
```

GET_OPCODE

Checks for an opcode. Starts checking at the token indicated by the STOP pointer. Used for multiple opcodes. The value of opcode is placed in VALUE.

Example:

CMA,RLC,DAA

After parsing the CMA instruction, we need to return to the instruction code parsing module to check for the RLC and the DAA instructions. This is achieved by calling GET_OPCODE after each instruction mnemonic is parsed.

GET_PROG_COUNTER

Returns the value of the user's source code program counter in the ACCUMULATOR.

ACCUMULATOR < -- PROGRAM_COUNTER

Example: (Note this is a Z80 instruction)

```
   ↓ STOP pointer before EXPRESSION is invoked.

JR LABEL
        ↑
        | STOP pointer after EXPRESSION is invoked.

EXPRESSION                      ;Get LABEL address.
GET_PROG_COUNTER                ;Get value of PC from ACCUMULATOR.
SUBTRACT VALUE                  ;Offset = PC - LABEL.
```

GET_START_CHAR

Retrieves the character indicated by the START pointer. A return 1 is executed if an end of line is found. A return 2 is executed when a valid character is found and placed in CHARACTER. The START pointer is then incremented by one.

Examples:

```
   ↓ START pointer before GET_START_CHAR is invoked.

MVI
   ↑
   | START pointer after return 1.
```

In this case, the START pointer was at an end of line.

```
          ↓ START pointer before GET_START_CHAR is invoked.

MVI A,LABEL,H
           ↑
           | START pointer after return 2
```

CHARACTER now contains ","

GET_STOP_CHAR

Retrieves the character indicated by the STOP pointer. A return 1 is executed if an end of line is found. A return 2 is executed if a valid character is found. The character is stored in CHARACTER and the STOP pointer is incremented by one.

Examples:

```
   | STOP pointer before GET_STOP_CHAR is invoked.
   V
MVI
   ^
   | STOP pointer after return 1.

           | STOP pointer before GET_STOP_CHAR is invoked.
           V
MVI A,LABEL,H
            ^
            | STOP pointer after return 2.
```

CHARACTER now contains "H"

GET_SYMBOL Checks for a symbol. Starts checking at the token indicated by the STOP pointer. A return 1 is executed if the token is not a symbol (label or user defined symbol) and the STOP pointer remains unchanged. A return 2 is executed if the symbol is not in the symbol table and the STOP pointer remains unchanged. A return 3 is executed if the symbol was identified. VALUE and TYPE contain the value and type of the identified symbol.

Example:

```
    | STOP pointer before GET_SYMBOL is invoked.
    V
MVI A,LABEL
     ^
     | STOP pointer after return 3.
```

If the symbol (A) is identified, the routine will set up the following parameters.

VALUE: the value assigned to the symbol.
TYPE: the type assigned to the symbol.

If the symbol is external, the routine will set up the following parameters.

EXT_ID_NUMB: identification number assigned to each external/global symbol.

EXT_OFFSET:	value of the program counter offset; e.g., used in program counter + displacement addressing modes (JP $+ EXT).

Note

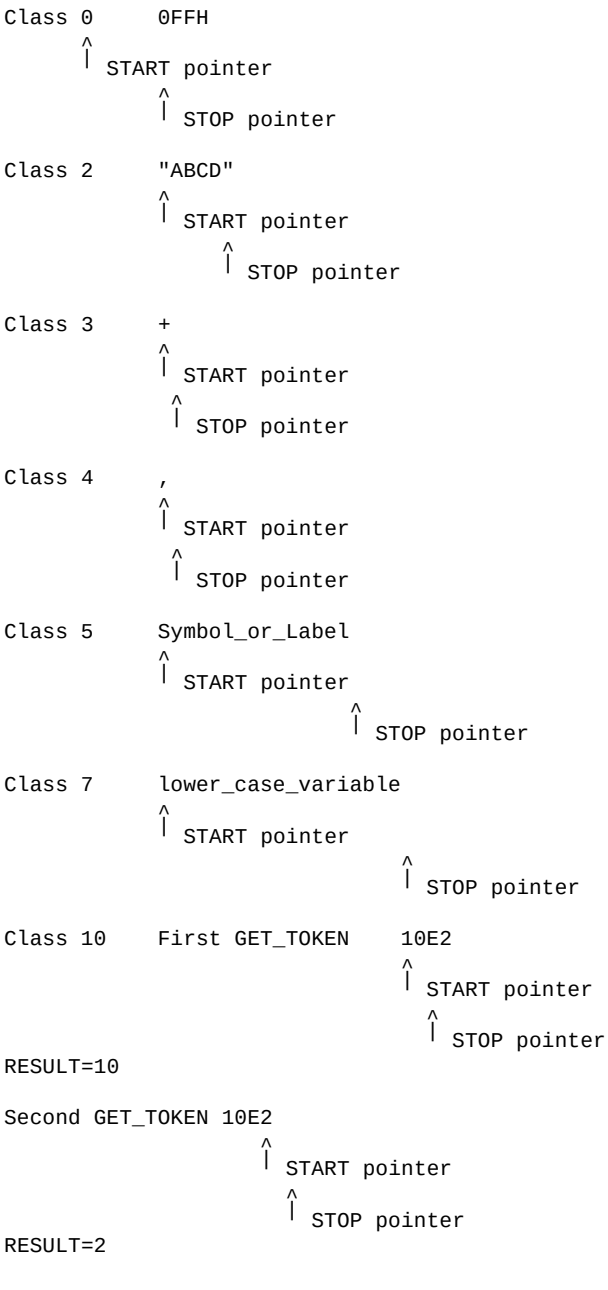
If a return 2 is executed in pass 1, the same return will be taken in pass 2 even though the symbol may have been defined for pass 2.

GET_TOKEN

Gets the next token in the source statement. The subroutine begins at the position of the STOP pointer and skips to the first nonblank column. A token is identified in the source statement with the START pointer at the beginning and the STOP pointer at the first column past the token. Does a return 1 with CLASS containing the class of the token and RESULT containing the value of the token if the token is a numeric constant (CLASS= 0). A numeric constant starts with a digit and ends with one of the following characters to define the constant base: B- binary constant, H- hexadecimal constant, or O or Q- octal constant. If no character is present, a decimal constant is assumed.

```
CLASS
0    Numeric constant
1    Undefined
2    String constant
3    Operator
4    Delimiter
5    Upper case variable
6    Undefined
7    Lower case variable
8    Undefined
9    End of line- no tokens in the string.
10    Decimal constant with E notation.
```

Examples:


Class 0 0FFH
START pointer
STOP pointer
Class 2 "ABCD"
START pointer
STOP pointer
Class 3 +
START pointer
STOP pointer
Class 4 ,
START pointer
STOP pointer
Class 5 Symbol_or_Label
START pointer
STOP pointer
Class 7 lower_case_variable
START pointer
STOP pointer
Class 10 First GET_TOKEN 10E2
START pointer
STOP pointer
RESULT=10
Second GET_TOKEN 10E2
START pointer
STOP pointer
RESULT=2

NOT_DUPLICATE

Can be used in conjunction with UPDATE_LABEL to prevent the assembler from marking a label as a duplicate. Normally, all labels are marked as a duplicate if they are used in the label field more than once. If the user wants the capability to redefine a label and assign it a different VALUE, this subroutine prevents the assembler from flagging the label as an error.

PRINT_LOCATION

Instructs the assembler to print the current value of the program counter on the source listing. Normally, this function is automatic when the subroutine GEN_CODE is called, but if an instruction does not generate code, then this subroutine can be used.

SAVE_ERROR

An error messge is displayed from the same list used for ERROR. The SAVE_PTR pointer is used as the error message pointer in the assembler listing and it must be correctly positioned by the programmer.

Example:

```
         MVI XX,LABEL                ;XX is an invalid operand
             ^
             | SAVE_PTR pointer
ERROR-IO     ^                       Error message in the assembler
             |                       listing.
```

SAVE_WARNING

A warning message is displayed from the same list used for ERROR. The SAVE_PTR pointer is used as the warning message pointer in the assembler listing and it must be correctly positioned by the programmer.

Example:

```
         MVI XX,LABEL                ;XX is an invalid operand.
             ^
             | SAVE_PTR pointer
WARNING-IO   ^                       Warning message in the
             |                       assembler listing.
```

SCAN_REAL

Converts real decimal numbers to binary real numbers. All assemblers currently have a REAL pseudo instruction that converts real decimal numbers to the IEEE standard for short or long real binary numbers. If this is not the encoding desired, SCAN_REAL in the User Definable Assembler can be used to

parse real numbers and generate them in any binary pattern. Exponents can be up to 16 bits and mantissas can be up to 64 bits.

SCAN_REAL is called in the same manner as other User Definable Assembler instructions and uses some of the temporary registers (TEMP38 through TEMP40). It expects the STOP pointer to be positioned at the beginning of a real decimal number (refer to the explanation of the REAL pseudo in the *Assembler/Linker Reference Manual* for real number syntax).

Example:

```
1.23E2                          ;Equals 123 decimal
^
|  STOP pointer
```

Temporary registers 38 through 40 are used to pass information to the SCAN_REAL routine and to obtain converted data.

```
MANTISSA_SIZE = TEMP38          ;Pass mantissa size to
                                ;SCAN_REAL.
EXPONENT      = TEMP38          ;Exponent passed from
                                ;SCAN_REAL.
MANTISSA_HI   = TEMP39          ;Upper 32 bits of mantissa
                                ;from SCAN_REAL.
MANTISSA_LO   = TEMP40          ;Lower 32 bits of mantissa
                                ;from SCAN_REAL.
```

Mantissa size (TEMP38) is initialized before the call to SCAN_REAL to indicate the bit size of the mantissa field for rounding purposes (maximum 64). The SCAN_REAL instruction can then be called to convert the decimal real number. If no syntax errors were found, then the results of the conversion will be in TEMP38 - TEMP40. If there is an error, a return 1 is executed and the stop pointer is not incremented. TEMP38 will hold the binary exponent, TEMP39 the upper 32 bits, and TEMP40 the lower 32 bits of the normalized mantissa. These results can be arranged and output in any manner. Example:

Assume that we will be converting a decimal number to a binary real number with a 50-bit mantissa and the STOP pointer positioned as follows.

```
1.23E2                                ;Decimal 123
^
|  STOP pointer
```

The code would look something like:

```
LOAD 50                          ;Set mantissa size.
STORE TEMP38

SCAN_REAL                        ;Convert decimal number.
GOTO NOT_REAL                    ;Return 1- real number expected.
                                 ;and not found.

--                               ;Return 2- real number found
                                 ;and converted.
```

Results:

```
TEMP38 = 00000006  ;Size of binary exponent.
TEMP39 = F6000000  ;Normalized high part of mantissa.
TEMP40 = 00000000  ;Low part of mantissa.
```

Note

SCAN_REAL will not parse minus signs in front of decimal numbers. Check for these before calling SCAN_REAL.

UPDATE_LABEL

Allows the user to redefine the VALUE and TYPE of the label on the current source statement. The main purpose of this subroutine is to allow the user to assign attributes to symbols and still permit the label to be relocatable. The lower four bits of the TYPE must not be changed; however, the upper 28 bits can be used to assign attributes to the label. These attributes will be carried with the symbol and returned when the EXPRESSION or GET_SYMBOL subroutines are used.

WARNING

A warning message is displayed from the same list used for ERROR. The START pointer is used as the warning message pointer in the assembler listing and it must be correctly positioned by the programmer.

Example:

```
          MVI XX,LABEL                ;XX is an invalid operand.
              ^
              | START pointer
WARNING-IO    ^                       Warning message in the assembler
              |                       listing.
```

Notes

5

Creating An Assembler

Introduction

This chapter explains how to create the user definable assembler source program after the target processor has been completely defined. The assembler program is treated like any other source program, except the output of the assembly process is in absolute format, eliminating the need for a linking sequence. The program is stored in a Model 64000 absolute file to be used to assemble any user target program for the defined microprocessor. Figure 5-1 indicates the sequence of events that occur when creating a user definable source program.

If further explanation is needed, a summary of the building process using the 8080 processor starts after figure 5-1. In Appendix A, the complete assembler code is included. Note that the source line numbers (SN) in the summary examples match those in the complete code in Appendix A.

Also included in this chapter is an example of the TRACE pseudo instruction. This instruction enables the user to examine execution of the user definable assembler program after it has been assembled.

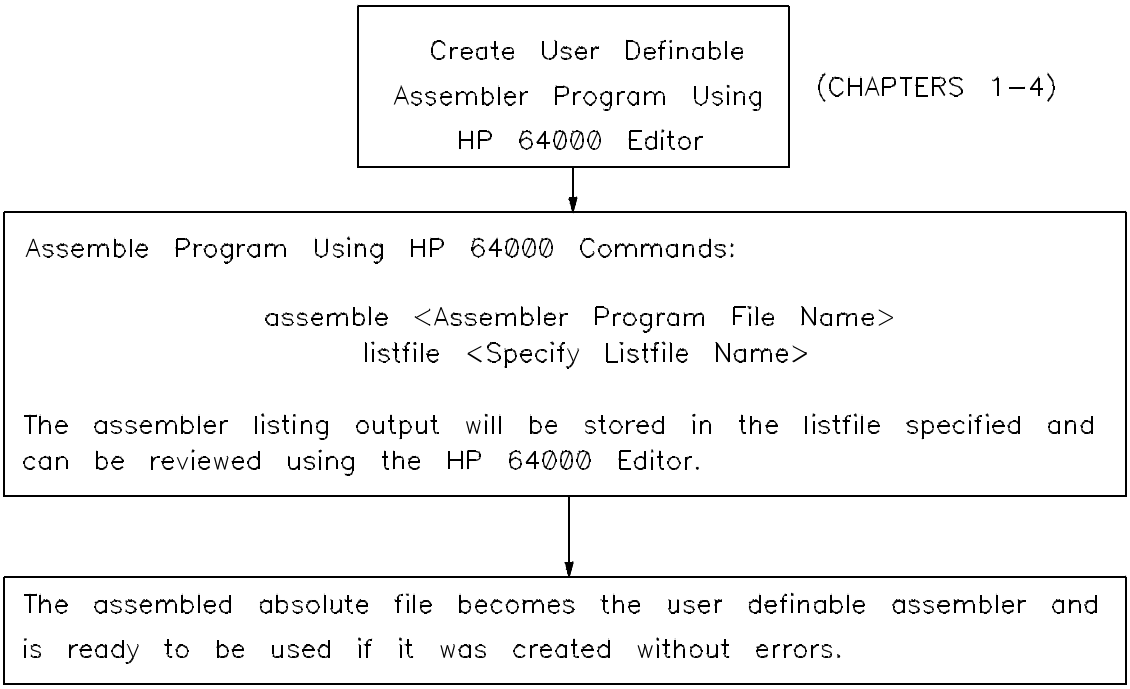


Figure 5-1. Creating the Assembler

Summary Of The Assembler Source Code Building Process for 8080 Processor

Assembler Setup Commands

In defining a processor, the first statement must be the ASSEMBLER setup command followed by the assembler directive in quotation marks. For example:

```
ASSEMBLER "8080"
```

Following the assembler directive statement, the basic parameters of the user processor are defined with the setup commands. These parameters include such things as word size, address size, assembler list title, print field size, linker file identifier, registers, status words, and stack pointers. Some examples of setup commands that may be entered after the ASSEMBLER directive follow.

Example:

```
SN
1  ASSEMBLER "8080"                ;Defines the processor.
.
.
9     WORD_SIZE = 8                ;Defines the word size.
10    ADDRESS_BASE = 8             ;Specifies the program
11                                 ;counter increment.
12    TITLE = "8080"               ;Title for the assembler list.
13    LOC_SIZE = 4                 ;Four characters in the print field for the
                                   ;location counter.
14    LINK_FILE L8080 : XX         ;Specifies linker file.
                                   ;XX is the USERID (1 to 6 characters).
15    PC_16                        ;Only the lower 16 bits
                                   ;of the program counter are used.
17    RELOC_FMT HIGH_LOW, SIZE=16  ;Relocate 16 bits.
18    RELOC_FMT LOW_HIGH, SIZE=16  ;Relocate and swap bytes.
19    RELOC_FMT LOW_BYTE, SIZE=8   ;Low byte, no error check.
20    RELOC_FMT HIGH_BYTE, SIZE=8  ;High byte, no error check.
21    RELOC_FMT LOW_CHECK, SIZE=8  ;Low byte, check for >256.
22    RELOC_FMT REL_8, SIZE=8      ;Plus minus 128.
23    RELOC_FMT PC_REL, SIZE=8     ;-126, +129
```

After the assembler setup commands have been established, the user must identify predefined registers, stack pointers, condition codes, etc., that are relevant to the specified processor. Using the assembler directive listing above as a base, the additional information about the specified microprocessor should be entered into the program as follows:

Example:

```
SN
1  ASSEMBLER "8080"                ;Defines the processor.
.
.
9     WORD_SIZE = 8                ;Defines the word size.
10    ADDRESS_BASE = 8             ;Specifies the program
11                                 ;counter increment.
12    TITLE = "8080"               ;Title for the assembler list.
```

```
13    LOC_SIZE = 4                ;Four characters in the
                                  ;print field for the location counter.
14    LINK_FILE L8080 : XX        ;Specifies linker file.
                                  ;XX is the USERID (1 to 6 characters).
15    PC_16                       ;Only the lower 16 bits
                                  ;of the program counter are used.
17    RELOC_FMT HIGH_LOW, SIZE=16 ;Relocate 16 bits.
.
.
.
25  CONSTANTS
26    HIGH_FLAG = TEMP1           ;Used as a flag if HIGH
                                  ;keyword is found.
27    COUNT = TEMP2               ;Used as a temporary count.
28    MEM_CHECK = TEMP3           ;Used to check memory
                                  ;reference on MOV instructions.
29  END

30
31  SYMBOLS = REGISTER            ;Defines the TYPE and
                                  ;VALUE assigned to the
32    A=7                         ;symbols. REGISTER is
                                  ;TYPE 6. Symbol C has
33    B=0                         ;a VALUE of 1.
34    C=1

.
.
.
40  END

SYMBOLS = XXX_XXX                 ;Continue to add symbol
.                               ;tables, such as condition
.                                 ;codes, where applicable
.                                 ;for the processor.
.                                 ;Terminate each table with
.                                 ;END instruction.
END
```

Defining and Parsing the Instruction Set (INSTR_DEF & INSTR_SET)

The instruction set must be divided into separate groups of instructions that are parsed in the same way by using the command INSTR_DEF. After INSTR_DEF, each instruction should be listed with its object code format. Next, the command INSTR_SET implements the instruction group parsing rules defined for the user processor. After a group (or a single instruction if it is unique) is defined by INSTR_DEF and INSTR_SET, the section is terminated by assembler instruction END. Continuing with the same sample program, implement INSTR_DEF and INSTR_SET as follows.

Example:

```
SN
1  ASSEMBLER "8080"                ;Defines the processor.
.
.
9     WORD_SIZE = 8                ;Defines the word size.
10    ADDRESS_BASE = 8             ;Specifies the program
.                                  ;counter increment.
.
17    RELOC_FMT HIGH_LOW, SIZE=16  ;Relocate 16 bits.
.
.
.
SYMBOLS = XXX_XXX                  ;Continue to add symbol
.                                  ;tables, such as condition
.                                  ;codes, where applicable
.                                  ;for the processor.
.                                  ;Terminate each table with
.                                  ;END instruction.
END

55  INSTR_DEF OPERAND=0
.
.
61    CMC = 3FH                    ;list of no operand
.                                  ;instructions
.
.
.
85    HLT = 76H

87  INSTR_SET
88
89    GEN_CODE ABS 8, OBJECT_CODE
90    DONE
91
92  END
.
.
.
.
```

Continue building INSTR_DEF/INSTR_SET tables until all instructions for the target processor are defined. Refer to Appendix A for complete user defined assembler code for 8080 processor.

Tracing The User Defined Assembler Execution Sequence

The TRACE pseudo instruction allows the user to examine the execution of the user defined assembler program. With it, the user can obtain a printout of the contents in the program counter, accumulator, and VALUE and TYPE variables. TRACE 1 traces pass 1, TRACE 2 traces pass 2, TRACE 3 traces both passes, and TRACE 0 disables the TRACE pseudo. Figure 5-2 shows a sample output from an 8080 source program using the TRACE 2 pseudo instruction. Refer to Appendix A for the complete 8080 source program.

```
       HEWLETT-PACKARD:  8080 ASSEMBLER

LOCATION OBJECT CODE LINE     SOURCE LINE
1  8080R2      TRACE 2
3 P 00000000 0066 EXP   A=00000000 V=00000007 T=0006 START=12 STOP=12
3 P 00000000 0067 IF    A=00000000 V=00000007 T=0006 START=12 STOP=12
3 P 00000000 006A LOAD  A=00000007 V=00000007 T=0006 START=12 STOP=12
3 P 00000000 006B LEFT  A=00000038 V=00000007 T=0006 START=12 STOP=12
3 P 00000000 006C OR    A=0000003E V=00000007 T=0006 START=12 STOP=12
3 P 00000000 006D ST    A=0000003E V=00000007 T=0006 START=12 STOP=12
3 P 00000000 006E COMA  A=0000003E V=00000007 T=0006 START=12 STOP=12
3 P 00000000 0070 CALL  A=0000003E V=00000007 T=0006 START=12 STOP=13
3 P 00000000 0085 ST_0  A=0000003E V=00000007 T=0006 START=12 STOP=13
3 P 00000000 0086 SYMB  A=0000003E V=00000007 T=0006 START=13 STOP=13
3 P 00000000 0087 GOTO  A=0000003E V=00000007 T=0006 START=13 STOP=13
3 P 00000000 008F LOAD  A=00002B6B V=00000007 T=0006 START=13 STOP=13
3 P 00000000 0090 ST    A=00002B6B V=00000007 T=0006 START=13 STOP=13
3 P 00000000 0070 RET   A=00002B6B V=00000007 T=0006 START=13 STOP=13
3 P 00000000 0071 EXP   A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000000 0072 CODE  A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000001 0073 IF    A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000001 0076 CALL  A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000001 0092 COMA  A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000001 0076 RET   A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000001 0077 IF    A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000001 007A CODE  A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000002 007B GOTO  A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000002 0015 EOL   A=00002B6B V=00000020 T=0000 START=13 STOP=16
3 P 00000002 0016 DONE  A=00002B6B V=00000020 T=0000 START=13 STOP=16
0000 3E20               3      MVI   A,20H
4      TRACE 0
ERRORS=  0
```

Figure 5-2 Example of TRACE 2 Output

```
KEY:     1st column is source code line number (here 3)
          2nd column is program counter in use (here P-PROG)
          3rd column is contents of user program counter
          4th column is assembler instruction location
          5th column is assembler instruction abbreviation
          6th column is contents of accumulator
          7th column is VALUE
          8th column is TYPE
          9th column is location of START pointer
         10th column is location of STOP pointer
```

Figure 5-2 Example of TRACE 2 Output (cont.)

Notes

6

Linker General Information

Introduction

A linker combines the relocatable object files generated by the assembler into one file, producing an absolute image that will load and execute within a specified area of physical memory.

Note

If the user already has a 64000 Assembler/Linker for the target processor, there is no need to define a linker program. The existing 64000 linker absolute file can be used unless additional relocatable formats are added to the assembler. It will be located in the 64000 directory under the processor name; e.g., I8085_Z80 : HP.

Linker Operation

As mentioned in Chapter 1, the user definable linker has two modules, the basic linker module and the user definable linker module. The functions performed by these modules are shown in figure 6-1. It is obvious most of the linker functions are performed by the basic linker module that is part of the operating system. The user definable linker module tailors the basic linker module for the target processor.

Certain operations such as performing range checks on the value of an external variable or merging this value with the opcode part of the instruction can only be performed by the user definable linker module. The value of an external variable is not available to the assembler.

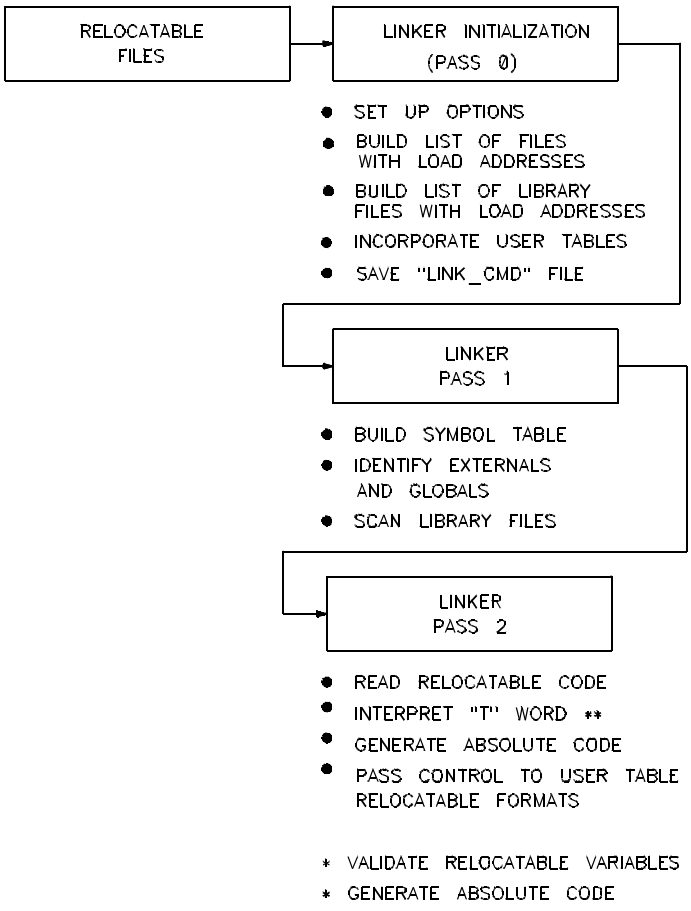


Figure 6-1. Linker Module Functions

6-2 Linker General Information

7

Linker Programming Rules

Linker Structure

The linker structure is similar to the assembler except there are only three sections to be defined by the user. First, the user processor structure is defined by word size, minimum addressable unit (byte or word), number of bits necessary to specify an address, etc. This is accomplished with the linker setup commands. Next, entry points for relocatable routines that will handle the relocatable formats listed in the assembler are defined. Finally, the routines to handle the relocatable code created by the user defined assembler are defined with linker instructions and predefined symbols.

The functional block diagram in figure 7-1 illustrates the linker building process. Each block corresponds to a paragraph title. Sample linker code for the 8080 processor will be used in the explanations. Appendix B contains a complete listing of user defined linker code for the 8080 processor. Note that the source line numbers (SN) in the examples match those in the complete listing in Appendix B.

Caution

The order in which the linker table is constructed is critical to linker operation. Parts of the table can be omitted and no errors will be flagged. Refer to Appendix B for a complete table.

Recall that in the assembler, one of the setup commands was ASSEMBLER "8080", which defined the user processor in the example shown in Chapter 5. There is no directive in the linker structure, only a general "LINK" command that identifies the file as a linker. A virtual processor is used and the setup command in the assembler, LINK_FILE L8080 : USERID, specifies the processor.

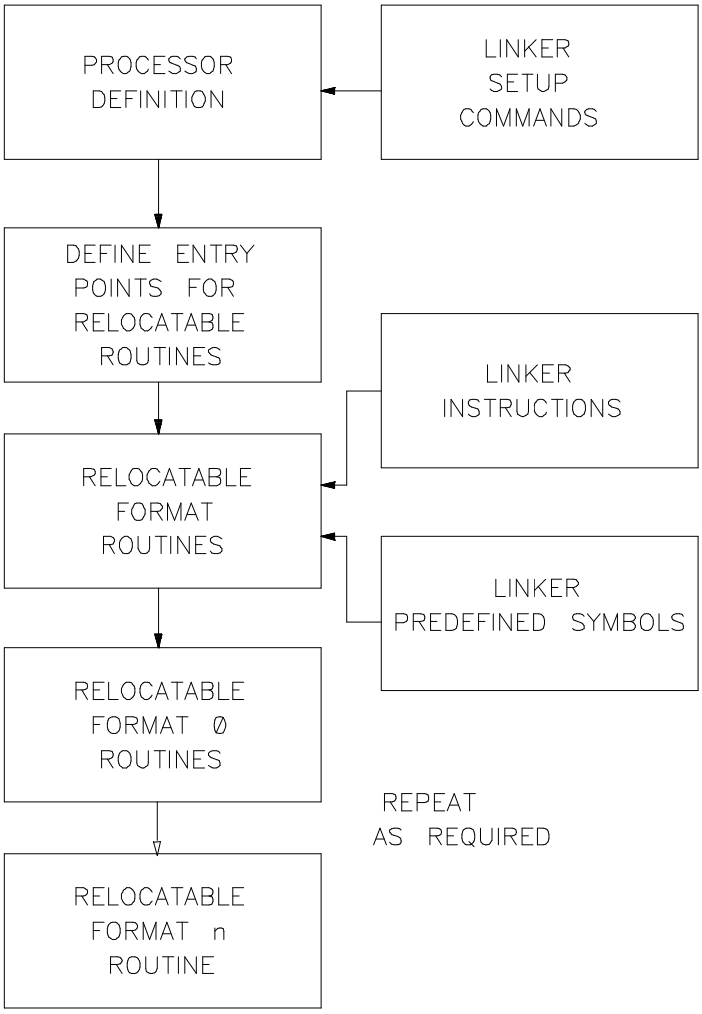


Figure 7-1. Linker Building Process

7-2 Linker Programming Rules

Linker Setup Commands

Use the following setup commands to define the processor structure.

ALIGN	aligns PROG, DATA, and COMMON for each relocatable module by incrementing the load address until: load address AND ALIGN = 0
BASE	smallest addressable unit in bits.
DIGITS0	number of digits to be displayed in pass 0 (initialization).
DIGITS2	number of digits to be displayed in pass 2 (load map)
DBLADR	if set true, treats the program counter as a 32-bit quantity. If set false, all arithmetic operations will only affect the lower 16 bits of the program counter.
HISHIFT	number of bits the high order word has to be shifted to perform the internal/external address conversion.
IDOFFSET	system global describing the number of VALUE words in a symbol (see Appendix D-DBL record). If IDOFFSET = 2 1 word of symbol value DBLARD = false If IDOFFSET = 3 2 words of symbol value DBLADR - true
IND	allows the linker to automatically build indirect links in base page for processors that allow indirect memory addressing modes.

MAXL MAXH	maximum address range allowed during the initialization phase of the linker (pass 0). MAXL contains the least significant 16 bits. MAXH contains the most significant 16 bits.
MULTISPACE	allows programmer to use high order address bits to describe multiple spaces. Note, the user must mask load addresses and symbol addresses internal to the linker.
SWAP	exchanges positions of upper and lower bytes when absolute code is generated.
WIDTH	word size in bits.

Processor Definition

Using the 8080 processor as an example, it is defined as follows:
Word size = 8 bits
Minimum addressable unit = 8 bits (byte)
Bits to define an address = 16

In the next section is sample code defining the 8080 processor. Become familiar with the linker setup commands before examining the sample code.

Sample Code Defining 8080 Processor

The sequence of linker setup commands that must be used is shown in the following sample source code. The sequence cannot be altered and the number od definition words must total 32 (20H). The pseudo instruction HEX is used to store information in the hexadecimal format (refer to *Assembler/Linker Reference Manual* for details). Note the next statement after the definition words must be the length of the table: DEF LAST-$. LAST is the last instruction in the table. Refer to Appendix B, where the complete user defined linker source code for the 8080 processor is included.

```
SN
1  "LINK"
.
.
5     HEX  10                    ;Number of valid constants.
                                 ;In lines 6 through 21 there
                                 ;are 16 constants (10H).
6     HEX  2    IDOFFSET         ;1 word of symbol value, DBLADR is false.
7     HEX  8    WIDTH            ;8-bit words.
8     HEX  8    BASE             ;Byte addressable.
9     HEX  0    ALIGN            ;ALIGN is 0. 8080 does not
                                 ;need to be word aligned.
10    HEX  5    DIGITS0          ;Number of digits to display
                                 ;in pass 0. Need 5H digits
                                 ;to put 16-bit address.
11    HEX  4    DIGITS2          ;Number of digits to display
                                 ;in pass 2. Need 4H digits
                                 ;to output 16-bit address.
12    HEX  0    DBLADR           ;DBLADR is false.
13    HEX  0    SWAP             ;No byte swapping.
14    HEX  0    IND              ;No memory indirect addressing.
15    HEX  0    MULTISPACE       ;True if multiple address spaces.
16    HEX FFFF  MAXL             ;Maximum legal address in
17    HEX  0    MAXH             ;pass 0 is 0FFFFH.
18    HEX  0    UNDEF            ;Included to keep
19    HEX  0    UNDEF            ;word count
20    HEX  0    UNDEF            ;correct.
21    HEX  0    HISHIFT          ;Upper word need not be shifted for internal/
                                 ;external address conversion.
22    HEX  0    UNDEF            ;Included to complete
23    HEX  0    UNDEF            ;word count
24    HEX  0    UNDEF            ;of 32.
25    HEX  0    UNDEF               .
26    HEX  0    UNDEF               .
27    HEX  0    UNDEF               .
28    HEX  0    UNDEF               .
29    HEX  0    UNDEF               .
30    HEX  0    UNDEF               .
31    HEX  0    UNDEF               .
32    HEX  0    UNDEF               .
33    HEX  0    UNDEF               .
34    HEX  0    UNDEF               .
35    HEX  0    UNDEF               .
36    HEX  0    UNDEF               .
37
.
.
41    DEF       LAST-$           ;Word length location must be
                                 ;at 20H (See Appendix B).
```

Define Entry Points For Relocatable Routines

Back in Chapter 2, "Defining The Processor", relocatable formats were defined with the RELOC_FMT setup command. These formats must now be handled with the linker instructions and predefined symbols. The first step is to define the entry points for routines that will handle each relocatable format listed in the assembler. It is essential that the same sequence used in the assembler be followed. The linker instruction DEF is used to define the entry points for the routines. The relocatable formats in Chapter 2 are repeated here with their DEF instructions. Linker instructions and predefined symbols are listed after this section. An explanation of the relocatable routines then follows.

```
RELOC_FMT HIGH_LOW, SIZE = 16          DEF FMT0
RELOC_FMT LOW_HIGH, SIZE = 16          DEF FMT1
RELOC_FMT LOW_BYTE, SIZE = 8           DEF FMT2
RELOC_FMT HIGH_BYTE, SIZE = 8          DEF FMT3
RELOC_FMT LOW_CHECK, SIZE = 8          DEF FMT4
RELOC_FMT REL_8, SIZE = 8              DEF FMT5
RELOC_FMT PC_REL, SIZE = 8             DEF FMT6

Formats FMT0 and FMT1 will be explained for illustration. The source line numbers (SN)
match those in the complete code in Appendix B.
SN
42  DEF FMT0  ;Two-byte address, HI,LO.
43  DEF FMT1  ;Two-byte address, LO,HI.
```

Linker Instructions

Use these linker instructions to write the relocatable format routines.

ADD op1,op2,op3	adds the contents of operand 3 to the contents of operand 2 and returns the result in operand 1. op1 < -- op2 + op3
AND op1,op2,op3	logically ANDs the contents of operand 3 with the contents of operand 2 and returns the result in operand 1. op1 < -- op2 AND op3

BLDLINK	creates indirect addressing links in a predefined area of memory if IND has been set. Finds predefined symbol LLA and loads ADR into LLA.
CALL label	transfers program control to subroutine label. Only one level of subroutines is allowed.
DEF expression	pseudo instruction that allows the definition of expressions typically used with immediate op1 instructions.
DONE	returns control to the basic linker module and generates absolute code.
ERROR "..." WARNING "..."	creates the error or warning message as defined by the immediate ASCII string.
GOTO label	transfers program control to the instruction following the label.
IMMEDIATE op1	loads the value of the constant specified in the next program line into operand 1. op1 < -- constant
IOR op1,op2,op3	performs an inclusive OR function on the contents of operand 2 and operand 3 and returns the result in operand 1. op1 < -- op2 IOR op3
LOADBYTES n	loads the n least significant bytes of LOADWRD into the output buffer.
LOADBITS n	loads the n least significant bits of LOADWRD into the output buffer.
MOVE op1,op2	moves the contents of operand 2 into operand 1. op1 < -- op2

ONECMP op1,op2	computes the one's complement of operand 2 and returns the result into operand 1. op1 < -- op2
RETURN n	returns to location n past CALL.
SEQ op1,op2	skips the next instruction if operand 1 is equal to operand 2.
SEQZ op1	skips the next instruction if operand 1 is equal to zero.
SGE op1,op2	skips the next instruction if operand 1 is greater than or equal to operand 2.
SHIFTL n,op1,op2	shifts the contents of operand 2, n bits to the left and returns the result in operand 1. n = 1 to 16.
SHIFTR n,op1,op2	shifts the contents of operand 2, n bits to the right and returns the result in operand 1. n = 1 to 16.
SKELETON	loads the skeleton of the object code into LOADWRD.
SNEZ op1	skips the next instruction if operand 1 is not equal to zero.
SWAPBYTES op1,op2	interchanges the upper byte with the lower byte in the least significant 16 bits of operand 2 and returns the result in the least significant 16 bits of operand 1.
SWAPWORDS op1,op2	interchanges the upper 16 bits with the lower 16 bits of operand 2 and returns the result in operand 1.

TRACE	prints the values of all the linker variables and registers plus the location code of the TRACE instruction. Helps debug linker code. TRACE must be inserted in the linker source code where required and then removed after the debugging phase is completed.
TWOCMP op1,op2	computes the two's complement of operand 2 and returns the result in operand 1. op1 < -- op2 + 1
XOR op1,op2,op3	performs an exclusive OR function on the contents of operand 2 and operand 3 and returns the result in operand 1. op1 < -- op2 XOR op3

Note

Operands op1,op2, and op3 must be one of the following predefined symbols.

Predefined Symbols

Use these predefined symbols to write the relocatable format routines.

ADR	absolute address of variable to be tested will be contained in ADR.
LLA	links load address. Used in conjunction with BLDLINK and IND.
LOADADR	contains the value of the program counter for the processor.

LOADWRD	machine code word output register. The linker will only generate absolute code with the contents of LOADWRD.
T0 through T3	temporary registers 0 through 3.

Relocatable Format Routines

The entry points for the relocatable routines have been defined with the DEF linker instruction. Now the routines must be written using the linker instructions and predefined symbols to convert the relocatable code to absolute code. Routines FMT0 and FMT1 will be explained for illustration. The source line numbers (SN) match those in the complete code in Appendix B.

```
SN
50  FMT0 MOVE LOADWRD,ADR          ;Move the contents of ADR to LOADWRD.
51       LOADBYTES 2               ;Output two bytes of code
                                   ;that is in LOADWRD.
52       DONE                      ;End of routine.
53  FMT1 SWAPBYTES LOADWRD,ADR     ;Take absolute address in
                                   ;ADR and store in LO HI format in LOADWRD.
54       LOADBYTES 2               ;Output two bytes of code
                                   ;that is in LOADWRD.
55       DONE                      ;End of routine.
```

Appendix D lists the actual relocatable and absolute record file formats by word.

8

Creating The Linker

Introduction

This section explains how to create the user definable linker program after the target processor has been defined. The program will then be stored in a Model 64000 absolute file for future use with the target processor. The program is generated by using the editor function of the Model 64000, following the structure defined in the previous sections. The program file constructed using the editor can now be assembled and linked into an absolute file just as any other source file, except for the use of the virtual processor "LINK". The user defined linker, now in the absolute file, will link the relocatable object code files for the target processor. Figure 8-1 illustrates the sequence of events that should be accomplished by the user.

Also included in this chapter is an example of the TRACE pseudo instruction. This instruction enables the user to examine execution of the user defined linker program.

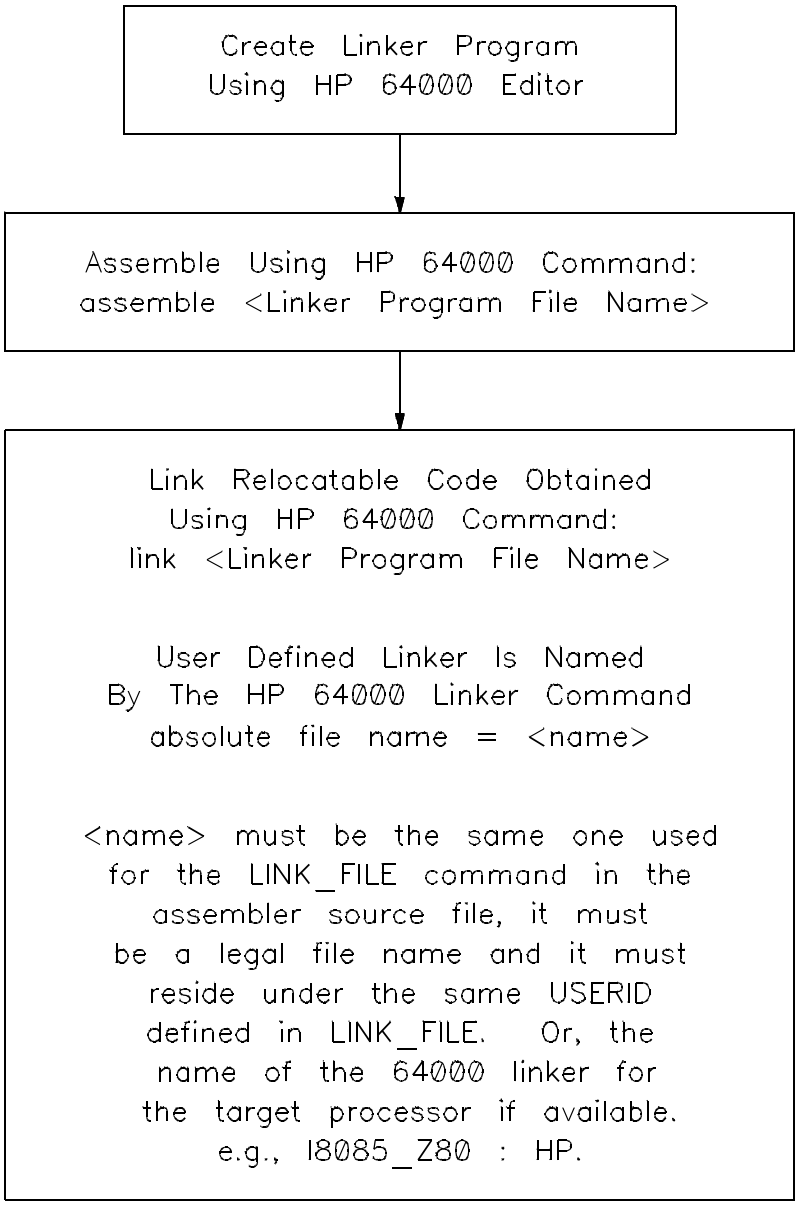


Figure 8-1. Creating the Linker

Tracing The User Defined Linker Execution Sequence

The TRACE instruction allows examination of the user defined linker code during execution. The instruction should not be inserted between IMMEDIATE and DEF or just after skip instructions. TRACE is used in the following example.

Example:

```
FILE: LTRACE: I8080     HEWLETT-PACKARD: USER DEFINABLE LINKER
              OBJECT
LOCATION      CODE      LINE       SOURCE LINE

    0028      0C85      50 FMT0    MOVE LOADWRD,ADR        ;LOADWRD=LOADADR
    0029      0056      51         LOADBYTES 2             ;LOAD 2 BYTES AND LOADBYTES,,
    002A      0018      52         DONE
    002B      0004      53 FMT1    TRACE
    002C      0C88      54         SWAPBYTES LOADWRD,ADR   ;LOADWRD=SWAPBYTES(LOADARD)
    002D      0004      55         TRACE
    002E      0056      56         LOADBYTES 2             ;LOAD 2 BYTES AND LOADBYTES,,
    002F      0004      57         TRACE
    0030      0018      58         DONE
    0031      0C85      59 FMT2    MOVE LOADWRD,ADR        ;LOADWRD=LOADADR
    0032      0036      60         LOADBYTES 1             ;LOAD 1 BYTE AND LOADBYTES,,
    0033      0018      61         DONE
```

The output will contain the following information.

```
HP 64000 LINKER 2.0                                   MON, 9 MAR 19   , 10:30

FILE/PROG   NAME                  PROGRAM    DATA       COMMON       ABSOLUTE        DATE                    TIME
TRACE:I8080                       1000                                               MON,   9 MAR 19   ,   10:29
TRACE AT 002BH LOADADR=1000H LOADWRD=9726H ADR=1002H T0=0000H T1=000H T2=000H T3=000H LLA=000H
TRACE AT 002DH LOADADR=1000H LOADWRD=0210H ADR=1002H T0=0000H T1=000H T2=000H T3=000H LLA=000H
TRACE AT 002FH LOADADR=1002H LOADWRD=0210H ADR=1002H T0=0000H T1=000H T2=000H T3=000H LLA=000H
next address                      1002


XFER address= 0000          Defined by   DEFAULT
absolute & link_com file name=TRACE:I8080
Total# of bytes loaded 0002
```

Notes

9

Uploading To The Mainframe

Introduction

The user defined assembler and linker tables you have created will be used by either the Model 64000 development station or the mainframe. The following instructions will explain how to upload the tables to the mainframe. Following these steps, your custom assembler will be ready for use in the HP-UX environment.

Uploading Assembler Tables

After you have created your user defined assembler table source and assembled it, the resulting table is in absolute format with HP userid and a name beginning with a capital A. For example:

A directive in the UDA source ASSEMBLER "68000" would create the assembler table A68000:HP:absolute.

To upload the assembler table to the mainframe, use the file transfer utility of the Hosted Development System in either the RS232 or High-Speed Link mode to the /usr/hp64000/tables directory. For example, using RS232:

```
transfer -fab A68000:HP:absolute
/usr/hp64000/tables/a68000
```

Using high-speed link:

```
transfer -fha A68000:HP:absolute
/usr/hp64000/tables/a68000
```

Uploading Linker Tables

After you have created your user defined linker table source and assembled it, you should create an absolute file using the linker with a name starting with "L" in the HP userid. The name must be

the same one used for the LINK_FILE command in the assembler source file. For example:

L68000:HP:absolute

To upload the linker table to the mainframe, use the file transfer utility of the Hosted Development System in either the RS232 or High-Speed Link mode to the /usr/hp64000/tables directory. For example, using RS232:

```
transfer -fab L68000:HP:absolute
/usr/hp64000/tables/l68000
```

Using high-speed link:

```
transfer -fha L68000:HP:absolute
/usr/hp64000/tables/l68000
```

Note

For more details on uploading, refer to "Using The File Transfer Utility" chapter in the *Users Guide - Hosted Development System*.

User Defined Assembler Code for 8080 Processor

```
Assembler: A8080:HP        64000 User Definable Assembler Utility

         1 ASSEMBLER "8080"
         2
         3 ;************************************;
         4 ;                                    ;
         5 ;    64840-10002  -  8080 Assembler  ;
         6 ;                                    ;
         7 ;************************************;
         8
0008     9  WORD_SIZE = 8                  ;8 bit processor
0008    10  ADDRESS_BASE = 8               ;byte addressing
        11
        12  TITLE = "8080 Assembler"
0004    13  LOC_SIZE = 4
        14  LINK_FILE 18085_Z80 : HP
        15  PC_16
        16
0000    17  RELOC_FMT HIGH_LOW, SIZE = 16   ;Relocate 16 bits
0001    18  RELOC_FMT LOW_HIGH, SIZE = 16   ;Relocate and swap bytes
0002    19  RELOC_FMT LOW_BYTE, SIZE = 8    ;low byte, no error check
0003    20  RELOC_FMT HIGH_BYTE, SIZE = 8   ;high byte, no error check
0004    21  RELOC_FMT LOW_CHECK, SIZE = 8   ;low byte, check for > 256
0005    22  RELOC_FMT REL_8, SIZE = 8       ;plus minus 128
0006    23  RELOC_FMT PC_REL, SIZE = 8      ;-126, +129
        24
        25  CONSTANTS
001C    26    HIGH_FLAG = TEMP1   ;Use as flag if HIGH keyword found
001E    27    COUNT = TEMP2       ;Use as a temporary count
0020    28    MEM_CHECK = TEMP3   ;Used to check memory reference on
                                  ;MOV instructions
        29  END
        30
0006    31  SYMBOLS = REGISTER
0007    32    A = 7
0000    33    B = 0
0001    34    C = 1
0002    35    D = 2
0003    36    E = 3
```

```
Assembler: A8080:HP        64000 User Definable Assembler Utility

0004    37    H = 4
0005    38    L = 5
0006    39    M = 6
        40  END
        41
0007    42  SYMBOLS = STATUS
0006    43    PSW = 6
        44  END
        45
0008    46  SYMBOLS = STACK
0006    47    SP = 6
        48  END
        49
0009    50  SYMBOLS = ADDR_OPER
0001    51    HIGH = 1
0000    52    LOW = 0
        53  END

0000    55  INSTR_DEF     OPERAND = 0
        56
        57 ;************************************;
        58 ;   No operand instructions            ;
        59 ;************************************;
        60
003F    61    CMC = 03FH
0037    62    STC = 37H
002F    63    CMA = 2FH
0000    64    NOP = 0
0027    65    DAA = 27H
0007    66    RLC = 7
000F    67    RRC = 0FH
0017    68    RAL = 17H
001F    69    RAR = 1FH
00EB    70   XCHG = 0EBH
00E3    71   XTHL = 0E3H
00F9    72   SPHL = 0F9H
00E9    73   PCHL = 0E9H
00C9    74    RET = 0C9H
00D8    75     RC = 0D8H
00D0    76    RNC = 0D0H
00C8    77     RZ = 0C8H
00C0    78    RNZ = 0C0H
00F8    79     RM = 0F8H
00F0    80     RP = 0F0H
00E8    81    RPE = 0E8H
00E0    82    RPO = 0E0H
00FB    83     EI = 0FBH
00F3    84     DI = 0F3H
0076    85    HLT = 76H
        86
```

A-2 User Defined Assembler Code for 8080 Processor

```
                87  INSTR_SET
                88
0001     C014   89    GEN_CODE ABS 8, OBJECT_CODE
0002     000E   90    DONE
                91
                92  END
                93
                94
                95  INSTR_DEF
                96
                97 ;****************************;
                98 ;    restart instruction     ;
                99 ;****************************;
               100
         00C7  101    RST = 0C7H
               102
               103  INSTR_SET
0004     0000  104    EXPRESSION
0005     2D0C  105    IF TYPE <> 0 THEN SAVE_ERROR IO_ERR
0008     2D0A  106    IF VALUE >7 THEN SAVE_ERROR IO_ERR
000B     050A  107    LOAD VALUE
000C     0183  108    SHIFT_LEFT 3
000D     4012  109    GOTO GEN_PRINT
               110
               111  END

               113  INSTR_DEF
               114
               115 ;*******************************;
               116 : operand:  reg 0-7              ;
               117 ;   object code, xxRRRxxx        ;
               118 ;*******************************;
               119
         0004  120    INR = 4
         0005  121    DCR = 5
               122
               123  INSTR_SET
               124
000F     801B  125    CALL GET_REGISTER
0010     050A  126    LOAD VALUE
0011     0183  127    SHIFT_LEFT 3
               128  GEN_PRINT
0012     1514  129    OR    OBJECT_CODE
0013     1914  130    STORE OBJECT_CODE
0014     C014  131    GEN_CODE ABS 8, OBJECT_CODE
               132  CHECK_END
0015     0014  133    CHECK_EOL
0016     000E  134     DONE
               135  EOL_ENTRY
0017     0581  136    LOAD STOP
```

```
Assembler: A8080:HP        64000 User Definable Assembler Utility

0018     1980 137    STORE START
0019     0061 138    ERROR EE_ERR
001A     000E 139    DONE
              140
              141   GET_REGISTER
001B     0000 142    EXPRESSION
001C     2D0C 143    IF TYPE <> REGISTER THEN SAVE_ERROR IO_ERR
001F     01C1 144    RETURN
              145   END
              146
              147
              148   INSTR_DEF
              149
              150 ;*****************************;
              151 ;   operand: reg 0-7          ;
              152 ;      object_code xxxxxRRR     ;
              153 ;*****************************;
              154
         0080 155    ADD = 80H
         0088 156    ADC = 88H
         0090 157    SUB = 90H
         0098 158    SBB = 98H
         00A0 159    ANA = 0A0H
         00AB 160    XRA = 0A8H
         00B0 161    ORA = 0B0H
         00B8 162    CMP = 0B8H
              163
              164   INSTR_SET
              165
0021     801B 166    CALL GET_REGISTER
0022     050A 167    LOAD VALUE
0023     4012 168    GOTO GEN_PRINT
              169
              170   END

              172   INSTR_DEF
              173
              174 ;*******************************;
              175 ;    operand: rp(b or d)        ;
              176 ;     object code, xxRRxxxx       ;
              177 ;*******************************;
              178
         0002 179    STAX = 2
         000A 180    LDAX = 0AH
              181
              182   INSTR_SET
              183
0025     801B 184    CALL GET_REGISTER
0026     050A 185    LOAD VALUE
0027     1002 186    AND 2
```

A-4 User Defined Assembler Code for 8080 Processor

```
0028     2D16 187    IF ACCUMULATOR <> VALUE SAVE_ERROR IO_ERR
002B     0183 188    SHIFT_LEFT 3
002C     4012 189    GOTO GEN_PRINT
              190  END
              191
              192
              193  INSTR_DEF
              194
              195 ;*********************************;
              196 ;   operand: rp b,d,h,sp           ;
              197 ;     xxRRxxxx                     +
              198 ;*********************************;
              199


          0009 200    DAD = 9
          0003 201    INX = 3
          000B 202    DCX = 0BH
              203
              204  INSTR_SET
              205
002E      0000 206    EXPRESSION
002F      2D0C 207    IF TYPE = STACK THEN GOTO FOUND_SP
              208  RP_ENTRY
0032      2D0C 209    IF TYPE <> REGISTER THEN GOTO SAVE_IO_ERROR
0035      2D0A 210    IF VALUE > 4 THEN GOTO SAVE_IO_ERROR
              211  FOUND_SP
0038      050A 212    LOAD VALUE
0039      1006 213    AND 6
003A      2D16 214    IF ACCUMULATOR <> VALUE THEN GOTO SAVE_IO_ERROR
003D      0183 215    SHIFT_LEFT 3
003E      4012 216    GOTO GEN_PRINT
              217
              218  SAVE_IO_ERROR
003F      008A 219    SAVE_ERROR IO_ERR
0040      4012 220    GOTO GEN_PRINT
              221
              222  END

              224  INSTR_DEF
              225
              226 ;*******************************;
              227 ;   operand: rp b,d,h,psw        ;
              228 ;     xxRRxxxx                   +
              229 ;*******************************;
              230
          00C5 231    PUSH = 0C5H
          00C1 232    POP = 0C1H
              233
              234  INSTR_SET
```

```
                235
0042     0000 236    EXPRESSION
0043     2D0C 237    IF TYPE = STATUS THEN GOTO FOUND_SP
0046     4032 238    GOTO RE_ENTRY
                239
                240  END
                241
                242
                243  INSTR_DEF
                244
                245 ;*********************************;
                246 ;   operand: rp b,d,h,sp , low,high  ;
                247 ;     xxRRxxxx                      ;
                248 ;*********************************;
                249
           0001 250    LXI = 1
                251
                252  INSTR_SET
                253
0048     0000 254    EXPRESSION
0049     2D0C 255    IF TYPE = STACK THEN GOTO LXI_SP
004C     2D0C 256    IF TYPE <> REGISTER THEN SAVE_ERROR IO_ERR
004F     2D0A 257    IF TYPE > 4 THEN SAVE_ERROR IO_ERR
                258  LXI_SP
0052     050A 259    LOAD VALUE
0053     0183 260    SHIFT_LEFT 3
0054     1514 261    OR OBJECT_CODE
0055     1914 262    STORE OBJECT_CODE
0056     0007 263    CHECK_COMMA
0057     405F 264     GOTO INVALID_DELIM
0058     0000 265    EXPRESSION
0059     2D0C 266    IF TYPE > 5 THEN SAVE_ERROR IO_ERR
005C     C014 267    GEN_CODE ABS 8, OBJECT_CODE
005D     E1E1 268    GEN_CODE LOW_HIGH VALUE
005E     4015 269    GOTO CHECK_END
                270
                271  INVALID_DELIM
005F     0581 272    LOAD STOP
0060     1980 273    STORE START
0061     004A 274    ERROR IO_ERR
0062     C014 275    GEN_CODE ABS 8, OBJECT_CODE
0063     E1E1 276    GEN_CODE LOW_HIGH VALUE
0064     000E 277    DONE
                278
                279  END

                281  INSTR_DEF
```

A-6 User Defined Assembler Code for 8080 Processor

```
                282 ;*********************************
                283 ;   operand: reg (0-7) , low or high ;
                284 ;     xxRRRxxx immediate byte        ;
                285 ;*********************************;
                286
           0006 287    MVI = 6
                288
                289  INSTR_SET
                290
0066       0000 291    EXPRESSION
0067       2D0C 292    IF TYPE <> REGISTER THEN SAVE_ERROR IO_ERR
006A       050A 293    LOAD VALUE
006B       0183 294    SHIFT_LEFT 3
006C       1514 295    OR OBJECT_CODE
006D       1914 296    STORE OBJECT_CODE
006E       0007 297    CHECK_COMMA
006F       405F 298     GOTO INVALID_DELIM
                299  MVI_ENTRY


0070       8085 300    CALL CHECK_HIGH_LOW
0071       0000 301    EXPRESSION
0072       C014 302    GEN_CODE ABS 8, OBJECT_CODE
0073       2D0C 303    IF TYPE > 5 THEN SAVE_ERROR IO_ERR
0076       8092 304    CALL CHECK_OLD_H
0077       2D1C 305    IF HIGH_FLAG = 1 THEN GOTO GEN_HIGH
007A       E0E2 306    GEN_CODE LOW_BYTE VALUE
007B       4015 307    GOTO CHECK_END
                308
                309  GEN_HIGH
007C       2D0C 310    IF TYPE = 0 THEN GOTO GEN_HIGH_ABS
007F       E0E3 311    GEN_CODE HIGH_BYTE VALUE
0080       4015 312    GOTO CHECK_END
                313
                314  GEN_HIGH_ABS
0081       050A 315    LOAD VALUE
0082       0148 316    SHIFT_RIGHT 8
0083       C016 317    GEN_CODE ABS 8, ACCUMULATOR
0084       4015 318    GOTO CHECK_END
                319
                320  CHECK_HIGH_LOW
0085       1D1C 321    STORE_0 HIGH_FLAG
0086       0001 322    GET_SYMBOL
0087       408F 323     GOTO NOT_OPER
0088       408F 324     GOTO NOT_OPER
0089       2D0C 325    IF TYPE<> ADDR_OPER THEN GOTO NOT_OPER
008C       050A 326    LOAD VALUE
008D       191C 327    STORE HIGH_FLAG
008E       0005 328    GET_TOKEN
                329
```

```
Assembler: A8080:HP        64000 User Definable Assembler Utility


                330  NOT_OPER
008F     0580   331    LOAD START
0090     1981   332    STORE STOP
0091     01C1   333    RETURN
                334
                335  CHECK_OLD_H
0092     0007   336    CHECK_COMMA
0093     01C1   337     RETURN
0094     000A   338    GET_STOP_CHAR
0095     409B   339     GOTO H_ERROR
0096     2D0E   340    IF CHARACTER <> H THEN GOTO H-ERROR

0099     211C   341    STORE_1 HIGH_FLAG
009A     01C1   342    RETURN
                343  H_ERROF
009B     004A   344    ERROR IO_ERROR
009C     01C1   345    RETURN
                346
                347  END
                348
                349
                350  INSTR_DEF
                351
                352 ;*********************************;
                353 ;   operand, immediate            ;
                354 ;     xxxxxxxx immediate          ;
                355 ;*********************************;
                356
          00C6  357    ADI = 0C6H
          00CE  358    ACI = 0CEH
          00D6  359    SUI = 0D6H
          00DE  360    SBI = 0DEH
          00E6  361    ANI = 0E6H
          00EE  362    XRI = 0EEH
          00F6  363    ORI = 0F6H
          00FE  364    CPI = 0FEH
          00DB  365     IN = 0DBH
          00D3  366    OUT = 0D3H
                367
                368  INSTR_SET
                369
009E      4070  370    GOTO MVI_ENTRY
                371
                372  END
                373
                374  INSTR_DEF
                375
```

A-8 User Defined Assembler Code for 8080 Processor

```
                376 ;*********************************;
                377 ;    operand: reg(0-7), reg(0-7)    ;
                377 ;      xxDDDSSS                    +
                379 ;*********************************;
                380
           0040 381    MOV = 040H
                382
                383  INSTR_SET
                384
00A0       801B 385    CALL GET_REGISTER
00A1       050A 386    LOAD VALUE
00A2       1920 387    STORE MEM_CHECK
00A3       0183 388    SHIFT_LEFT 3
00A4       1514 389    OR OBJECT_CODE
00A5       0007 390    CHECK_COMMA
00A6       403F 391     GOTO SAVE_IO_ERROR
00A7       801B 392    CALL GET_REGISTER
00A8       150A 393    OR VALUE
00A9       C016 394    GEN_CODE ABS 8, ACCUMULATOR
00AA       2D20 395    IF MEM_CHECK <> 6 THEN GOTO CHECK_END
00AD       2D0A 396    IF VALUE = 6 THEN SAVE_ERROR IO_ERR
00B0       4015 397    GOTO CHECK_END
                398
                399  END


                401  INSTR_DEF
                402
                403 ;*********************************;
                404 ;    operand: low, high data       ;
                405 ;      xxxxxxxx low, high          ;
                406 ;*********************************;
                407
           0032 408    STA = 032H
           003A 409    LDA = 03AH
           00E2 410    JPO = 0E2H
           0022 411   SHLD = 022H
           002A 412   LHLD = 02AH
           00C3 413    JMP = 0C3H
           00DA 414     JC = 0DAH
           00D2 415    JNC = 0D2H
           00CA 416     JZ = 0CAH
           00C2 417    JNZ = 0C2H
           00FA 418     JM = 0FAH
           00F2 419     JP = 0F2H
           00EA 420    JPE = 0EAH
           00CD 421   CALL = 0CDH
           00DC 422     CC = 0DCH
           00D4 423    CNC = 0D4H
```

```
Assembler: A8080:HP        64000 User Definable Assembler Utility

         00CC 424     CZ = 0CCH
         00C4 425    CNZ = 0C4H
         00FC 426     CM = 0FCH
         00F4 427     CP = 0F4H
         00EC 428    CPE = 0ECH
         00E4 429    CPO = 0E4H
              430
              431  INSTR_SET
              432
00B2     0000 433    EXPRESSION
00B3     2D0C 434    IF TYPE > 5 THEN SAVE_ERROR ET_ERR
00B6     C014 435    GEN_CODE ABS 8, OBJECT_CODE
00B7     E1E1 436    GEN_CODE LOW_HIGH VALUE
00B8     4015 437    GOTO CHECK_END
              438
              439  END
              440
              441
              442  INSTR_DEF
              443
              444 ;*****************************;
              445 ;    define storage pseudo      ;
              446 ;*****************************;
              447
         0000 448    DS = 0
              449
              450  INSTR_SET
              451
00BA     0016 452    PRINT_LOCATION
00BB     0000 453    EXPRESSION
00BC     000D 454    CHECK_PASS1_ERROR
00BD     40C5 455     GOTO DS_ERROR
00BE     2D0C 456    IF TYPE = 0 THEN GOTO TYPE_OK
00C1     0086 457    SAVE_ERROR ET_ERR
00C2     4015 458    GOTO CHECK_END
              459  TYPE_OK
00C3     0013 460    COUNTER_UPDATE
00C4     4015 461    GOTO CHECK_END
              462
              463  DS_ERROR
00C5     008E 464    SAVE_ERROR DE_ERR
00C6     4015 465    GOTO CHECK_END
              466
              467  END
              468
              469
              470  INSTR_DEF
              471
```

A-10 User Defined Assembler Code for 8080 Processor

```
                 472 ;******************************;
                 473 ;    define byte               ;
                 474 ;******************************;
                 475
           0000  476    DB = 0
                 477
                 478  INSTR_SET
                 479
                 480  DP_TOP
00C8       0005  481    GET_TOKEN
00C9       2D82  482    IF CLASS = 2 THEN GOTO BYTE_STRING
                 483  NOT_STRING
00CC       0580  484    LOAD START
00CD       1981  485    STORE STOP
00CE       8085  486    CALL CHECK_HIGH_LOW
00CF       0000  487    EXPRESSION
00D0       2D1C  488    IF HIGH_FLAG = 1 THEN GOTO HIGH_DB
00D3       E0E2  489    GEN_CODE LOW_BYTE VALUE
00D4       40D6  490    GOTO CHECK_NEXT
                 491  HIGH_DB
00D5       E0E3  492    GEN_CODE HIGH_BYTE VALUE
                 493  CHECK_NEXT
00D6       0014  494    CHECK_EOL
00D7       000E  495     DONE
00D8       0007  496    CHECK_COMMA
00D9       4017  497     GOTO EOL_ENTRY
00DA       40C8  498     GOTO DB_TOP
                 499
                 500  BYTE_STRING
00DB       0014  501    CHECK_EOL
00DC       40E0  502     GOTO NOT_EXPR
00DD       0007  503    CHECK_COMMA
00DE       40CC  504     GOTO NOT_STRING
00DF       2981  505    DECREMENT STOP
                 506  NOT_EXPR
00E0       0012  507    GET_ASCII_BYTE
00E1       40D6  508     GOTO CHECK_NEXT
00E2       114C  509    AND AND_WORD
00E3       154E  510    OR OR_WORD
00E4       C016  511    GEN_CODE ABS 8, ACCUMULATOR
00E5       40E0  512    GOTO NOT_EXPR
                 513
                 514  END

                 516  INSTR_DEF
                 517
                 518 ;******************************;
                 519 ;    define word               ;
                 520 ;******************************;
                 521
```

```
Assembler: A8080:HP        64000 User Definable Assembler Utility

         0000 522    DW = 0
              523
              524  INSTR_SET
              525
              526  DW_TOP
00E7     0005 527    GET_TOKEN
00E8     2D82 528    IF CLASS = 2 THEN GOTO WORD_STRING
              529  NOT_STRING1
00EB     0580 530    LOAD START
00EC     1981 531    STORE STOP
00ED     0000 532    EXPRESSION
00EE     E1E1 533    GEN_CODE LOW_HIGH VALUE
              534  CHECK_NEXT1
00EF     0014 535    CHECK_EOL
00F0     000E 536     DONE
00F1     0007 537    CHECK_COMMA
00F2     4017 538     GOTO EOL_ENTRY
00F3     40E7 539     GOTO DW_TOP
              540
              541  WORD_STRING
00F4     1D1E 542    STORE_0 COUNT
00F5     0014 543    CHECK_EOL
00F6     40FA 544     GOTO NOT_EXPR1
00F7     0007 545   CHECK_COMMA
00F8     40EB 546     GOTO NOT_STRING1
00F9     2981 547    DECREMENT STOP
              548  NOT_EXPR1
00FA     0012 549    GET_ASCII_BYTE
00FB     40FF 550     GOTO DONE_STRING
00FC     C016 551    GEN_CODE ASB 8, ACCUMULATOR
00FD     251E 552    INCREMENT COUNT
00FE     40FA 553    GOTO NOT_EXPR1
              554
              555  DONE_STRING
00FF     051E 556    LOAD COUNT
0100     1001 557    AND 1
0101     2D16 558    IF ACCUMULATOR = 0 THEN GOTO CHECK_NEXT1
0104     0420 559    LOAD 20H
0105     C016 560    GEN_CODE ABS 8, ACCUMULATOR
0106     40EF 561    GOTO CHECK_NEXT1
              562
              563  END

End of generation, errors = 0

Words of opcodes = 568, Words of table code = 263, Total = 831
```

User Defined Linker Code for 8080 Processor

```
FILE: L8085_Z80:I8080        HEWLETT-PACKARD: User Definable Linker

         OBJECT
LOCATION  CODE   LINE        SOURCE LINE

                   1  "LINK"
                   2  ******************************************
                   3  ******** 8080/85 Z80  LINKER TABLES *********
                   4  ******************************************
  0000   0010     5   HEX 10   NO OF VALID CONSTANTS
  0001   0002     6   HEX 0002 IDOFFSET
  0002   0008     7   HEX 0008 WIDTH
  0003   0008     8   HEX 0008 BASE
  0004   0000     9   HEX 0000 ALIGN
  0005   0005    10   HEX 0005 DIGITS0    ;#DIGITS TO DISPLAY IN PASS0
  0006   0004    11   HEX 0004 DIGITS2    ;#DIGITS TO DISPLAY IN PASS2
                                           ;(MAP)
  0007   0000    12   HEX 0000 DBLADR
  0008   0000    13   HEX 0000 SWAP
  0009   0000    14   HEX 0000 IND
  000A   0000    15   HEX 0000 MULTISPACE ;TRUE IFF MULTIPLE ADR SPACES
  000B   FFFF    16   HEX FFFF MAXL       ;MAX LEGAL ADR ENTERABLE
                                           ;IN PASS0
  000C   0000    17   HEX 0000 MAXH       ;MAX LEGAL ADR ENTERBLE
                                           ;IN PASS0
  000D   0000    18   HEX 0000 UNDEFINED
  000E   0000    19   HEX 0000 UNDEFINED
  000F   0000    20   HEX 0000 UNDEFINED
  0010   0000    21   HEX 0000 HISHIFT    ;SHIFT COUNT, INTERNAL TO
                                           ;ACTUAL ADDRESS
  0011   0000    22   HEX 0000 UNDEFINED
  0012   0000    23   HEX 0000 UNDEFINED
  0013   0000    24   HEX 0000 UNDEFINED
  0014   0000    25   HEX 0000 UNDEFINED
  0015   0000    26   HEX 0000 UNDEFINED
  0016   0000    27   HEX 0000 UNDEFINED
  0017   0000    28   HEX 0000 UNDEFINED
  0018   0000    29   HEX 0000 UNDEFINED
  0019   0000    30   HEX 0000 UNDEFINED
```

```
FILE: L8085_Z80:I8080       HEWLETT-PACKARD: User Definable Linker

         OBJECT
LOCATION  CODE   LINE       SOURCE LINE

  001A   0000    31   HEX 0000 UNDEFINED
  001B   0000    32   HEX 0000 UNDEFINED
  001C   0000    33   HEX 0000 UNDEFINED
  001D   0000    34   HEX 0000 UNDEFINED
  001E   0000    35   HEX 0000 UNDEFINED
  001F   0000    36   HEX 0000 UNDEFINED


                37 ;
                38 ; LIST OF RELOCATABLE FORMATS FOR THE 8080/85 AND
                39 ; Z80 ASSEMBLERS
                40
  0020   003F    41   DEF LAST-$               ;LENGTH WORD MUST BE AT 20H
  0021   0028    42   DEF FMT0                 ;TWO BYTE ADDRESS, HI,LO
  0022   002B    43   DEF FMT1                 ;TWO BYTE ADDRESS, LO,HI
  0023   002E    44   DEF FMT2                 ;ONE BYTE ADDRESS, LO
                                                ;NO RANGE CHECK
  0024   0031    45   DEF FMT3                 ;ONE BYTE ADDRESS, HI
                                                ;NO RANGE CHECK
  0025   0034    46   DEF FMT4                 ;ONE BYTE ADDRESS, LO
                                                ;(   0 TO 255)
  0026   003B    47   DEF FMT5                 ;ONE BYTE ADDRESS, LO
                                                ;(-128 TO 127)
  0027   0045    48   DEF FMT6                 ;ONE BYTE P_RELATIVE
                                                ;(-126 TO 129)
  0028    0C85   50 FMT0  MOVE LOADWRD,ADR      ;LOADWRD=LOADADR
  0029    0056   51       LOADBYTES 2           ;LOAD 2 BYTES AND
                                                ;LOADBYTES,,
  002A    0018   52       DONE
  002B    0C88   53 FMT1  SWAPBYTES LOADWRD,ADR  ;LOADWRD-SWAPBYTES
                                                ;(LOADADR)
  002C    0056   54       LOADBYTES 2           ;LOAD 2 BYTES AND
                                                ;LOADBYTES,,
  002D    0018   55       DONE
  002E    0C85   56 FMT2  MOVE LOADWRD,ADR      ;LOADWRD=LOADADR
  002F    0036   57       LOADBYTES 1           ;LOAD 1 BYTE AND
                                                ;LOADBYTES,,
  0030    0018   58       DONE
  0031    0C88   59 FMT3  SWAPBYTES LOADWRD,ADR  ;LOADWRD=SWAPBYTES
                                                ;(LOADADR)
  0032    0036   60       LOADBYTES 1           ;LOAD 1 BYTE AND
                                                ;LOADBYTES,,
  0033    0018   61       DONE
  0034    0C85   62 FMT4  MOVE LOADWRD,ADR      ;MOVE THE,ADDRESS
                                                ;INTO LOAD WORD
  0035    0036   63       LOADBYTES 1
  0036    0012   64       IMMEDIATE T0          ;GET UPPER BOUND=256
```

B-2 User Defined Linker Code for 8080 Processor

```
FILE: L8085_Z80:I8080        HEWLETT-PACKARD: User Definable Linker

         OBJECT
LOCATION  CODE   LINE        SOURCE LINE

  0037    0100   65        DEF 0100H
  0038    00CC   66        SGE ADR,T0              ;SKIP IF ADR IS
                                                   ;.GE. 256
  0039    0018   67        DONE
  003A    0A79   68        GOTO ERROR 1            ;ADR OUT OF RANGE,
                                                   ;ERROR
  003B    0C85   69 FMT5   MOVE LOADWRD,ADR        ;MOVE THE,ADDRESS
                                                   ;INTO LOAD WORD
  003C    0036   70        LOADBYTES 1
  003D    0012   71        IMMEDIATE T0            ;THE UPPER 9 BITS
                                                   ;SHOULD BE ALL 1'S
                                                   ;OR 0'S
  003E    FF80   72        DEF 0FF80H              ;MASK UPPER 9 BITS
  003F    0CC1   73        AND ADR,ADR,T0          ;LOOK AT UPPER 9 BITS
                                                   ;OF ADR
  0040    00CF   74        SNEZ ADR                ;SKIP IF UPPER 9 BITS
                                                   ;ARE NOT ALL 0's
  0041    0018   75        DONE
  0042    00CD   76        SEQ ADR,T0              ;SKIP IF UPPER 9 BITS
                                                   ;ARE ALL 1'S
  0043    0A79   77        GOTO ERROR1             ;ADR OUT OF RANGE
  0044    0018   78        DONE
  0045    0A87   79 FMT6   TWOCMP LOADWRD,LOADADR
  0046    8C80   80        ADD LOADWRD,ADR,LOADWRD ;LOADWRD=ADR-LOADADR
  0047    0012   81        IMMEDIATE T0
  0048    FFFF   82        DEF 0FFFFH
  0049    0880   83        ADD LOADWRD,LOADWRD,T0 ;LOADWRD=(ADR-LOADADR)
                                                   ;-1
  004A    0036   84        LOADBYTES 1
  004B    0052   85        IMMEDIATE T2
  004C    FF80   86        DEF 0FF80H              ;GET MASK OF UPPER
                                                   ;9 BITS
  004D    4821   87        AND T1,LOADWRD,T2       ;T1=LOADWRD.AN.T2
  004E    002F   88        SNEZ T1                 ;ARE THEY ALL ZEROS?
  004F    0018   89        DONE
  0050    042D   90        SEQ T1,T2               ;ARE THEY ALL ONES
  0051    0A79   91        GOTO ERROR1             ;UPPER 9 BITS NOT ALL
                                                   ;ONES
  0052    0018   92        DONE
  0053    001C   93ERROR1 ERROR "Address out of range"
          144164
  005F    0018   94 LAST   DONE

ERRORS= 0
```

Note

1. The first section of the linker table must contain 32 words of initialization.
2. The next statement must be the length of the table: DEF LAST-$.
3. The next section is a list of addresses to formats in the linker. This list must have as many entries as formats defined in the assembler (see ASSEMBLER command section in sample program listed in Chapter 5).
4. The label LAST must appear on the same line as the last DONE instruction.

Summary of Assembler Subroutines

The assembler subroutines that were explained in Chapter 4 are summarized here alphabetically for quick reference.

ADD_LABEL	puts a label found in the operand field in the symbol table during pass 1. Stores VALUE and TYPE.
CHECK_AUTO_DEC	checks for auto decrement in the form of a trailing operator(s); e.g., An-.
CHECK_AUTO_INC	checks for auto increment in the form of a trailing operator(s); e.g., An+ .
CHECK_COMMA	checks the token at the STOP pointer for a comma.
CHECK_DELIMITER	checks for a delimiter at the position indicated by the STOP pointer.
CHECK_EOL	checks for a valid end of line; i.e., a blank, a semicolon, or the actual end of line.
CHECK_EXPR_ ERROR	after the EXPRESSION handler is called, CHECK_EXPR_ERROR can determine if an error has been flagged by EXPRESSION.
CHECK_PASS1_ ERROR	executes a return 1 when a symbolic reference is not defined in pass 1 and is defined in pass 1 and is defined in pass 2. Executes a return 2 if the symbolic reference is defined in both passes.

COUNTER_UPDATE	increments the program counter by the amount contained in VALUE.
ERROR code	displays an error message.
EVEN n	increments the program counter to an even word boundary if it is set to an odd value "n" sets the program counter to the next value with 'n' trailing zeros.
EXECUTE_OPCODE	assumes that the STOP pointer is positioned at the start of a user defined opcode. It will look up the opcode, initialize OBJECT_CODE, and branch to the proper format in the user defined machine code, just as if the opcode was the first one encountered in the source statement.
EXPRESSION	evaluates expressions in the operand field and flags syntax errors in the expressions.
FIND_DELIMITER	finds the next delimiter in the present operand field.
GEN_CODE	generates absolute or relocatable object code according to the parameters chosen.
GET_ASCII_BYTE	retrieves one ASCII character from an ASCII string within quotation marks.
GET_OPCODE	checks for an opcode. Starts checking at the token indicated by the STOP pointer. Used for multiple opcodes; e.g., CMA,INA.

GET_PROG_ COUNTER	returns the VALUE of the user's source code program counter in the ACCUMULATOR.
GET_START_CHAR	retrieves the character indicated by the START pointer. @LABELW1 = GET_STOP_CHAR
	retrieves the character indicated by the STOP pointer. @LABELW1 = GET_SYMBOL
	checks for a symbol. Starts checking at the token indicated by the STOP pointer.
GET_TOKEN	gets the next token in the source statement. The subroutine begins at the STOP pointer and skips to the first nonblank column. A token is identified in the source statement with the START pointer at the beginning and the STOP pointer at the first column past the token.
NOT_DUPLICATE	can be used in conjunction with UPDATE_LABEL to prevent the assembler from marking a label as a duplicate.
PRINT_LOCATION	instructs the assembler to print the current VALUE of the program counter on the source listing.
SAVE_ERROR code	displays an error message.
SAVE_WARNING code	displays a warning message.

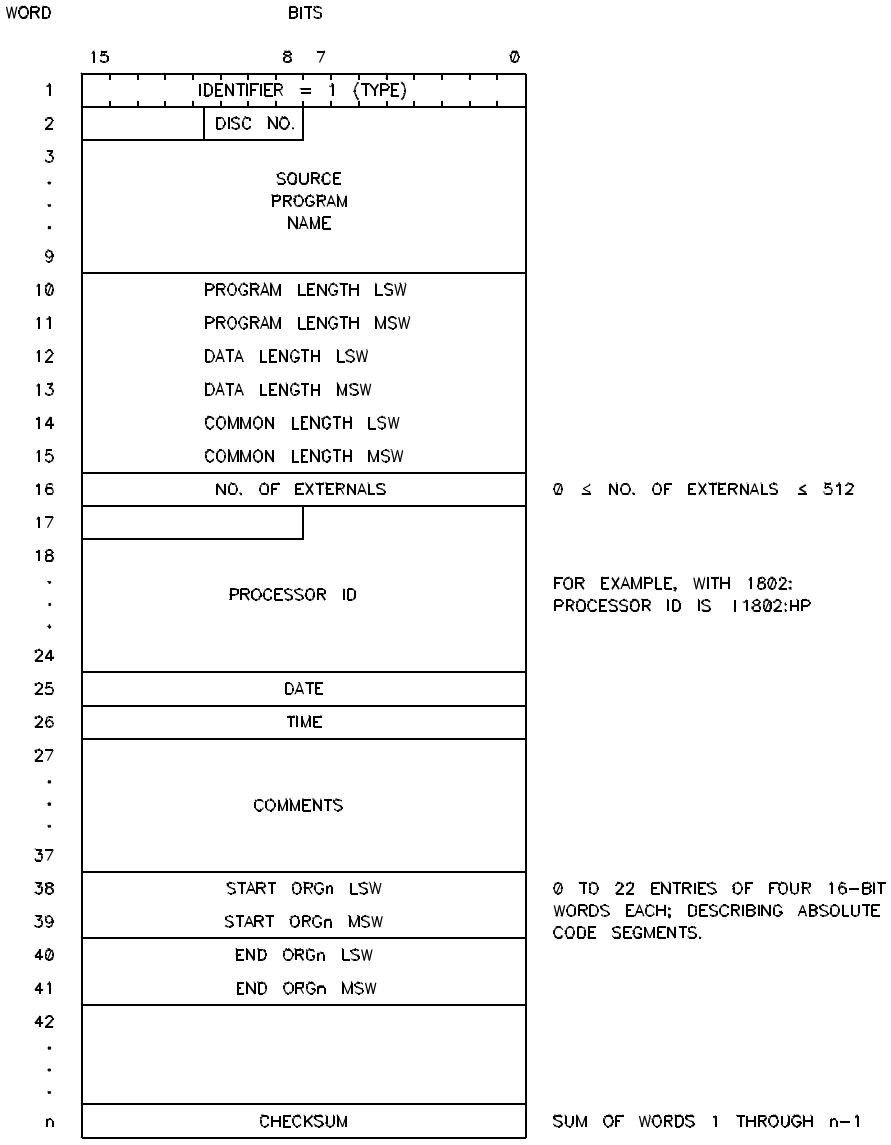
UPDATE_LABEL	allows the user to redefine the VALUE and TYPE of the label on the current line.
WARNING code	displays a warning message.

D

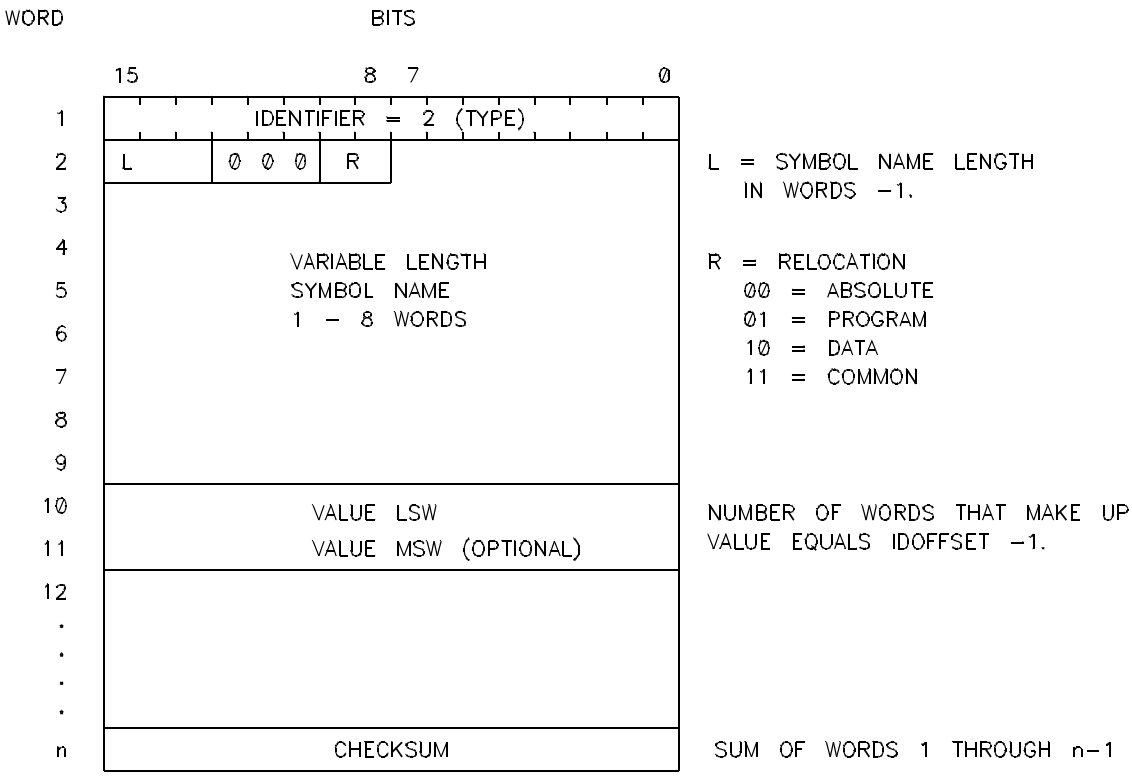
Relocatable and Absolute File Formats

The relocatable file formats for NAM, GLB, DBL, EXT, and END records, plus the absolute file format are included here. Note that the maximum length of a record is 128 words.

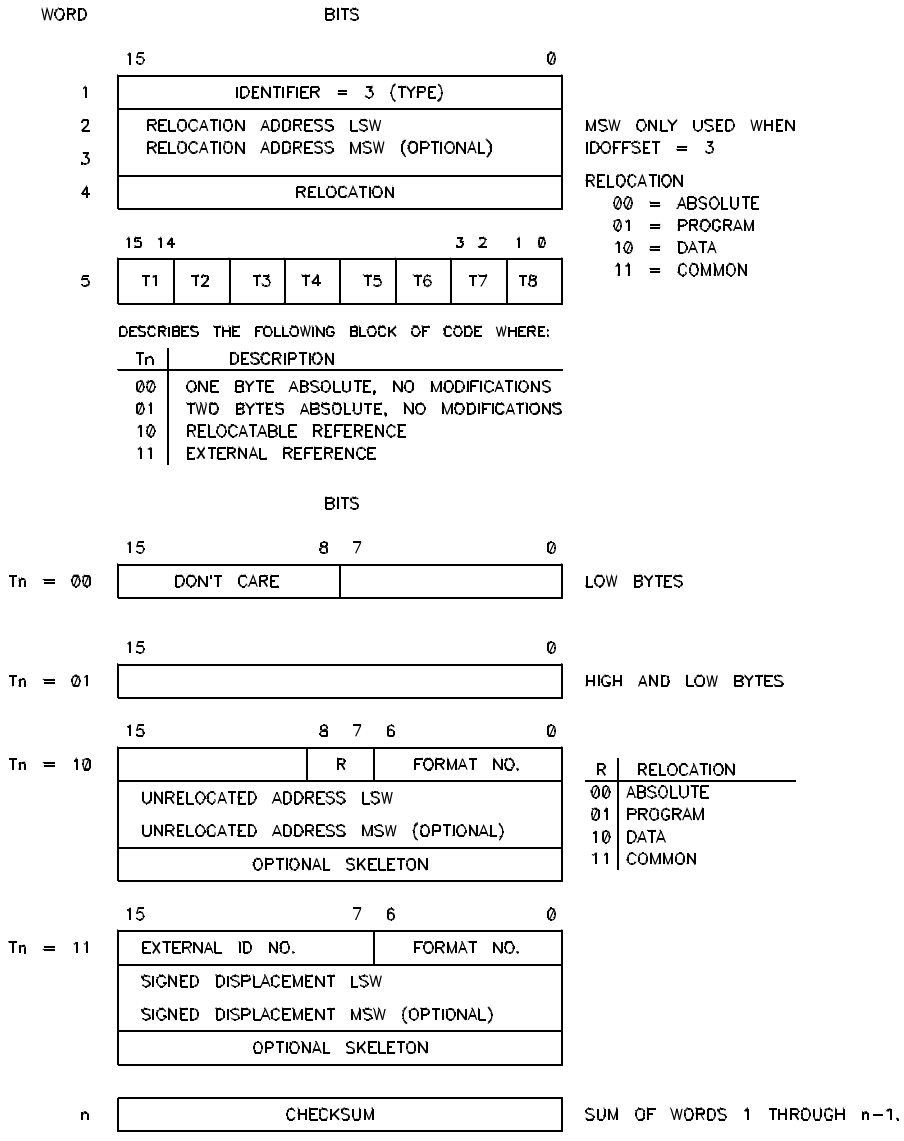
Nam Record
(record Type = 1)



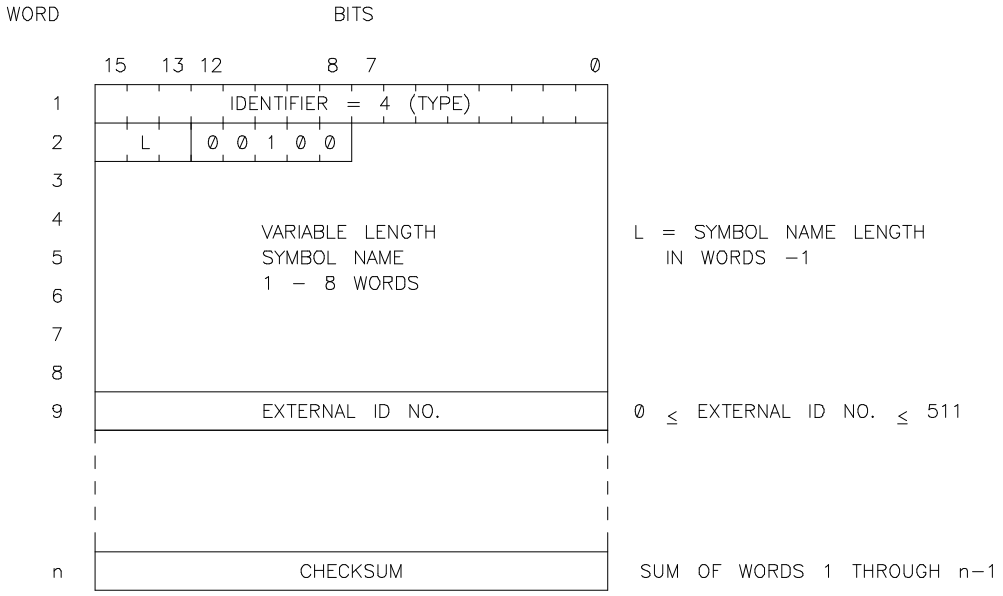
Glb Record
(record Type = 2)



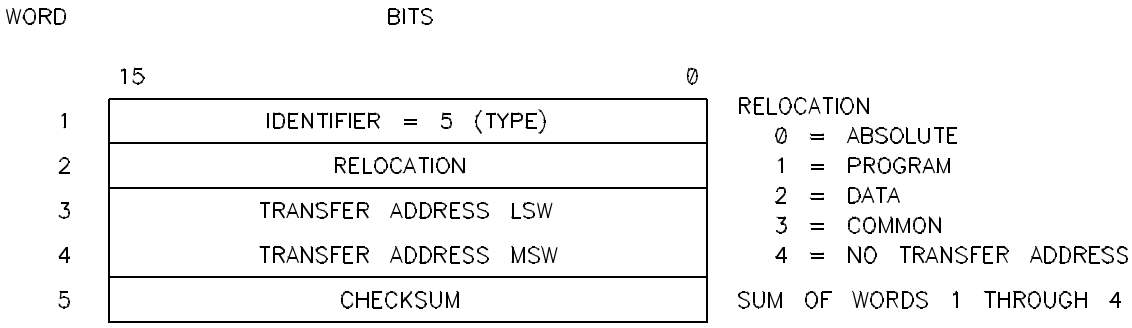
Dbl Record
(record Type = 3)



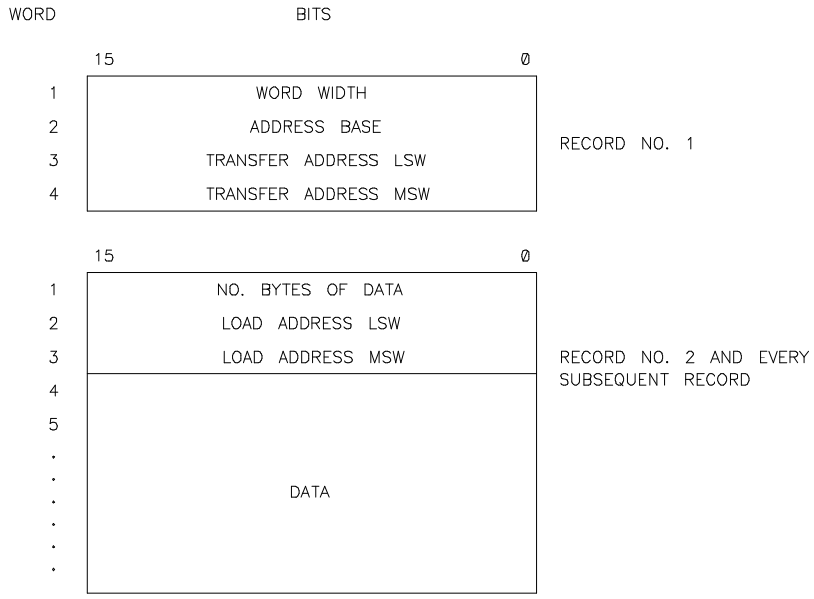
Ext Record
(record Type = 4)



End Record
(record Type = 5)



Absolute File



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