PDP–11 MACRO–11 Language Reference Manual

Order Number AA–KX10A–TC

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This manual describes how to use the MACRO–11 relocatable assembler to develop PDP–11 assembly language programs. Although no prior knowledge of MACRO–11 is required, you should be familiar with the PDP–11 processor addressing modes and instruction set. This manual presents detailed descriptions of MACRO–11's features, including source and command string control of assembly and listing functions, directives for conditional assembly and program sectioning, and user-defined and system macro libraries. The chapters on operating procedures were previously found in two separate manuals (the *Macro–11 Language Reference Manual* and the *IAS/RSX Macro–11 Reference Manual*). This manual should be used with a system-specific user's guide as well as a Linker or a Task Builder manual.

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IAS
MICRO/RSX
MICRO/RSTS
RSTS/E
RSX–11M
RSX–11M–PLUS
RT–11
P/OS
VAX/VMS

Software: MACRO–11 Version 5.5

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Preface

Manual Objectives and Reader Assumptions

This manual is intended to enable you to write programs in the MACRO–11 assembly language.

No prior knowledge of the MACRO–11 Relocatable Assembler is assumed, but you should be familiar with PDP–11 processors and related terminology, as presented in the *PDP–11 Processor Handbook*. You are also encouraged to become familiar with the linking process, as presented in the applicable system manual (see the Associated Documents section below), because linking is necessary for the development of executable programs.

If a terminal is available, we suggest that you try some of the examples in the manual or write a few simple programs that illustrate the concepts covered. Even experienced programmers find that working with a simple program helps them to understand a confusing feature of a new language.

The examples in this manual were done on an RT–11 system. You can also use MACRO–11 on IAS, RSX–11M, RSX–11M–PLUS and RSTS systems (see Part IV for information about operating procedures).

All references to RSX–11M also apply to RSX–11M–PLUS with the exception of those in Chapter 8, which deals with each system individually.

Document Structure

This manual has four parts and eight appendixes.

Part I introduces MACRO–11:

- Chapter 1 lists the key features of MACRO–11.
- Chapter 2 discusses the advantages of following programming standards and conventions and describes the format used in coding MACRO–11 source programs.

Part II presents general information essential to programming with the MACRO–11 assembly language:

- Chapter 3 lists the character set and describes the symbols, terms, and expressions that form the elements of MACRO–11 instructions.
- Chapter 4 describes MACRO–11 output and presents concepts essential to the proper relocation and linking of object modules.
- Chapter 5 describes how data stored in memory can be accessed and manipulated by using the addressing modes recognized by the PDP–11 hardware.

Part III describes the MACRO–11 directives that control the processing of source statements during assembly:

- Chapter 6 discusses directives used for generalized MACRO–11 functions.
- Chapter 7 discusses directives used in the definition and expansion of macros.

Part IV presents the operating procedures for assembling MACRO–11 programs:

- Chapter 8 covers the IAS, RSX–11M, and RSX–11M–PLUS systems.
- Chapter 9 covers the RSTS/RT–11 systems.

Appendix A lists the ASCII and Radix–50 character sets used in MACRO–11 programs.

Appendix B lists the special characters recognized by MACRO–11, summarizes the syntax of the various addressing modes used in PDP–11 processors, and briefly describes the MACRO–11 directives in alphabetical order.

Appendix C lists alphabetically the permanent symbols that have been defined for use with MACRO–11.

Appendix D lists alphabetically the error codes produced by MACRO–11 to identify various types of errors detected during the assembly process.

Appendix E contains a coding standard that is recommended practice in preparing MACRO–11 programs.

Appendix F discusses several methods of conserving dynamic memory space for users of small systems who may experience difficulty in assembling MACRO–11 programs.

Appendix G is a discussion of position-independent code (PIC).

Appendix H contains an assembly and cross-reference listing.

Appendix I contains obsolete MACRO–11 directives, syntax, and command line options.

Appendix J describes the differences from the last release of MACRO–11.

Associated Documents

For descriptions of documents associated with this manual, refer to the applicable documentation directory listed below:

IAS Documentation Directory
RSX–11M–PLUS Information Directory and Master Index
RSX–11M/RSX–11S Information Directory and Index
Guide to RT–11 Documentation
RSTS/E Documentation Directory

Conventions

The color `red` is used in command string examples to indicate user input.

The term **printing characters** includes all characters that display or print a symbol.

The term **nonprinting characters** includes all characters other than those defined as printing characters. It includes space, horizontal and vertical tab, carriage return, line feed, and form feed, even though those characters cause cursor or print head movement.

The symbols defined below are used throughout this manual.

Symbol	Definition
[ ]	Brackets indicate that the enclosed argument is optional.
. . .	Ellipsis indicates optional continuation of an argument list in the form of the last specified argument.
UPPERCASE CHARACTERS	Uppercase characters indicate elements of the language that must be used exactly as shown.
lowercase characters	Lowercase characters indicate elements of the language that are supplied by the programmer.
Subscripts	Subscripts indicate the radix of a number. For example, 100_8 indicates 100, base 8.
(base)	The symbol (base) indicates the radix of numbers in code examples. For example, 100(octal) indicates that 100 is an octal value, while 100(decimal) indicates a decimal value.
CTRL/x or ^x	CTRL/x signifies a control character, generated by simultaneously pressing the CTRL key and the *x* key. CTRL characters are sometimes represented in command line examples by ^x; do not confuse this representation of CTRL characters with MACRO–11 unary operators such as ^B, ^D, ^O, and ^R (see Section 6.4.1.2).

Part I

Chapter 1
The MACRO–11 Assembler

MACRO–11 provides the following features:

- Source and command string control of assembly functions
- Device and filename specifications for input and output files
- Error listing on command output device
- Alphabetized, formatted symbol table listing; optional cross-reference listing of symbols
- Relocatable object modules
- Global symbols for linking object modules
- Conditional assembly directives
- Program sectioning directives
- User-defined macros and macro libraries
- Comprehensive system macro library
- Extensive source and command string control of listing functions

MACRO–11 assembles one or more source files containing MACRO–11 statements into a single relocatable binary object file. The output of MACRO–11 consists of a binary object file and a listing file containing the table of contents, the assembly listing, and the symbol table. An optional cross-reference listing of symbols and macros is available. A sample assembly listing is provided in Appendix H.

1.1 Assembly Pass 1

During pass 1, MACRO–11 locates and reads all required macros from libraries, builds symbol tables and program section tables for the program, and performs a rudimentary assembly of each source statement.

In the first step of assembly pass 1, MACRO–11 initializes all the impure areas (areas containing data) that will be used internally for the assembly process. These areas include all dynamic storage and buffer areas used as file storage regions. MACRO–11 then calls a system subroutine which transfers a command line into memory. This command line contains the specifications of all files to be used during assembly. After scanning the command line for proper syntax, MACRO–11 opens the specified output files. These files are opened to determine if valid output file specifications have been passed in the command line.

MACRO–11 then initiates a routine which reads source lines from the input file. If no input file is open, as is the case at the beginning of assembly, MACRO–11 opens the next input file specified in the command line and starts assembling the source statements. MACRO–11 first determines the length of the instructions, then assembles them according to length as one word, two words, or three words.

At the end of assembly pass 1, MACRO–11 reopens the output files described above. Such information as the object module name, the program version number, and the global symbol directory (GSD) for each program section are written to the object file to be used later in linking the object modules. After writing out the GSD for a given program section, MACRO–11 scans through the symbol tables to find all the global symbols that are bound to that particular program section. MACRO–11 then writes out GSD records to the object file for these symbols. This process is done for each program section.

1.2 Assembly Pass 2

On pass 2 MACRO–11 writes the object records to the binary output file. MACRO–11 also generates the assembly listing and the symbol table listing for the program, plus a cross-reference table if one was requested.

Basically, assembly pass 2 consists of the same steps performed in assembly pass 1, except that all source statements containing MACRO–11-detected errors are flagged with an error code as the assembly listing file is created. The object file that is created as the final consequence of pass 2 contains all the object records, together with relocation records that hold the information necessary for linking the object file.

The information in the object file, when passed to the Task Builder or Linker, enables the global symbols in the object modules to be associated with absolute or virtual memory addresses, thereby forming an executable body of code.

You may want to become familiar with the macro object file format and description, although you do not need to know the format to use MACRO–11 successfully. This information is presented in the applicable system manual (see the Associated Documents section in the Preface).

Chapter 2
Source Program Format

2.1 Programming Standards and Conventions

Programming standards and conventions allow code written by a person (or group) to be easily understood by another person or group. These standards also make the program easier to:

- Plan
- Comprehend
- Test
- Modify
- Convert

The actual standard used must meet local user requirements. A sample coding standard is provided in Appendix E. Used by DIGITAL and its users, this coding example simplifies both communications and the continuing task of software maintenance and improvement.

2.2 Statement Format

A source program is composed of assembly-language statements. Each statement must be completed on one line. Although a line can contain 132_{10} characters (a longer line causes an error (L) in the assembly listing), a line of 80_{10} characters is recommended because of constraints imposed by listing format and terminal line size. Blank lines, although valid, have no significance in the source program.

A MACRO–11 statement may have as many as four fields. These fields are identified by their order within the statement and/or by the separating characters between the fields. The general format of a MACRO–11 statement is:

```
Label:  Operator Operand        ;Comment(s)
```

All the fields are optional, although the operator and operand fields are interdependent; when both operator and operand fields are present in a source statement, each field is evaluated by MACRO–11 in the context of the other.

A statement can contain an operator and no operand, but the reverse is not true. A statement containing an operand with no operator is invalid and is interpreted by MACRO–11 during assembly as an implicit .WORD directive (see Section 6.3.2).

MACRO–11 interprets and processes source program statements one by one. Each statement causes MACRO–11 either to perform a specified assembly process or to generate one or more binary instructions or data words.

2.2.1 Label Field

A label is a user-defined symbol which is assigned the value of the current location counter and entered into the user-defined symbol table. The current location counter is used by MACRO–11 to assign memory addresses to the source program statements as they are encountered during the assembly process. Thus, a label is a means of symbolically referring to a specific statement.

When a program section is absolute, the value of the current location counter is absolute; its value references an absolute virtual memory address, such as location 1100_8. Similarly, when a program section is relocatable, the value of the current location counter is relocatable; a relocation bias calculated at link time is added to the apparent value of the current location counter to establish its effective absolute virtual address at execution time. (For a discussion of program sections and their attributes, see Section 6.7.)

If present, a label must be the first field in a source statement and must be terminated by a colon (:). For example, if the value of the current location counter is absolute 1100_8, the statement:

```
ABCD:    MOV     A,B
```

assigns the value 1100_8 to the label ABCD. If the location counter value were relocatable, the final value of ABCD would be 1100_8+K, where K represents the relocation bias of the program section, as calculated by the Task Builder or Linker at link time.

You can assign multiple labels to the same location by putting them on successive lines. For example, the statements:

```
ABC:
$DD:
A7.7:    MOV     A,B
```

assign the same value to all three labels. This method of assigning multiple labels is preferred, because positioning the fields consistently within the source program makes the program easier to read (see Section 2.3).

More than one label can appear also within a single label field. Each label so specified is assigned the same address value. For example, if the value of the current location counter is 1100_8, the multiple labels in the following statement are each assigned the value 1100_8:

```
ABC:    $DD:    A7.7:    MOV     A,B
```

However, this method of assigning multiple labels to the same location is more difficult to read and is not recommended.

A double colon (::) defines the label as a global symbol. For example, the statement:

```
ABCD::   MOV     A,B
```

establishes the label ABCD as a global symbol. A global symbol can be referenced from an object module other than the module in which the global symbol is defined (see Section 6.8). References from other modules to a global symbol are resolved when the modules are linked as a composite executable image.

The valid characters for defining labels are:

- A through Z
- 0 through 9
- Period (.)
- Dollar Sign ($)

NOTE

By convention, the dollar sign ($) and period (.) are reserved for use in defining DIGITAL system software symbols. Therefore these characters should not be used in defining labels in MACRO–11 source programs.

A label can be any length; however, only the first six characters are significant and, therefore, must be unique among all the labels in the source program. An error code (M) is generated in the assembly listing if the first six characters in two or more labels are the same.

A symbol used as a label must not be redefined within the source program. If the symbol is redefined, a label with a multiple definition results, causing MACRO–11 to generate an error code (M) in the assembly listing. Furthermore, any statement in the source program which references a multi-defined label generates an error code (D) in the assembly listing.

2.2.2 Operator Field

The operator field specifies the action to be performed. It can consist of an instruction mnemonic (op code), an assembler directive, or a macro call. Chapters 6 and 7 describe these three types of operators.

When the operator is an instruction mnemonic, a machine instruction is generated and MACRO–11 evaluates the addresses of the operands which follow. When the operator is a directive, MACRO–11 performs certain control actions or processing operations during the assembly of the source program. When the operator is a macro call, MACRO–11 inserts the code generated by the macro expansion.

Leading and trailing spaces or tabs in the operator field have no significance; such characters serve only to separate the operator field from the preceding and following fields.

An operator is terminated by a tab, space, or any non-Radix–50 character,[1] as in the following examples:

```
MOV     @A,B    ;The tab terminates the operator MOV.
MOV @A,B        ;The space terminates the operator MOV.
MOV@A,B         ;The @ character terminates the operator MOV.
```

[1] Section A.2 contains a table of Radix–50 characters.

Although the statements above are all equivalent in function, the first statement is the recommended form because it is the most readable and conforms to MACRO–11 coding conventions.

2.2.3 Operand Field

When the operator is an instruction mnemonic (op code), the operand field contains program variables that are to be evaluated/manipulated by the operator. The operand field can also supply arguments to MACRO–11 directives and macro calls, as described in Chapters 6 and 7, respectively.

Operands can be expressions or symbols, depending on the operator. Multiple expressions used in the operand field of a MACRO–11 statement must be separated by a comma; multiple symbols similarly used must be delimited by a valid separator (a comma, tab, and/or space). An operand should be preceded by an operator field; if it is not, the statement is treated by MACRO–11 as an implicit `.WORD` directive (see Section 6.3.2).

When the operator field contains an op code, associated operands are always expressions, as shown in the following statement:

```
MOV     R0,A+2(R1)
```

On the other hand, when the operator field contains a MACRO–11 directive or a macro call, associated operands are normally symbols, as shown in the following statement. Assume `.COMPR` is the name of a user-defined macro:

```
.COMPR  ALPHA  SYM1,SYM2
```

Refer to the description of each MACRO–11 directive (Chapter 7) to determine the type and number of operands required in issuing the directive.

The operand field is terminated by a semicolon when the field is followed by a comment. For example, in the following statement:

```
LABEL:  MOV     A,B     ;Comment field
```

the tab between `MOV` and `A` terminates the operator field and defines the beginning of the operand field, a comma separates the operands `A` and `B`, and a semicolon terminates the operand field and defines the beginning of the comment field. When no comment field follows, the operand field is terminated by the end of the source line.

2.2.4 Comment Field

The comment field normally begins in column 33 and extends through the end of the line, although comments can also be entirely separate lines within the program. This field is optional and can contain any 7-bit ASCII or 8-bit DEC Multinational printing characters plus space and horizontal tab. All other characters appearing in the comment field, even special characters reserved for use in MACRO–11, are checked only for ASCII validity and then included in the assembly listing as they appear in the source text.

Comment fields must begin with a semicolon (;). When a lengthy comment extends beyond the end of the source line (column 80), the comment can be continued on the

following line. The continued comment must be preceded by another semicolon. For readability the continued comment can be indented to begin in the same column as the start of the comment on the previous line.

Comments do not affect assembly processing or program execution. However, comments are necessary in source listings for later analysis, debugging, or documentation purposes.

2.3 Format Control

Horizontal formatting of the source program is controlled by the space and tab characters. These characters have no effect on the assembly process unless they are embedded within a symbol, number, or ASCII text string, or unless they are used as the operator field terminator. Thus, space and tab characters can be used to make the source program orderly and readable.

DIGITAL's standard source line format is shown below:

- Label—begins in column 1
- Operator—begins in column 9
- Operands—begin in column 17
- Comments—begin in column 33

These formatting conventions are not mandatory; free-field coding is permissible. However, note the increased readability after formatting in the example below:

```
REGTST:BIT#MASK,VALUE;COMPARES BITS IN OPERANDS.

1       9       17              33      (columns)
REGTST: BIT     #MASK,VALUE     ;Compares bits in operands.
```

Page formatting and assembly listing considerations are discussed in Chapter 6 in the context of MACRO–11 directives that can be specified to accomplish desired formatting operations. Appendix E contains a sample coding standard.

Part II

Chapter 3
Symbols and Expressions

This chapter describes the components of MACRO–11 instructions: the character set, the conventions for constructing symbols, and the use of numbers, operators, terms, and expressions.

3.1 Character Set

The following characters are valid in MACRO–11 source programs:

- The letters A through Z. Both uppercase and lowercase letters are acceptable, although lowercase can be forced to uppercase if desired (see Section 6.2.1, .DSABL LC).
- Characters in the DEC Multinational character set (MCS). Appendix A contains a table showing the MCS. Specific support for the MCS is included with the description of each directive.
- The digits 0 through 9.
- The characters period (.) and dollar sign ($). These characters are reserved for use in Digital Equipment Corporation system program symbols.
- The special characters listed in Table 3–1.

Table 3–1: Special Characters Used in MACRO–11

Character	Designation	Function
:	Colon	Label terminator
::	Double colon	Label terminator; defines the label as a global label
=	Equal sign	Direct assignment operator and macro keyword indicator
==	Double equal sign	Direct assignment operator; defines the symbol as a global symbol
=:	Equal sign colon	Direct assignment operator; macro keyword indicator; causes error (M) in listing if an attempt is made to change the value of the symbol
==:	Double equal sign colon	Direct assignment operator; defines the symbol as a global symbol; causes error (M) in listing if an attempt is made to change the value of the symbol
%	Percent sign	Register term indicator

Table 3–1 (Cont.): Special Characters Used in MACRO–11

Character	Designation	Function
TAB	Horizontal tab	Item or field terminator
SP	Space	Item or field terminator
#	Number sign	Immediate expression indicator
@	At sign	Deferred addressing indicator
(	Left parenthesis	Initial register indicator
)	Right parenthesis	Terminal register indicator
.	Period	Current location counter
,	Comma	Operand field separator
;	Semicolon	Comment field indicator
<	Left angle bracket	Initial argument or expression indicator
>	Right angle bracket	Terminal argument or expression indicator
+	Plus sign	Unary plus, arithmetic addition operator, or autoincrement indicator
-	Minus sign	Unary minus, arithmetic subtraction operator, or autodecrement indicator
*	Asterisk	Arithmetic multiplication operator
/	Slash	Arithmetic division operator
&	Ampersand	Logical AND operator
!	Exclamation point	Logical inclusive OR operator
"	Double quote	Double ASCII character indicator
'	Single quote	Single ASCII character indicator or concatenation indicator
^	Circumflex	Universal unary operator or argument indicator
\	Backslash	Macro call numeric argument indicator

3.1.1 Separating and Delimiting Characters

Valid separating characters and valid argument delimiters are defined in Table 3–2 and Table 3–3, respectively.

Table 3–2: Valid Separating Characters

Character	Definition	Usage
Space	One or more spaces and/or tabs	A space is a valid separator between instruction fields and between symbolic arguments within the operand field. Spaces within expressions are ignored (see Section 3.9).
,	Comma	A comma is a valid separator between symbolic arguments within the operand field. Multiple expressions used in the operand field must be separated by a comma.

3.1.2 Invalid Characters

A character is invalid for one of two reasons:

- If a character is not an element of the recognized MACRO–11 character set, it is replaced in the listing by a question mark, and an error code (I) is printed in the assembly listing. The exception to this is an embedded null which, when detected, is ignored.
- If a valid MACRO–11 character is used in a source statement with invalid or questionable syntax, an error code (Q) is printed in the assembly listing.

Table 3–3: Valid Argument Delimiters

Character	Definition	Usage
<...>	Paired angle brackets	Paired angle brackets can be used anywhere in a program to enclose an expression for treatment as a single term. Paired angle brackets are also used to enclose a macro argument, particularly when that argument contains separating characters (see Section 7.3).
^x...x	Circumflex (unary operator) construction, where the circumflex is followed by an argument that is bracketed by any paired printing characters (x).	This construction is equivalent in function to the paired angle brackets described above and is generally used only where the argument itself contains angle brackets.

3.1.3 Unary and Binary Operators

Table 3–4 describes valid MACRO–11 unary operators. Unary operators are used in connection with single terms (arguments or operands) to indicate an action to be performed on that term during assembly. Because a term preceded by a unary operator is considered to contain that operator, a term so specified can be used alone or as an element of an expression.

Table 3–4: Valid Unary Operators

Unary Operator	Name	Example	Explanation
+	Plus sign	+A	Ignored; equivalent to the value of A
–	Minus sign	–A	Produces the negative (two's complement) value of A
^	Circumflex, universal unary operator; this usage is described in detail in Section 6.4	^C24	Produces the one's complement value of 24_8. Other unary operators using this syntax include ^B, ^D, ^F, ^O, ^R, and ^X.

Unary operators can be used adjacent to each other or in constructions involving multiple terms, as shown below:

–^D50	Equivalent to – <^D50>
^C^O12	Equivalent to ^C <^O12>

Although angle brackets are not required, DIGITAL recommends that you use them for clarity.

Table 3–5 describes valid MACRO–11 binary operators. In contrast to unary operators, binary operators specify actions to be performed on multiple items or terms within an expression.

Table 3–5: Valid Binary Operators

Binary Operator	Name	Example	Explanation
+	Addition operator	A+B	Produces two's complement sum of A and B
–	Subtraction operator	A–B	Produces two's complement difference of A and B
*	Multiplication operator	A*B	Produces two's complement signed 16-bit product
/	Division operator	A/B	Produces two's complement signed 16-bit quotient
&	Logical AND operator	A&B	Performs bitwise logical AND between A and B
!	Logical inclusive OR operator	A!B	Performs bitwise logical inclusive OR between A and B

All binary operators have equal priority. Terms enclosed by angle brackets are evaluated first, and remaining operations are performed from left to right, as shown in the examples below:

```
.WORD   1+2*3           ;Equals 11(8)
.WORD   1+<2*3>         ;Equals 7(8)
```

3.2 MACRO–11 Symbols

MACRO–11 maintains a symbol table for each of the three symbol types that may be defined in a MACRO–11 source program: the Permanent Symbol Table, the User Symbol Table, and the Macro Symbol Table. The Permanent Symbol Table contains all the permanent symbols defined within (and thus automatically recognized by) MACRO–11 and is part of the MACRO–11 image. The User Symbol Table (for user-defined symbols) and Macro Symbol Table (for macro symbols) are constructed as the source program is assembled.

3.2.1 Permanent Symbols

Permanent symbols consist of the instruction mnemonics (see Appendix C) and MACRO–11 directives (see Chapters 6 and 7 and Appendix B). These symbols are a permanent part of the MACRO–11 image and need not be defined before being used in the operator field of a MACRO–11 source statement (see Section 2.2.2).

3.2.2 User-Defined and Macro Symbols

User-defined symbols are those symbols that are equated to a specific value through a direct assignment statement (see Section 3.3), appear as labels (see Section 2.2.1), or act as dummy arguments (see Section 7.1.1). These symbols are added to the User Symbol Table as they are encountered during assembly.

Macro symbols are those symbols used as macro names (see Section 7.1). They are added to the Macro Symbol Table as they are encountered during assembly.

The following rules govern the creation of user-defined and macro symbols:

- Symbols can be composed of alphanumeric characters, dollar signs ($), and periods (.) only (see Note below).
- The first character of a symbol must not be a number (except in the case of local symbols; see Section 3.5).
- The first six characters of a symbol must be unique. A symbol can be written with more than six valid characters, but the seventh and subsequent characters are checked only for ASCII validity and are not otherwise evaluated or recognized by MACRO–11.
- Spaces, tabs, and invalid characters must not be embedded within a symbol. The valid MACRO–11 character set is defined in Section 3.1.

NOTE

The dollar sign ($) and period (.) characters are reserved for use in defining Digital Equipment Corporation system software symbols. For example, `$READ` and `.READ` are file-processing system macros for RSX–11 and RT–11, respectively. DIGITAL suggests that you not use these

characters in constructing user-defined symbols or macro symbols to avoid possible conflicts with existing or future Digital Equipment Corporation system software symbols.

The value of a symbol depends upon its use in the program. A symbol in the operator field can be any one of the three symbol types described above; permanent, user-defined, or macro. To determine the value of an operator-field symbol, MACRO-11 searches the symbol tables in the following order:

1. Macro Symbol Table
2. Permanent Symbol Table
3. User Symbol Table

This search order allows permanent symbols to be used as macro symbols, but you must keep in mind the sequence in which the search for symbols is performed to avoid incorrect interpretation of the symbol's use.

When a symbol appears in the operand field, the search order is:

1. User Symbol Table
2. Permanent Symbol Table

Depending on their use in the source program, user-defined symbols have either a local (internal) attribute or a global (external) attribute.

Normally, MACRO-11 treats all user-defined symbols as local; that is, their definition is limited to the module in which they appear. However, symbols can be explicitly declared to be global symbols through one of three methods:

- Use of the `.GLOBL` directive (see Section 6.8.1)
- Use of the double colon (::) in defining a label (see Section 2.2.1)
- Use of the double equal sign (==) or double equal colon sign (==:) in a direct assignment statement (see Section 3.3)

All symbols within a module that remain undefined at the end of assembly are treated as default global references, unless you use the `.DSABL GBL` directive (see Section 6.2.1). If `.ENABL GBL` is in effect, the undefined symbols are assigned a value of 0 and placed into the User Symbol Table as undefined default global references. If the `.DSABL GBL` directive is in effect, however, the statement containing the undefined symbol is flagged with an error code (U) in the assembly listing.

Global symbols provide linkages between independently assembled object modules within the task image. For example, a global symbol defined as a label may serve as an entry point address to another section of code within the image. Such symbols are referenced from other source modules in order to transfer control throughout execution. These global symbols are resolved at link time, ensuring that the resulting image is a logically coherent and complete body of code.

3.3 Direct Assignment Statements

The general format for a direct assignment statement is:

```
symbol=expression
```

or:

```
symbol==expression
```

where:

expression	can have only one level of forward reference (see list of rules, below) and cannot contain an undefined global reference.

The colon format for a direct assignment statement is:

```
symbol=:expression
```

or:

```
symbol==:expression
```

where:

expression	can have only one level of forward reference (see list of rules, below) and cannot contain an undefined global reference.

All the direct assignment statements above allow you to equate a symbol with a specific value. After the symbol has been defined, it is entered into the User Symbol Table. If the general format is used (= or ==) the value of the symbol can be changed in subsequent direct assignment statements. However, if the colon format is used (=: or ==:), any attempt to change the value of the symbol generates an error (M) in the assembly listing.

A direct assignment statement using either the double equal (==) sign or the double equal colon (==:) sign, as shown above, defines the symbol as global (see Section 6.8.1). The following examples illustrate the coding of direct assignment statements.

```
; Example 1:

        A=10     ;Direct assignment

        B==30    ;Global assignment

        A=15     ;Valid reassignment

        L=:5     ;Equal colon assignment

        M==:A+2  ;Double equal colon assignment
                 ;M becomes equal to 17

        L=4      ;Invalid reassignment
                 ;M error is generated
```

```
; Example 2:

C:
        D=.             ;The symbol D is equated to ., and
E:      MOV #1,ABLE     ;the labels C and E are assigned a
                        ;value that is equal to the location
                        ;of the MOV instruction.  C, D, and E
                        ;all have the same value.
```

The code in Example 2 above would not usually be used and is shown only to illustrate the performance of MACRO–11 in such situations. See Section 3.6 for a description of the period (.) as the current location counter symbol.

The following rules apply to the coding of direct assignment statements:

- An equal sign (=), double equal sign (==), equal colon sign (=:), or double equal colon sign (==:) must separate the symbol from the expression defining the symbol's value. Spaces preceding and/or following the direct assignment operators, although permissible, have no significance in the resulting value.
- The symbol being assigned in a direct assignment statement is placed in the label field.
- Only one symbol can be defined in a single direct assignment statement.
- A direct assignment statement can be followed only by a comment field.
- Only one level of forward referencing is allowed. The following example would cause an error code (U) in the assembly listing on the line containing the invalid forward reference:

```
X=Y     ;Invalid forward reference
Y=Z     ;Valid forward reference
Z=1
```

Although one level of forward referencing is allowed for local symbols, no forward referencing is allowed for global symbols. In other words, the expression being assigned to a global symbol can contain only previously defined symbols. A forward reference in a direct assignment statement defining a global symbol causes an error code (A) in the assembly listing.

3.4 Register Symbols

The eight general registers of the PDP–11 processor are numbered 0 through 7 and can be expressed in the source program in the following manner:

```
%0
%1
 .
 .
 .
%7
```

where % indicates a reference to a register rather than a location. The digit specifying the register can be replaced by any valid, absolute term that can be evaluated during the first assembly pass.

The register definitions listed below are the normal default values predefined by MACRO–11. They remain valid for all register references within a source program.

```
R0=%0   ;Register 0 definition.
R1=%1   ;Register 1 definition.
R2=%2   ;Register 2 definition.
R3=%3   ;Register 3 definition.
R4=%4   ;Register 4 definition.
R5=%5   ;Register 5 definition.
SP=%6   ;Stack pointer definition.
PC=%7   ;Program counter definition.
```

Registers 6 and 7 are given special names because of their unique system functions. The symbolic default names assigned to the registers, as listed above, are the conventional names used in all DIGITAL-supplied PDP–11 system programs. For this reason, you are advised to follow these conventions.

A register symbol can be defined in a direct assignment statement appearing in the program. The defining expression of a register symbol must be a valid, absolute value between 0 and 7, inclusive, or an error code (R) will appear in the assembly listing. Although you can reassign the standard register symbols through the use of the .DSABL REG directive (see Section 6.2.1), this practice is not recommended. An attempt to redefine a default register symbol without first specifying the .DSABL REG directive to override the normal register definitions causes that assignment statement to be flagged with an error code (R) in the assembly listing. All nonstandard register symbols must be defined before they are referenced in the source program.

The % character can be used with any valid term or expression to specify a register. For example, the statement:

```
CLR     %3+1
```

is equivalent in function to the statement:

```
CLR     %4
```

and clears the contents of register 4.

In contrast, the statement:

```
CLR     4
```

clears the contents of virtual memory location 4.

The accumulator registers used in floating-point instructions can be defined in a similar manner. For example, with the definition:

```
AC0=%0
```

the statement:

```
MULF    @R0,AC0
```

multiplies the contents of floating-point accumulator register AC0 by the floating-point number addressed by R0.

3.5 Local Symbols

Local symbols are specially formatted symbols used as labels within a block of coding that has been delimited as a local symbol block. Local symbols are of the form n$, where n is a decimal integer from 1 to 65535, inclusive. Examples of local symbols are:

```
  1$:
 27$:
 59$:
104$:
```

A local symbol block is delimited in one of three ways:

- The range of a local symbol block usually consists of those statements between two normally constructed symbolic labels (see Figure 3–1). Note that a statement of the form:

  ```
  ALPHA=EXPRESSION
  ```

  is a direct assignment statement (see Section 3.3) but does not create a label and thus does not delimit the range of a local symbol block.

- The range of a local symbol block is normally terminated upon encountering a `.PSECT`, `.CSECT`, `.ASECT`, or `.RESTORE` directive in the source program (see Figure 3–1).

- The range of a local symbol block is delimited through MACRO–11 directives, as follows:

  Starting delimiter: `.ENABL LSB` (see Section 6.2.1)
  Ending delimiter: `.DSABL LSB`

  or one of the following:

  Symbolic label (see Section 2.2.1)
  `.PSECT` (see Section 6.7.1)
  `.CSECT` (see Section 6.7.2)
  `.ASECT` (see Section 6.7.2)
  `.RESTORE` (see Section 6.7.4)

  encountered after a `.DSABL LSB` (see Section 6.2.1).

Local symbols provide a convenient means of generating labels for branch instructions and other such references within local symbol blocks. Using local symbols reduces the possibility of symbols with multiple definitions appearing within a user program. In addition, the use of local symbols differentiates entry-point labels from local labels, since local symbols cannot be referenced from outside their respective local symbol blocks. Thus, local symbols of the same name can appear in other local symbol blocks without conflict. Local symbols do not appear in cross-reference listings and require less symbol table space than other types of symbols. Their use is recommended.

When defining local symbols, use the range from 1$ to 29999$ first. Local symbols within the range 30000$ through 65535$, inclusive, can be generated automatically as a feature of MACRO–11. Such local symbols are useful in the expansion of macros during assembly (see Section 7.3.5).

Be sure to avoid multiple definitions of local symbols within the same local symbol block. For example, if the local symbol 10$ is defined more than once within the same local symbol block, each symbol represents a different address value. Such a multidefined symbol causes an error code (P) in the assembly listing.

For examples of local symbols and local symbol blocks as they appear in a source program, see Figure 3–1.

Figure 3–1: Assembly Listing Showing Local Symbol Block

```
 1                      ;+
 2                      ; Simple illustration of local symbols; the second block is delimited
 3                      ; by the label XCTPAS.
 4                      ;-
 5
 6 000000  012700  XCTPRG: MOV     #IMPURE,R0      ;Point to impure area
           000000G
 7 000004  005020  1$:     CLR     (R0)+           ;Clear a word
 8 000006  020027          CMP     R0,#IMPURT      ;Test if at top of area
           000000G
 9 000012  001374          BNE     1$              ;Iterate if not
10                                                 ;Fall in to perform pass initialization
11 000014  012700  XCTPAS: MOV     #IMPPAS,R0      ;Point to pass storage area
           000000G
12 000020  005020  1$:     CLR     (R0)+           ;Clear the area
13 000022  020027          CMP     R0,#IMPPAT      ;Test if at top of area
           000000G
14 000026  001374          BNE     1$              ;Iterate if not
15 000030  000207          RETURN                  ;Return if so
16
```

3.6 Current Location Counter

The period (.) is the symbol for the current location counter. When used in the operand field of an instruction, the period represents the address of the first word of the instruction, as shown in this example:

```
A:      MOV     #.,R0           ;The period (.) refers to the address
                                ;of the MOV instruction.
```

The function of the number sign (#) is explained in Section 5.9.

When used in the operand field of a MACRO–11 directive, the period represents the address of the current byte or word, as shown here:

```
SAL=0
.WORD 177535,.+4,SAL    ;The operand .+4 in the .WORD
                        ;directive represents a value
                        ;that is stored as the second
                        ;of three words during
                        ;assembly.
```

Assume that the current value of the location counter is 1500_8. During assembly, MACRO–11 reserves storage in response to the .WORD directive (see Section 6.3.2), beginning with location 1500_8. The operands accompanying the .WORD directive determine the values so stored. The value 177535_8 is thus stored in location 1500. The value represented by .+4 is stored in location 1502; this value is derived as the current value of the location counter (which is now 1502), plus the absolute value 4, thereby depositing the value 1506 in location 1502. Finally, the value of SAL, previously equated to 0, is deposited in location 1504:

```
Location 1500:   177535
Location 1502:   001506
Location 1504:   000000
```

At the beginning of each assembly pass, MACRO–11 resets the location counter. Normally, consecutive memory locations are assigned to each byte of object data generated. However, the value of the location counter can be changed through a direct assignment statement of the following form:

```
.=expression
```

The current location counter symbol (.) is either absolute or relocatable, depending on the attribute of the current program section.

The attribute of the current location counter can be changed only through the program sectioning directives (.PSECT, .ASECT, .CSECT, and .RESTORE), as described in Section 6.7. Therefore, assigning to the current location counter an expression having an attribute other than that of the current program section will generate an error code (A) in the assembly listing.

Furthermore, an expression assigned to the current location counter cannot contain a forward reference (a reference to a symbol that is not previously defined). You must also be sure that the expression assigned does not force the current location counter into another program section, even if both sections involved have the same relocatability. Either of these conditions causes MACRO–11 to generate incorrect object file code, and may cause statements following the error to be flagged with an error code (P) in the assembly listing.

The following coding illustrates the use of the current location counter:

```
        .ASECT
.=1500                          ;Set location counter to
                               ;absolute 1500(octal).
FIRST:  MOV     .+10,COUNT      ;The label "FIRST" has the value
                               ;1500(octal).
                               ;.+10 equals 1510(octal). The
                               ;contents of the location
                               ;1510(octal) will be deposited
                               ;in the location "COUNT".
.=1520                          ;The assembly location counter
                               ;now has a value of
                               ;absolute 1520(octal).
SECOND: MOV     .,INDEX         ;The label "SECOND" has the
                               ;value 1520(octal).
                               ;The contents of location
                               ;1520(octal), that is, the binary
                               ;code for the instruction
                               ;itself, will be deposited in the
                               ;location "INDEX".
        .PSECT
.=.+20                          ;Set location counter to
                               ;relocatable 20 of the
                               ;unnamed program section.
THIRD:  .WORD   0               ;The label "THIRD" has the
                               ;value of relocatable 20.
```

Storage areas can be reserved in the program by advancing the location counter. For example, if the current value of the location counter is 1000, each of the following statements:

```
.=.+40
```

or:

```
.BLKB 40
```

or:

```
.BLKW 20
```

reserves 40_8 bytes of storage space in the source program starting at location 1000. The .BLKB and .BLKW directives, however, are the preferred ways to reserve storage space (see Section 6.5.3).

3.7 Numbers

MACRO–11 assumes that all numbers in the source program are to be interpreted in octal radix, unless otherwise specified. An exception to this assumption is that operands associated with Floating Point Processor instructions and Floating Point Data directives are treated as decimal (see Section 6.4.2). The default radix (octal) can be changed with the .RADIX directive (see Section 6.4.1.1). Also, individual numbers can be designated as binary, octal, decimal, or hexadecimal numbers through temporary radix control operators (see Section 6.4.1.2).

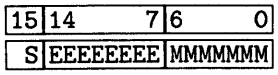
If a statement in the source program contains a digit that is not in the current radix, MACRO–11 generates an error code (N) in the assembly listing. However, MACRO–11 continues with the scan of the statement and evaluates each such number encountered as a decimal value.

Negative numbers must be preceded by a minus sign; MACRO–11 translates such numbers into two's complement form. Positive numbers may (but need not) be preceded by a plus sign.

A number containing more than 16 significant bits (greater than 177777_8) is truncated from the left and flagged with an error code (T) in the assembly listing.

Numbers are always considered to be absolute values; therefore, they are never relocatable.

Single-word floating-point numbers can be generated with the ^F operator (see Section 6.4.2.3) and are stored in the following format:



Sign (1 bit)
Exponent (8 bits)
Mantissa (7 bits)

Refer to the *PDP–11 Processor Handbook* for details of the floating-point number format.

3.8 Terms

A term is a component of an expression and can be one of the following:

- A number (see Section 3.7) whose 16-bit value is used.
- A symbol (see Section 3.2). Symbols are evaluated as follows:
  a. A period (.) specified in an expression causes the value of the current location counter to be used.
  b. A defined symbol is located in the User Symbol Table and its value is used.
  c. A permanent symbol's basic value is used, with zero substituted for the addressing modes. (Appendix C lists all op codes and their values.)
  d. An undefined symbol is assigned a value of zero and inserted in the User Symbol Table as an undefined default global reference. If the `.DSABL GBL` directive (see Section 6.2.1) is in effect, the automatic global reference default function of MACRO-11 is inhibited, and the statement containing the undefined symbol is flagged with an error code (U) in the assembly listing.
- A single quote followed by a single ASCII character, or a double quote followed by two ASCII characters. This type of expression construction is explained in detail in Section 6.3.3.
- An expression enclosed in angle brackets (<>). Any expression so enclosed is evaluated and reduced to a single term before the remainder of the expression in which it appears is evaluated. For example, angle brackets can be used to alter the left-to-right evaluation of expressions, as in `A*B+C` versus `A*<B+C>`, or to apply a unary operator to an entire expression, as in `-<A+B>`.[1]
- A unary operator followed by a symbol or number.

3.9 Expressions

Expressions are combinations of terms joined together by binary operators (see Table 3–5). Expressions reduce to a 16-bit value. The evaluation of an expression includes the determination of its attributes. A resultant expression value can be any one of four types: relocatable, absolute, external, or complex relocatable.

Expressions are evaluated from left to right with no operator hierarchy rules, except that unary operators take precedence over binary operators. A term preceded by a unary operator is considered to contain that operator. (Terms are evaluated, where necessary, before their use in expressions.) Multiple unary operators are valid and are treated as follows:

```
-+-A
```

is equivalent to:

```
-<+<-A>>
```

[1] The maximum depth of an expression is governed by the MACRO-11 assembler's expression stack space. If an expression exceeds the assembler's maximum expression depth, the statement is marked with an (E) error, and processing continues.

A missing term, expression, or external symbol is interpreted as a zero. A missing or invalid operator terminates the expression analysis, causing error codes (A) and/or (Q), to be generated in the assembly listing, depending on the context of the expression itself. For example, the expression:

```
A + B 177777
```

is evaluated as:

```
A + B
```

because the first nonblank character following the symbol B is not a valid binary operator, an expression separator (a comma), or an operand field terminator (a semicolon or the end of the source line).

Spaces within expressions can serve as delimiters only between symbols. In other words, the expressions:

```
A + B
```

and:

```
A+B
```

are the same, but the symbols:

```
B17
```

and:

```
B 17
```

are not (B 17 is not a single symbol).

At assembly time the value of an external (global) expression is equal to the value of the absolute part of that expression. For example, the expression EXTERN+A, where EXTERN is an external symbol, has a value at assembly time that is equal to the value of the internal (local) symbol A. However, when evaluated at link time, this expression takes on the resolved value of the symbol EXTERN plus the value of symbol A.

When evaluated by MACRO–11, expressions are one of four types: relocatable, absolute, external, or complex relocatable. The following distinctions are important:

- An expression is **relocatable** if its value is fixed relative to the base address of the program section in which it appears; it will have an offset value added at link time. Terms that contain labels defined in relocatable program sections will have a relocatable value; similarly, a period (.) in a relocatable program section, representing the value of the current location counter, will also have a relocatable value.
- An expression is **absolute** if its value is fixed. An expression whose terms are numbers and ASCII conversion characters will reduce to an absolute value. A relocatable expression or term minus a relocatable term, where both elements being evaluated belong to the same program section, is an absolute expression. This is because every term in a program section has the same relocation bias. When one term is subtracted from another, the resulting bias is zero. MACRO–11 can then treat the expression as absolute and reduce it to a single term upon completion

of the expression scan. Terms that contain labels defined in an absolute program section also have an absolute value.

- An expression is **external** (or global) if it contains a single global reference (plus or minus an absolute expression value) that is not defined within the current program. Thus, an external expression is only partially defined following assembly and must be resolved at link time.
- An expression is **complex relocatable** if any one of the following conditions applies:
  - It contains a global reference and a relocatable symbol.
  - It contains more than one global reference.
  - It contains relocatable terms belonging to different program sections.
  - The value resulting from the expression has more than one level of relocation. For example, if the relocatable symbols `TAG1` and `TAG2`, associated with the same program section, are specified in the expression `TAG1+TAG2`, two levels of relocation will be introduced, since each symbol is evaluated in terms of the relocation bias in effect for the program section.
  - An operation other than addition is specified on an undefined global symbol.
  - An operation other than addition, subtraction, negation, or complementation is specified for a relocatable value.

The evaluation of relocatable, external, and complex relocatable expressions is completed at link time. The maximum number of terms that can be specified in a complex expression is 20_{10} and is limited by the maximum size of the object record.

Chapter 4
Relocation and Linking

The output of MACRO–11 is an object module that must be processed or linked before it can be loaded and executed. Linking fixes (makes absolute) the values of relocatable or external symbols in the object module, thus transforming the object module, or several object modules, into an executable image.

To allow the value of an expression to be fixed at link time, MACRO–11 writes certain instructions in the object file, together with other required parameters. For relocatable expressions in the object module, the base of the associated relocatable program section is added to the value of the relocatable expression provided by MACRO–11. For external expression values (those containing a reference to a global symbol defined in another module), the value of the external term in the expression (since the external symbol must be defined in one of the other object modules being linked together) is determined and then added to the absolute portion of the external expression, as provided by MACRO–11.

All instructions that require modification at link time are flagged in the assembly listing, as illustrated in the example below. The single quote (') following the octal expansion of the instruction indicates that simple relocation is required; the letter G indicates that the value of an external (global) symbol must be added to the absolute portion of an expression; and the letter C indicates that complex relocation analysis at link time is required in order to fix the value of the expression.

Example:

```
005065  CLR     RELOC(R5)       ;Assuming that the value of the
000040'                         ;symbol "RELOC", 40, is relocatable
                                ;the relocation bias
                                ;will be added to this value.

005065  CLR     EXTERN(R5)      ;The value of the symbol "EXTERN" is
000000G                         ;assembled as zero and is
                                ;resolved at link time.

005065  CLR     EXTERN+6(R5)    ;The value of the symbol "EXTERN"
000006G                         ;is resolved at link time
                                ;and added to
                                ;the absolute portion (+6) of
                                ;the expression.

005065  CLR     -<EXTERN+RELOC>(R5)     ;This expression is complex
000000C                         ;relocatable because it requires
                                ;the negation of an expression
                                ;that contains a global "EXTERN"
                                ;reference and a relocatable term.
```

For a complete description of object records written by MACRO–11, refer to the applicable system manual (see the Associated Documents section in the Preface).

Chapter 5
Addressing Modes

To understand how the address modes operate and how they assemble, you must understand the action of the program counter. The key rule to remember is:

> "Whenever the processor implicitly uses the program counter (PC) to fetch a word from memory, the program counter is automatically incremented by 2 after the fetch operation is completed."

The PC always contains the address of the *next* word to be fetched. This word will be either the address of the next instruction to be executed or the second or third word of the current instruction.

Table 5–1 lists the symbols used in this chapter to describe the address modes, and Table 5–2 lists the address modes. This chapter illustrates each mode of address using the single operand instruction `CLR` or the double operand instruction `MOV`. Section B.2 gives a summary of address mode syntax.

Certain special instruction/address mode combinations, which are rarely or never used, do not operate the same on all PDP–11 processors. There are three major classes of instructions you are most likely to encounter. These are listed in Table 5–3.[1] Avoid using these addressing modes if there is the slightest chance a program will ever have to run on more than one type of processor. MACRO–11 prints an error code (Z) in the assembly listing with each instruction containing an addressing mode incompatible among all members of the PDP–11 family.

Table 5–1: Symbols Used in Chapter 5

Symbol	Explanation
E	Any expression, as defined in Chapter 3.

R	A register expression; that is, any expression containing a term preceded by a percent sign (%) or a symbol previously equated to such a term, as shown below:
	`R0=%0 ;General register 0.`
	`R1=R0+1 ;General register 1.`
	`R2=1+%1 ;General register 2.`
	This symbol may also represent any of the normal default register definitions (see Section 3.4).

ER	A register expression or an absolute expression in the range 0 to 7, inclusive.

[1] The *PDP–11 Architecture Handbook* lists all the differences among all PDP–11 processors.

Table 5–2: Addressing Modes

Mode	Form	Reference[3]
Register mode[1]	R	5.1
Register deferred mode[1]	@R or (ER)	5.2
Autoincrement mode[1]	(ER)+	5.3
Autoincrement deferred mode[1]	@(ER)+	5.4
Autodecrement mode[1]	-(ER)	5.5
Autodecrement deferred mode[1]	@-(ER)	5.6
Index mode[2]	E(ER)	5.7
Index deferred mode[2]	@E(ER)	5.8
Immediate mode[2]	#E	5.9
Absolute mode[2]	@#E	5.10
Relative mode[2]	E	5.11
Relative deferred mode[2]	@E	5.12
Branch	Address	5.13

[1] Does not increase the length of an instruction.

[2] Adds one word to the instruction length for each occurrence of an operand of this form.

[3] Section B.2 contains a summary of addressing mode syntax.

Table 5–3: Instruction Differences Among PDP–11 Processors

Instruction		Operation A	Operation B
OPR[1]	R,(R)+[2]	Contents of R are incremented (or decremented) by 2 before being used as the source operand[5]	Initial contents of R are used as the source operand[6]
OPR	R,-(R)		
OPR	R,@(R)+		
OPR	R,@-(R)		
OPR	PC,E(R)	Location A will contain the PC of OPR+4[5]	Location A will contain the PC of OPR+2[6]
OPR	PC,@E(R)		
OPR	PC,A[3]		
OPR	PC,@A		
JMP	(R)+	Contents of R are incremented by 2, then used as the new PC[7]	Initial contents of R are used as the new PC[8]
JSR	Rn,(R)+[4]		

[1] OPR represents any two-operand instruction

[2] R is the same for both source and destination

[3] A represents any address expression

[4] Rn is not necessarily the same as R

[5] 23/24, 15/20, 35/40, 60, J11, and T11 processors

[6] 04, 05/10, 34, 44, 45, and 70 processors

[7] 05/10 and 15/20 processors

[8] All except 05/10 and 15/20 processors

5.1 Register Mode

Format:

```
R
```

The register R contains the operand for the instruction.

Example:

```
CLR     R3              ;Clears register 3.
```

5.2 Register Deferred Mode

Format:

```
@R
(ER)
```

The register R contains the address of the operand for the instruction.

Example:

```
CLR     @R1             ;All these instructions clear
CLR     (R1)            ;the word at the address
CLR     (%1)            ;contained in register 1.
```

5.3 Autoincrement Mode

Format:

```
(ER)+
```

The contents of the register ER are incremented immediately after being used as the address of the operand (see Table 5–3 for possible processor incompatibilities).

Example:

```
CLR     (R0)+           ;Each instruction clears
CLR     (R4)+           ;the word at the address
CLR     (R2)+           ;contained in the specified
                        ;register and increments
                        ;that register's contents
                        ;by 2.
```

5.4 Autoincrement Deferred Mode

Format:

```
@(ER)+
```

The register ER contains a pointer to the address of the operand. The contents of the register are incremented after being used as pointer.

Example:

```
CLR     @(R3)+          ;The contents of register 3 point
                        ;to the address of a word to be
                        ;cleared before the contents of the
                        ;register are incremented by 2.
```

5.5 Autodecrement Mode

Format:

```
-(ER)
```

The contents of the register ER are decremented before being used as the address of the operand (see Table 5–3 for possible processor incompatibilities).

Example:

```
CLR     -(R0)           ;Decrement the contents of the
                        ;specified register (0, 3, or 2)
CLR     -(R3)           ;by 2 before using its contents
CLR     -(R2)           ;as the address of the word to be
                        ;cleared.
```

5.6 Autodecrement Deferred Mode

Format:

```
@-(ER)
```

The contents of the register ER are decremented before being used as a pointer to the address of the operand.

Example:

```
CLR     @-(R3)          ;Decrement the contents of
                        ;register 3 by 2 before
                        ;using its contents as a pointer
                        ;to the address of the word to be
                        ;cleared.
```

5.7 Index Mode

Format:

```
E(ER)
```

An expression E, plus the contents of a register ER, yields the effective address of the operand. In other words, the value E is the offset of the instruction, and the contents of register ER form the base. The value of the expression E is stored as the second or third word of the instruction.

Example:

```
CLR     X+2(R1)         ;The effective address of the word
                        ;to be cleared is X+2, plus the
                        ;contents of register 1.
MOV     R0,-2(R3)       ;The effective address of the
                        ;destination location is -2, plus
                        ;the contents of register 3.
```

5.8 Index Deferred Mode

Format:

```
@E(ER)
```

An expression E, plus the contents of register ER, yields a pointer to the address of the operand. The value E is the offset of the instruction, and the contents of register ER form the base. The value of the expression E is stored as the second or third word of the instruction.

Example:

```
CLR     @114(R4)        ;If register 4 contains 100, this
                        ;value, plus the offset 114, yields
                        ;the pointer 214. If location 214
                        ;contains the address 2000, location
                        ;2000 would be cleared.
```

NOTE

The expression @(ER) can be used, but it will be assembled as if it were written @0(ER), and a word will be used to store the 0.

5.9 Immediate Mode

Format:

```
#E
```

Immediate mode stores the operand itself (E) as the second or third word of the instruction. The number sign (#) is an addressing mode indicator. This character appearing in the operand field specifies the immediate addressing mode, indicating to MACRO-11 that the operand itself immediately follows the instruction word. This mode is assembled as an autoincrement of the PC.

Example:

```
MOV     #100,R0         ;Move the value 100 into register 0.
MOV     #X,R0           ;Move the value of symbol X into
                        ;register 0.
```

The operation of this mode can be shown through the first example, `MOV #100,R0`, which assembles as two words:

```
Location n:    012700
Location n+2:  000100
Location n+4:  Next instruction
```

The source operand (the value 100) is assembled immediately following the instruction word. Upon execution of the instruction, the processor fetches the first word (MOV) and increments the PC by 2, so that it points to the second word, location n+2, which contains the source operand.

After the next fetch and increment cycle, the source operand (100) is moved into register 0, leaving the PC pointing to location n+4 (the next instruction).

5.10 Absolute Mode

Format:

```
@#E
```

Absolute mode is the equivalent of immediate mode deferred. The address expression `@#E` specifies an absolute address that is stored as the second or third word of the instruction. In other words, the value immediately following the instruction word is taken as the absolute address of the operand. Absolute mode is assembled as an autoincrement deferred of the PC. You can use this mode to reference specific memory addresses from within position-independent code.

Example:

```
MOV     @#100,R0        ;Move the contents of absolute
                        ;location 100 into register R0.
CLR     @#X             ;Clear the contents of the location
                        ;whose address is specified by
                        ;the symbol X.
```

The operation of this mode can be shown through the first example:

```
MOV     @#100,R0
```

which assembles as two words:

```
Location n:    013700
Location n+2:  000100
Location n+4:  Next instruction
```

The absolute address 100 is assembled immediately following the instruction word. Upon execution of the instruction, the processor fetches the first word (MOV) and increments the PC by 2, so that it points to the second word, location n+2, which contains the absolute address of the source operand. After the next fetch and increment cycle, the contents of absolute address 100 (the source operand) are moved into register 0, leaving the PC pointing to location n+4 (the next instruction).

5.11 Relative Mode

Format:

```
E
```

Relative mode is the normal mode for memory references within your program. It is assembled as index mode, using the PC as the index register. The offset for the address calculation is assembled as the second or third word of the instruction. This value is added to the contents of the PC to yield the address of the source operand.

Example:

```
CLR     100             ;Clear absolute location 100
MOV     R0,Y            ;Move the contents of register 0
                        ;to location Y
```

Assume the current value of the PC is 1020. The operation of relative mode can be shown with the statement:

```
MOV     100,R3
```

which assembles as two words:

```
Location 1020: 016703
Location 1022: 177054
Location 1024: Next instruction
```

The offset, the constant 177054, is assembled immediately following the instruction word. Upon execution of the instruction, the processor fetches the first word (MOV) and increments the PC by 2, so that it points to the second word, location 1022, containing the value 177054. After the next fetch and increment cycle, the processor calculates the effective address of the source operand by taking the contents of location 1022 (the offset) and adding it using two's complement arithmetic to the current value of the PC, which now points to location 1024 (the next instruction). Thus, the source operand address is the result of the calculation:

OFFSET+PC = 177054+1024 = 100_8

so the contents of location 100 are moved into register 3.

The index mode statement:

```
MOV     100-.-4(PC),R3
```

is equivalent to the relative mode statement:

```
MOV     100,R3
```

The term 100-.-4 is the offset for the index mode statement. The current location counter (.) holds the address of the first word of the instruction (1020, in this case), and the PC has to move down four bytes to reach location 1024 (the next instruction). So, the offset could be written as 100-1020-4, or 177054_8.

Therefore, for the index mode, the offset (177054_8) added to the PC (1024_8) yields the effective address (177054 + 1024 = 100_8) of the operand.

Thus, both statements move the contents of location 100 into register 3.

NOTE

The addressing form `@#E` differs from form `E` in that the second or third word of the instruction contains the absolute address of the operand, rather than the relative distance between the operand and the PC (see Section 5.10). Thus, the instruction `CLR @#100` clears absolute location 100, even if the instruction is moved from the point at which it was assembled. See Section 6.2.1 for a description of the `.ENABL AMA` function, which causes all relative mode addresses to be assembled as absolute mode addresses.

5.12 Relative Deferred Mode

Format:

```
@E
```

Relative deferred mode is similar in operation to relative mode, except that the expression `E` is used as a pointer to the address of the operand. In other words, the operand following the instruction word is added to the contents of the PC to yield a pointer to the address of the operand.

Example:

```
MOV     @X,R0           ;Relative to the current value of
                        ;the PC, move the contents of the
                        ;location whose address is pointed
                        ;to by location X into register 0.
```

5.13 Branch Instruction Addressing

Branch instructions are 1-word instructions. The high-order byte contains the operator, and the low-order byte contains an 8-bit signed offset (seven bits, plus sign), which specifies the branch address relative to the current value of the PC. The hardware calculates the branch address as follows:

1. Extends the sign of the offset through bits 8 to 15.
2. Multiplies the result by 2, creating a byte offset rather than a word offset.

3. Adds the result to the current value of the PC to form the effective branch address.

MACRO–11 performs the reverse operation to form the word offset from the specified address:

Word offset = (E–PC)/2, truncated to eight bits.

When the offset is added to the PC, the PC is moved to the next word (PC=.+2). Hence the –2 in the following calculation:

Word offset = (E–.–2)/2, truncated to eight bits.

The following conditions generate an error code (A) in the assembly listing:

- Branching from one program section to another
- Branching to a location that is defined as an external (global) symbol
- Specifying a branch address that is out of range, meaning that the branch offset is a value that exceeds the range -128_{10} to $+127_{10}$

5.14 Using TRAP Instructions

Since the EMT and TRAP instructions do not use the low-order byte of the instruction word, information is transferred to the trap handlers in the low-order byte. If the EMT or TRAP instruction is followed by an expression, the value of the expression is stored in the low-order byte of the word. Expressions greater than 377_8 are truncated to eight bits, and an error code (A) is generated in the assembly listing.

For more information on traps, see the *PDP–11 Processor Handbook* and the applicable system manual (see the Associated Documents section in the Preface).

Part III

Chapter 6
General Assembler Directives

A MACRO–11 directive is placed in the operator field of a source line. Only one directive is allowed per source line. A directive may have a blank operand field or one or more operands. Valid operands differ with each directive.

General assembler directives are divided into the following categories:

- Listing control
- Function control
- Data storage
- Radix and numeric control
- Location counter control
- Terminator
- Program sectioning and boundaries
- Symbol control
- Conditional assembly
- File control

Each is described in its own section of this chapter. See Table 6–1 for an alphabetical listing of the directives and the associated section reference. Also refer to Section B.3 for a complete list of all MACRO–11 assembler directives.

Table 6–1: Directives in Chapter 6

Directive	Function	Section Reference
.ASCII	Stores delimited string as a sequence of the 8-bit ASCII code of their characters.	6.3.4
.ASCIZ	Same as .ASCII except the string is followed by a zero byte.	6.3.5
.ASECT	Similar to .PSECT.	6.7.2
.BLKB	Allocates bytes of data storage.	6.5.3
.BLKW	Allocates words of data storage.	6.5.3
.BYTE	Stores successive bytes of data.	6.3.1
.CROSS	Enables cross referencing.	6.2.2

Table 6–1 (Cont.): Directives in Chapter 6

Directive	Function	Section Reference
.CSECT	Similar to .PSECT.	6.7.2
.DSABL	Disables specified assembler functions.	6.2.1
.ENABL	Enables specified assembler functions.	6.2.1
.END	Indicates end of source input.	6.6
.ENDC	Indicates end of conditional assembly block.	6.9.1
.EVEN	Ensures that current value of the location counter is even.	6.5.1
.FLT2	Generates 2 words of storage for each floating-point number argument.	6.4.2.2
.FLT4	Generates 4 words of storage for each floating-point number argument.	6.4.2.2
.GLOBL	Defines listed symbols as global.	6.8.1
.IDENT	Provides additional means of labeling an object module.	6.1.4
.IF	Assembles block if specified conditions are met.	6.9.1
.IFF	Assembles block if condition tests false.	6.9.2
.IFT	Assembles block if condition tests true.	6.9.2
.IFTF	Assembles block regardless of whether condition tests true or false.	6.9.2
.IIF	Permits writing a 1-line conditional assembly block.	6.9.3
.INCLUDE	Includes another MACRO–11 source file.	6.10.2
.LIBRARY	Adds file to MACRO–11 library search list.	6.10.1
.LIMIT	Allocates 2 words for storage. At link time the Linker or Task Builder puts the lowest address of the load image in the first of the saved words and the address of the first free word following the image in the second.	6.5.4
.LIST	Increments listing count or lists certain types of code.	6.1.1
.NLIST	Decrements listing count or suppresses certain types of code.	6.1.1
.NOCROSS	Disables cross referencing.	6.2.2
.ODD	Ensures that the current value of the location counter is odd.	6.5.2
.PACKED	Generates packed decimal data, two digits per byte.	6.3.8
.PAGE	Starts a new listing page.	6.1.5
.PSECT	Declares names for program sections and establishes their attributes.	6.7.1
.RAD50	Generates data in Radix–50 packed format.	6.3.6

Table 6–1 (Cont.): Directives in Chapter 6

Directive	Function	Section Reference
.RADIX	Changes the default radix throughout or in portions of the source program.	6.4.1.1
.REM	Delimits a section of comments.	6.1.6
.RESTORE	Retrieves a previously .SAVEd program section.	6.7.4
.SAVE	Places the current program section on top of the program section context stack.	6.7.3
.SBTTL	Produces a table of contents immediately preceding the assembly listing and puts subheadings on each page in the listing.	6.1.3
.TITLE	Assigns a name to the object module and puts headings on each page of the assembly listing.	6.1.2
.WEAK	Defines listed symbols as WEAK.	6.8.2
.WORD	Generates successive words of data in the object module.	6.3.2

6.1 Listing Control Directives

Listing control directives control the content, format, and pagination of all line printer (see Figure 6–1) and terminal (see Figure 6–2) assembly listing output. On the first line of each page, MACRO–11 prints the following (from left to right):

1. Title of the object module, as established through the .TITLE directive (see Section 6.1.2)
2. Assembler version identification
3. Day of the week
4. Date
5. Time of day
6. Page number

The second line of each assembly listing page contains the subtitle text specified in the last-encountered .SBTTL directive (see Section 6.1.3).

In line printer format (Figure 6–1), binary extensions for statements generating more than one word are listed horizontally.

In terminal format (Figure 6–2), binary extensions for statements generating more than one word are listed vertically. There is no explicit truncation of output to 80 characters by the assembler.

Figure 6–1: Example of Line Printer Assembly Listing

```
 1                                      ;+
 2                                      ; GETSYM
 3                                      ; Scan off a RAD50 symbol.  Leave with scan pointer set at next non-blank
 4                                      ; char past end of symbol. Symbol buffer clear and Z set if no symbol
 5                                      ; seen; in this case scan pointer is unaltered.
 6                                      ;-
 7
 8 000126  010146                       GETSYM::MOV     R1,-(SP)          ;Save work register
 9 000130  016767  000000G 000000G              MOV     CHRPNT,SYMBEG     ;Save scan pointer in case of rescan
10 000136  012701  000004G                      MOV     #SYMBOL+4,R1      ;Point at end of symbol buffer
11 000142  005041                               CLR     -(R1)             ;Now clear it
12 000144  005041                               CLR     -(R1)
13 000146  136527  000000G 000000G             BITB    CTTBL(R5),#CT.ALP  ;Test first char for alphabetic
14 000154  001436                               BEQ     4$                ;Exit if not, with Z set
15 000156  116500  000262'             1$:     MOVB    CTTBL2(R5),R0     ;Map to RAD50
16 000162  003431                               BLE     3$                ;Exit if not valid RAD50
17 000164  006300                               ASL     R0                ;Make word index
18 000166  016011  000000G                      MOV     R50TB1(R0),(R1)   ;Load the high char
19 000172                                       GETCHR                    ;Get another char
20 000176  116500  000262'                      MOVB    CTTBL2(R5),R0     ;Handle it as above
21 000202  003421                               BLE     3$
22 000204  006300                               ASL     R0
23 000206  066011  000000G                      ADD     R50TB2(R0),(R1)
24 000212                                       GETCHR                    ;Now get low order char
25 000216  116500  000262'                      MOVB    CTTBL2(R5),R0     ;Map and test it
26 000222  003411                               BLE     3$
27 000224  060021                               ADD     R0,(R1)+          ;Just add in the low char, advance pointer
28 000226                              2$:      GETCHR                    ;Get following char
29 000232  020127  000004G                      CMP     R1,#SYMBOL+4      ;Test if at end of symbol buffer
30 000236  001347                               BNE     1$                ;Go again if no
31 000240  105765  000262'                      TSTB    CTTBL2(R5)        ;Flush to end of symbol if it yes
32 000244  003370                               BGT     2$
33 000246                              3$:      SETNB                     ;Now scan to a non-blank char
34 000252  012601                      4$:      MOV     (SP)+,R1          ;Restore work register
35 000254  016700  000000G                      MOV     SYMBOL,R0         ;Set Z if no symbol found
36 000260  000207                               RETURN
37
38                                      ;+
39                                      ; Table CTTBL2
40                                      ; Index with 7-bit ASCII value to get corresponding RAD50 value
41                                      ; If EQ 0 then space, if LT 0 then not RAD50; Other bits reserved.
42                                      ;-
43                                              .NLIST  BEX
44 000262      200     200     200     CTTBL2: .BYTE   200,200,200,200,200,200,200,200 ;
45 000272      200     200     200             .BYTE   200,200,200,200,200,200,200,200 ;
46 000302      200     200     200             .BYTE   200,200,200,200,200,200,200,200 ;
47 000312      200     200     200             .BYTE   200,200,200,200,200,200,200,200 ;
48 000322      200     200     200             .BYTE   200,200,200,200,033,200,200,200 ;    $
49 000332      200     200     200             .BYTE   200,200,200,200,200,200,034,200 ;
50 000342      036     037     040             .BYTE   036,037,040,041,042,043,044,045 ;01234567
51 000352      046     047     200             .BYTE   046,047,200,200,200,200,200,200 ;89
52 000362      200     001     002             .BYTE   200,001,002,003,004,005,006,007 ; ABCDEFG
53 000372      010     011     012             .BYTE   010,011,012,013,014,015,016,017 ;HIJKLMNO
54 000402      020     021     022             .BYTE   020,021,022,023,024,025,026,027 ;PQRSTUVW
55 000412      030     031     032             .BYTE   030,031,032,200,200,200,200,200 ;XYZ
56 000422      200     001     002             .BYTE   200,001,002,003,004,005,006,007 ; abcdefg
```

Figure 6–2: Example of Terminal Assembly Listing

```
 1                      ;+
 2                      ; GETSYM
 3                      ; Scan off a RAD50 symbol.  Leave with scan pointer set at next non-blank
 4                      ; char past end of symbol. Symbol buffer clear and Z set if no symbol
 5                      ; seen; in this case scan pointer is unaltered.
 6                      ;-
 7
 8 000126  010146  GETSYM::MOV     R1,-(SP)          ;Save work register
 9 000130  016767          MOV     CHRPNT,SYMBEG     ;Save scan pointer in case of rescan
           000000G
           000000G
10 000136  012701          MOV     #SYMBOL+4,R1      ;Point at end of symbol buffer
           000004G
11 000142  005041          CLR     -(R1)             ;Now clear it
12 000144  005041          CLR     -(R1)
13 000146  136527          BITB    CTTBL(R5),#CT.ALP  ;Test first char for alphabetic
           000000G
           000000G
14 000154  001436          BEQ     4$                ;Exit if not, with Z set
15 000156  116500  1$:     MOVB    CTTBL2(R5),R0     ;Map to RAD50
           000262'
16 000162  003431          BLE     3$                ;Exit if not valid RAD50
17 000164  006300          ASL     R0                ;Make word index
18 000166  016011          MOV     R50TB1(R0),(R1)   ;Load the high char
           000000G
19 000172                  GETCHR                    ;Get another char
20 000176  116500          MOVB    CTTBL2(R5),R0     ;Handle it as above
           000262'
21 000202  003421          BLE     3$
22 000204  006300          ASL     R0
23 000206  066011          ADD     R50TB2(R0),(R1)
           000000G
24 000212                  GETCHR                    ;Now get low order char
25 000216  116500          MOVB    CTTBL2(R5),R0     ;Map and test it
           000262'
26 000222  003411          BLE     3$
27 000224  060021          ADD     R0,(R1)+          ;Just add in the low char, advance pointer
28 000226          2$:     GETCHR                    ;Get following char
29 000232  020127          CMP     R1,#SYMBOL+4      ;Test if at end of symbol buffer
           000004G
30 000236  001347          BNE     1$                ;Go again if no
31 000240  105765          TSTB    CTTBL2(R5)        ;Flush to end of symbol if it yes
           000262'
32 000244  003370          BGT     2$
33 000246          3$:     SETNB                     ;Now scan to a non-blank char
34 000252  012601  4$:     MOV     (SP)+,R1          ;Restore work register
35 000254  016700          MOV     SYMBOL,R0         ;Set Z if no symbol found
           000000G
36 000260  000207          RETURN
37
38                      ;+
39                      ; Table CTTBL2
40                      ; Index with 7-bit ASCII value to get corresponding RAD50 value
41                      ; If EQ 0 then space, if LT 0 then not RAD50; Other bits reserved.
42                      ;-
43                              .NLIST  BEX
44 000262     200  CTTBL2: .BYTE   200,200,200,200,200,200,200,200 ;
45 000272     200         .BYTE   200,200,200,200,200,200,200,200 ;
46 000302     200         .BYTE   200,200,200,200,200,200,200,200 ;
47 000312     200         .BYTE   200,200,200,200,200,200,200,200 ;
48 000322     200         .BYTE   200,200,200,200,033,200,200,200 ;    $
49 000332     200         .BYTE   200,200,200,200,200,200,034,200 ;
50 000342     036         .BYTE   036,037,040,041,042,043,044,045 ;01234567
51 000352     046         .BYTE   046,047,200,200,200,200,200,200 ;89
52 000362     200         .BYTE   200,001,002,003,004,005,006,007 ; ABCDEFG
53 000372     010         .BYTE   010,011,012,013,014,015,016,017 ;HIJKLMNO
54 000402     020         .BYTE   020,021,022,023,024,025,026,027 ;PQRSTUVW
55 000412     030         .BYTE   030,031,032,200,200,200,200,200 ;XYZ
56 000422     200         .BYTE   200,001,002,003,004,005,006,007 ; abcdefg
```

6.1.1 .LIST And .NLIST Directives

Format:

```
.LIST
.LIST   arg
.NLIST
.NLIST  arg
```

where:

arg	represents one or more of the optional symbolic arguments defined in Table 6–2.

As indicated above, the listing control directives can be used without arguments, in which case the listing directives alter the listing level count. The listing level count is initialized to zero. At each occurrence of a .LIST directive, the listing level count is incremented; at each occurrence of a .NLIST directive, the listing level count is decremented. When the level count is negative, the listing is suppressed (unless the line contains an error). Conversely, when the level count is greater than zero, the listing is generated regardless of the context of the line. Finally, when the count is zero, the line is either listed or suppressed, depending on the listing controls currently in effect for the program. The following macro definition employs the .LIST and .NLIST directives to list selected portions of the macro body when the macro is expanded:

```
        .MACRO  LTEST   ;List test
; A-this line should list       ;Listing level count is 0.
        .NLIST          ;Listing level count is -1.
; B-this line should not list
        .NLIST          ;Listing level count is -2.
; C-this line should not list
        .LIST          ;Listing level count is -1.
; D-this line should not list
        .LIST          ;Listing level count is 0.
; E-this line should list       ;Listing level count is 0.
; F-this line should list       ;Listing level count is 0.
; G-this line should list       ;Listing level count is 0.
        .ENDM
          .
          .
          .
        .LIST  ME               ;List macro expansion.
        LTEST                   ;Call the macro
; A-this line should list       ;Listing level count is 0.
; E-this line should list       ;Listing level count is 0.
; F-this line should list       ;Listing level count is 0.
; G-this line should list       ;Listing level count is 0.
```

Note that the lines following line E will list because the listing level count remains 0. If a .LIST ME directive is placed at the beginning of a program, all macro expansions will be listed unless a .NLIST directive is encountered.

An important purpose of the level count is to allow macro expansions to be listed selectively and yet exit with the listing level count restored to the value existing prior to the macro call.

When used with arguments, the listing directives do not alter the listing level count. However, the .LIST and .NLIST directives can be used to override current listing control, as shown in the example below:

```
        .MACRO  XX
          .
          .
          .
        .LIST           ;List next line.
X=.
        .NLIST          ;Do not list remainder of macro
          .             ;expansion.
          .
          .
        .ENDM

        .NLIST  ME      ;Do not list macro expansions.
        XX
X=.
```

Table 6–2 describes the symbolic arguments you can use with .LIST and .NLIST. These arguments can be used singly or in combination with each other. If multiple arguments are specified in a listing directive, each argument must be separated by a comma, tab, or space. For any argument not specifically included in the control statement, the associated default assumption (List or No List) is applicable throughout the source program. The default assumptions for the listing control directives also appear in Table 6–2.

Table 6–2: Symbolic Arguments of Listing Control Directives

Argument	Default	Function
BEX	List	Controls the listing of binary extensions (the locations and binary contents beyond those that will fit on the source statement line). This is a subset of the BIN argument.
BIN[1]	List	Controls the listing of generated binary code. If this field is suppressed through a .NLIST BIN directive, left-justification of the source code field occurs in the same manner described above for the LOC field.
CND	List	Controls the listing of unsatisfied conditional coding and associated .IF and .ENDC directives in the source program. A .NLIST CND directive lists only satisfied conditional coding.
COM	List	Controls the listing of comments. This is a subset of the SRC argument. The .NLIST COM directive reduces listing time and space when comments are not desired.

[1] If the .NLIST arguments SEQ, LOC, BIN, and SRC are in effect at the same time, that is, if all four significant fields in the listing are to be suppressed, the printing of the resulting blank line is inhibited.

Table 6–2 (Cont.): Symbolic Arguments of Listing Control Directives

Argument	Default	Function
HEX	No list	Controls radix used for assembly listing. If you specify .LIST HEX, addresses and contents are given in hexadecimal, rather than octal.
LOC[1]	List	Controls the listing of the current location counter field. Normally, this field is not suppressed. However, if it is suppressed through the .NLIST LOC directive, MACRO–11 does not generate a tab, nor does it allocate space for the field, as is the case with the SEQ field described above. Thus, the suppression of the current location counter (LOC) field effectively left-justifies all subsequent fields (while preserving positional relationships) to the position normally occupied by the counter's field.
MC	List	Controls the listing of macro calls and repeat range expansions.
MD	List	Controls the listing of macro definitions and repeat range expansions.
ME	No list	Controls the listing of macro expansions.
MEB	No list	Controls the listing of macro expansion binary code. A .LIST MEB directive lists only those macro expansion statements that generate binary code. This is a subset of the ME argument.
SEQ[1]	List	Controls the listing of the sequential numbers assigned to the source lines. If this number field is suppressed through a .NLIST SEQ directive, MACRO–11 generates a tab, effectively allocating blank space for the field. Thus, the positional relationships of the other fields in the listing remain undisturbed. During the assembly process, MACRO–11 examines each source line for possible error conditions. For any line in error, the error code is printed preceding the number field. (MACRO–11 does not assign line numbers to files that have had line numbers assigned by an editor such as SOS.)
SRC[1]	List	Controls the listing of source lines.
SYM	List	Controls the listing of the symbol table resulting from the assembly of the source program.
TOC	List	Controls the listing of the table of contents during assembly pass 1 (see Section 6.1.3 describing the .SBTTL directive). This argument does not affect the printing of the full assembly listing during assembly pass 2.
TTM	No list	Controls the listing output format. The default is set to line printer format. Figure 6–1 illustrates line printer output format; Figure 6–2 illustrates terminal output format.

[1] If the .NLIST arguments SEQ, LOC, BIN, and SRC are in effect at the same time, that is, if all four significant fields in the listing are to be suppressed, the printing of the resulting blank line is inhibited.

If you use an argument in a .LIST/.NLIST directive other than those listed in Table 6–2, the directive is flagged with an error code (A) in the assembly listing.

You can also specify the listing control options at assembly time through qualifiers included in the command string to MACRO–11 (see Table 8–3 and/or the appropriate system manual). The use of these qualifiers overrides all corresponding listing control (.LIST or .NLIST) directives specified in the source program.

Figure 6–3 shows a listing produced in line printer format that shows the use of .LIST and .NLIST directives in the source program and the effects the directives have on the assembly listing output.

Figure 6–3: Listing Produced with Listing Control Directives

```
 1                                      .TITLE  LISTING CONTROL EXAMPLE
 2
 3                                      .LIST   ME              ;List macro expansions
 4
 5                              ;+
 6                              ; Listing control test macro
 7                              ;-
 8
 9                                      .MACRO  LSTMAC  ARG
10                                      .NLIST  ARG
11                                      .WORD   1,2,3,4         ;This is a test comment
12                                      .LIST   ARG
13                                      .ENDM
14
15 000000                              LSTMAC  LOC             ;Location counter test
                                .NLIST  LOC
   000001  000002  000003       .WORD   1,2,3,4         ;This is a test comment
   000004
                                       .LIST   LOC
16
17 000010                              LSTMAC  BIN             ;Generated binary test
                .NLIST  BIN
   000010       .WORD   1,2,3,4        ;This is a test comment
                                       .LIST   BIN
18
19 000020                              LSTMAC  BEX             ;Binary extensions test
                                       .NLIST  BEX
   000020  000001  000002  000003      .WORD   1,2,3,4         ;This is a test comment
                                       .LIST   BEX
20
21 000030                              LSTMAC  SRC             ;Source lines test
   000030  000001  000002  000003
   000036  000004
                                       .LIST   SRC
22
23 000040                              LSTMAC  COM             ;Comment lines test
                                       .NLIST  COM
   000040  000001  000002  000003      .WORD   1,2,3,4
   000046  000004
                                       .LIST   COM
24
25 000050                              LSTMAC  <COM,BEX>       ;Comment lines and extended binary test
                                       .NLIST  COM,BEX
   000050  000001  000002  000003      .WORD   1,2,3,4
                                       .LIST   COM,BEX
26
```

Figure 6–3 Cont'd. on next page

Figure 6–3 (Cont.): Listing Produced with Listing Control Directives

```
27                              .LIST   TTM             ;Enable narrow listing
28
29 000060                       LSTMAC  SEQ             ;Sequence numbers test
                                .NLIST  SEQ
   000060  000001               .WORD   1,2,3,4         ;This is a test comment
   000062  000002
   000064  000003
   000066  000004
                                .LIST   SEQ
30
31 000070                       LSTMAC  BEX             ;Binary extensions test
                                .NLIST  BEX
   000070  000001               .WORD   1,2,3,4         ;This is a test comment
                                .LIST   BEX
32
33          000001              .END
```

6.1.2 .TITLE Directive

Format:

```
.TITLE string
```

where:

string — represents an identifier of from one to six Radix–50 characters. The identifier can be followed by a string of one or more 7-bit ASCII or 8-bit DEC Multinational printing characters plus space and horizontal tab. Any MCS character must be preceded by six Radix–50 characters. Characters after the first 31_{10} do not appear in the title line of the listing.

Section A.1 contains a table that includes all MCS characters. Section A.2 contains a table of Radix–50 characters.

The .TITLE directive assigns a name to the object module. The name assigned is the first six nonblank Radix–50 characters following the .TITLE directive. MACRO–11 ignores all spaces and/or tabs up to the first nonspace/nontab character following the .TITLE directive. Any characters beyond the first six Radix–50 characters are optional, and are checked only for MCS validity.

The name of an object module (specified in the .TITLE directive) appears in the load map produced at link time. This is also the module name which the Librarian will recognize.

If the .TITLE directive is not specified, MACRO–11 assigns the default name .MAIN. to the object module. If more than one .TITLE directive is specified in the source program, the last .TITLE directive encountered during assembly pass 1 establishes the name for the entire object module.

If the .TITLE directive is specified without an object module name, or if the first nonspace/nontab character in the object module name is not Radix–50 character, the directive is flagged with an error code (A) in the assembly listing; some combinations of invalid characters may also give a (Q) error.

6.1.3 .SBTTL Directive

Format:

```
.SBTTL string
```

where:

string	represents an identifier of one or more 7-bit ASCII or 8-bit DEC Multinational printing characters plus space and horizontal tab. Only the first 80_{10} characters appear in the subtitle line of the listing, although .SBTTL strings up to the full width of the line appear on the contents page.

The text strings following .SBTTL directives produce a table of contents listing immediately preceding the assembly listing. The text following each .SBTTL directive also prints as the second line of the header of each page in the listing following the .SBTTL directive. The subheading is listed until altered by a subsequent .SBTTL directive in the program. For example, the directive:

```
.SBTTL  Conditional assemblies
```

prints the text:

```
Conditional assemblies
```

as the second line in the header of the assembly listing.

During assembly pass 1, a table of contents containing the line sequence number, the page number, and the text accompanying each .SBTTL directive is printed for the assembly listing. The listing of the table of contents is suppressed whenever a .NLIST TOC directive is encountered in the source program (see Table 6–2). An example of a table of contents listing is shown in Figure 6–4.

Figure 6–4: Assembly Listing Table of Contents

```
MTTEMT - RT--11 MULTI-TTY EMT SE        MACRO V05.04  Tuesday 02-Jun-87 15:47
Table of contents

   50-   1      .MTOUT - Single character output EMT
   51-   1      .MTRCTO - Reset CTRL/O EMT
   52-   1      .MTATCH - Attach to terminal EMT
   54-   1      .MTDTCH - Detach from a terminal EMT
   55-   1      .MTPRNT - Print message EMT
   56-   1      .MTSTAT - Return multi-terminal system status EMT
   57-   1      MTTIN - Single character input
   58-   1      MTTGET - Get a character from the ring buffer
   59-   1      TTRSET - Reset terminal status bits
   60-   1      MTTPUT - Single character output
   62-   1      MTRSET - Stop and detach all terminals attached to a job
   63-   1      ESCAPE SEQUENCE TEST SUBROUTINE
```

6.1.4 .IDENT Directive

Format:

```
.IDENT  /string/
```

where:

string	represents a string of six or fewer Radix-50 characters which establish the program identification or version number. This string is included in the global symbol directory of the object module and is printed in the link map and Librarian listing.
/ . . . /	represent delimiting characters. These delimiters can be any paired printing characters other than the colon (:) and left angle bracket (<), as long as the delimiting character is not contained within the text string itself. The equal sign (=) and the semicolon (;) can be used with caution, as explained in Section 6.3.4. If the delimiting characters do not match, or if an invalid delimiting character is used, the directive is flagged with an error code (A) in the assembly listing.

In addition to the name assigned to the object module with the .TITLE directive (see Section 6.1.3), the .IDENT directive allows you to label the object module with the program version number.

An example of the .IDENT directive is shown below:

```
.IDENT /V01.00/
```

The character string is converted to Radix-50 representation and is included in the global symbol directory of the object module. This character string also appears in the link map produced at link time and the Librarian directory listings.

When more than one .IDENT directive is encountered in a given program, the last such directive encountered establishes the character string which forms part of the object module identification[1] .

The RSX-11M Task Builder allows a .IDENT string for each module in the program. The Task Builder uses the first .IDENT directive in each module to establish the character string that will be identified with that module. Like the RT-11 Linker, the RSX-11M Task Builder uses the .IDENT directives encountered on the first pass.

6.1.5 .PAGE Directive/Page Ejection

Format:

```
.PAGE
```

The .PAGE directive is used within the source program to start the listing on a new page at desired points in the listing. This directive takes no arguments and causes a skip to the top of the next page when encountered. It also increments the page number and (under RT-11) clears the line sequence counter. The .PAGE directive does not appear in the listing.

[1] The RT-11 Linker allows only one .IDENT string in a program. The Linker uses the first .IDENT directive encountered during the first pass to establish the character string that will be identified with all of the object modules.

When used within a macro definition, the .PAGE directive is ignored during the assembly of the macro definition. Rather, the page eject operation is performed as the macro itself is expanded. In this case, the page number is also incremented. .PAGE directives in unexpanded macros are ignored.

Page ejection is accomplished in three other ways:

- After reaching a count of 58 lines in the listing, MACRO–11 automatically performs a page eject to skip over page perforations on line printer paper and to formulate terminal output into pages. The page number is not changed.
- A page eject is performed when a form feed character is encountered. If the form feed character appears within a macro definition, a page eject occurs during the assembly of the macro definition, but not during the expansion of the macro itself. A page eject resulting from the use of the form feed character increments the page number and (under RT–11) clears the line sequence counter.
- A page eject is performed when a new source file is encountered. In this case, the page number is incremented and the line sequence count reset.

If the listing is already at top-of-page, no action is taken.

6.1.6 .REM Directive/Begin Remark Lines

Format:

```
.REM comment-character
```

where:

comment-character	represents a 7-bit ASCII or 8-bit DEC Multinational character that marks the end of the comment block when the character recurs.

The .REM directive lets you insert a block of comments into a MACRO–11 source program without having to precede the comment lines with the comment character (;). The text between the specified delimiting characters is treated as comments. The comments can span any number of lines. The following example uses ampersand (&) as the delimiting character:

```
.TITLE   Remark example
.REM     &
All the text that resides here is interpreted by MACRO--11
to be comment lines until another ampersand character is
found.  Any character can be used in place of the ampersand.&
CLR      PC
.END
```

6.2 Function Directives

The following function directives are included in a source program to invoke or inhibit certain MACRO–11 functions and operations incidental to the assembly process itself.

6.2.1 .ENABL and .DSABL Directives

Format:

```
.ENABL   arg
.DSABL   arg
```

where:

arg — represents one or more of the optional symbolic arguments defined in Table 6–3.

If you specify any argument in a .ENABL/.DSABL directive other than those listed in Table 6–3, the line will be flagged with an error code (A) in the assembly listing.

Table 6–3: Symbolic Arguments of Function Control Directives

Argument	Default	Function
ABS	Disable	Enabling this function produces output in absolute binary (.LDA) format.
AMA	Disable	Enabling this function causes all relative addresses (address mode 67) to be assembled as absolute addresses (address mode 37). This function is useful during the debugging phase of program development.
CDR	Disable	Enabling this function causes source columns from 73 to the end of the line to be treated as a comment. The most common use of this feature is to permit sequence numbers in card columns 73 to 80.
CRF	Enable	Disabling this function inhibits the generation of cross-reference output. This function has meaning only if cross-reference output generation is specified in the command string.
FPT	Disable	Enabling this function causes floating-point truncation; disabling this function causes floating-point rounding.
GBL	Enable	Disabling this function causes MACRO–11 to mark all undefined references in assembly pass 2 with a (U) error in the assembly listing. The default for this option is Enable, so MACRO–11 normally treats all undefined symbol references as global, allowing the Linker to resolve them.
LC	Enable	Disabling this function causes MACRO–11 to convert all ASCII input to uppercase before processing it. An example of the .ENABL LC and .DSABL LC directives, as typically used in a source program, is shown in Figure 6–5.
LCM	Disable	Enabling this function causes the MACRO–11 conditional assembly directives .IF IDN and .IF DIF to be alphabetically case sensitive. By default, these directives are not case sensitive.

Table 6–3 (Cont.): Symbolic Arguments of Function Control Directives

Argument	Default	Function
LSB	Disable	This argument permits the enabling or disabling of a local symbol block. Although a local symbol block is normally established by encountering a new symbolic label, a .PSECT directive, or a .RESTORE directive in the source program, a .ENABL LSB directive establishes a new local symbol block which is not terminated until another .ENABL LSB is encountered, or another symbolic label, .PSECT directive, or .RESTORE directive is encountered following a paired .DSABL LSB directive. The basic function of this directive with regard to .PSECT is limited to those instances where it is desirable to leave a program section temporarily to store data, followed by a return to the original program section. This temporary dismissal of the current program section can also be accomplished through the .SAVE and .RESTORE directives (see Sections 6.7.3 and 6.7.4). Attempts to define local symbols in an alternate program section are flagged with an error code (P) in the assembly listing.
MCL	Disable	Enabling this function causes MACRO–11 to search all known macro libraries for a macro definition that matches any undefined symbols appearing in the op code field of a MACRO–11 statement. By default, this option is disabled. If MACRO–11 finds an unknown symbol in the op code field, it either declares a (U) undefined symbol error or declares the symbol an external symbol, depending on the .ENABL/.DSABL setting of GBL.
PNC	Enable	Disabling this function inhibits binary output until a .ENABL PNC statement is encountered within the same module.
REG	Enable	Disabling this function inhibits the normal MACRO–11 default register definitions. The default register definitions are listed below: R0=%0 R1=%1 R2=%2 R3=%3 R4=%4 R5=%5 SP=%6 PC=%7 The .ENABL REG directive can be used as the logical complement of the .DSABL REG directive. The use of these directives, however, is not recommended. For logical consistency, use the normal default register definitions listed above.

Figure 6–5: Example of .ENABL and .DSABL Directives

```
.ENABL/.DSABL  MACRO V05.04  Wednesday 03-Jun-87 09:48  Page 1

     1                                      .TITLE  .ENABL/.DSABL
     2
     3                                  ;+
     4                                  ; ILLUSTRATE .ENABL/.DSABL LC
     5                                  ;-
     6
     7                                      .ENABL  LC              ;Store macro in lowercase
     8
     9                                  .MACRO  TEXT    $$$
    10                                      .ASCII  /This $$$ a lowercase string/
    11                                      .EVEN
    12                                      .ENDM
    13
    14                                      .LIST   ME
    15                                      .NLIST  BEX
    16
    17 000000                               TEXT    is              ;Call macro in lowercase mode
       000000     124     150     151       .ASCII  /This is a lowercase string/
                                            .EVEN
    18
    19                                      .DSABL  LC              ;Now disable lowercase mode
    20
    21 000032                               TEXT    WAS             ;CALL MACRO AGAIN IN UPPERCASE
       000032     124     110     111       .ASCII  /THIS WAS A LOWERCASE STRING/
                                            .EVEN
    22
    23         000001                       .END
```

6.2.2 Cross-Reference Directives: .CROSS and .NOCROSS

Format:

```
.CROSS
.CROSS sym1,sym2,...symn
.NOCROSS
.NOCROSS sym1,sym2,...symn
```

where:

sym1, sym2,...symn	represent valid symbolic names. When multiple symbols are specified, they are separated by any valid separator (comma, space, and/or tab).

The .CROSS and the .NOCROSS directives control which symbols are included in the cross-reference listing produced by the MACRO–11 assembler. These directives have an effect only if the /C[R] or the /CROSS qualifier was used in the command line to select the cross-reference capability.

By default, the cross-reference listing includes the definition and all the references to every user symbol in the module. The cross-reference listing can be disabled for all symbols or for a specified list of symbols.

When the .NOCROSS directive is used without a symbol list, the cross-reference listing of all the symbols in the module is disabled. The cross-reference listing of all the symbols in the module is reenabled when the .CROSS directive is used without a symbol list. Any symbol definition or reference that appears after a .NOCROSS directive that is used without a symbol list and before the next .CROSS directive that is used without a symbol list is excluded from the cross-reference listing.

The .NOCROSS directive used with a symbol list disables the cross-reference listing for the listed symbols. When the .CROSS directive is used with a symbol list, the cross-reference listing of the listed symbols is reenabled.

In the following example, the definition of LABEL1 and the reference to LOC1 and LOC2 are not included in the cross-reference listing.

```
        .NOCROSS                ;Stop cross reference
LABEL1: MOV     LOC1,LOC2       ;Copy data
        .CROSS                  ;Reenable cross reference
```

In the next example, the definition of LABEL2 and the reference to LOC2 are included in the cross reference, but the reference to LOC1 is not included.

```
        .NOCROSS LOC1           ;Do not cross reference LOC1
LABEL2: MOV     LOC1,LOC2       ;Copy data
        .CROSS LOC1             ;Reenable cross reference
                                ;of LOC1.
```

The .CROSS directive used without a symbol list cannot be used to reenable the cross-reference listing of a symbol specified in the symbol list of a .NOCROSS directive. In addition, if the cross-reference listing of all the symbols in a module is disabled, the .CROSS directive used with a symbol list will have no effect until the cross-reference listing is reenabled by the .CROSS directive used without a symbol list.

The .CROSS directive with no symbol list is equivalent to the .ENABL CRF directive, and the .NOCROSS directive with no symbol list is equivalent to the .DSABL CRF directive.

6.3 Data Storage Directives

A wide range of data and data types can be generated with the directives, ASCII conversion characters, and radix-control operators described in the following sections.

6.3.1 .BYTE Directive

Format:

```
.BYTE  exp          ;Stores the binary value of the
                    ;expression in the next byte.

.BYTE  exp1,exp2,expn  ;Stores the binary values of the list
                    ;of expressions in successive bytes.
```

where:

exp1, exp2,...expn	represent expressions that must be reduced to eight bits of data or less. Each expression will be read as a 16-bit word expression, the high-order byte to be truncated. The high-order byte must be all zeros, or a (A) error results. Multiple expressions must be separated by commas.

The .BYTE directive stores successive bytes of binary data in the object module.

Example:

```
        SAM=5
.=1410
        .BYTE  ^D48,SAM          ;The value 060 (octal equivalent of 48
                                 ;decimal) is stored in location 1410.
                                 ;The value 005 is stored in location
                                 ;1411.
```

The construction ^D in the first operand of the .BYTE directive above illustrates the use of a temporary radix-control operator. The function of these special unary operators is described in Section 6.4.1.2. At link time, it is likely that a relocatable expression will result in a value having more than eight bits, in which case the Linker or Task Builder issues a truncation (T) error for the object module in question. For example, the following statements create such a possibility:

```
        .BYTE 23         ;Stores octal 23 in next byte.
A:
        .BYTE A          ;Relocatable value A will probably
                         ;cause truncation error.
```

If an expression following the .BYTE directive is null, it is interpreted as a zero:

```
.=1420
        .BYTE   ,,,      ;Zeros are stored in bytes 1420, 1421,
                         ;1422, and 1423.
```

In the above example, four bytes of storage result from the .BYTE directive. The three commas in the operand field represent an implicit declaration of four null values, each separated from the other by a comma. Hence, four bytes, each containing a value of zero (0), are reserved in the object module.

6.3.2 .WORD Directive

Formats:

```
        .WORD   exp      ;Stores the binary equivalent of the
                         ;expression in the next word.

        .WORD   exp1,exp2,expn ;Stores the binary equivalents of the
                         ;list of expressions in successive words.
```

where:

exp1, exp2,...expn	represent expressions that must reduce to 16 bits of data or less. Multiple expressions must be separated by commas.

The .WORD directive stores successive words of data in the object module.

Example:

```
        SAL=0
.=1500
        .WORD  177535,.+4,SAL    ;Stores the values 177535, 1506, and
                                 ;0 in words 1500, 1502, and 1504,
                                 ;respectively.
```

If an expression following the .WORD directive contains a null value, it is interpreted as a zero, as shown in the following example:

```
.=1500
        .WORD   ,5,             ;Stores the values 0, 5, and 0 in
                                ;location 1500, 1502, and 1504,
                                ;respectively.
```

A statement with a blank operator field (one that contains a symbol other than a macro call, an instruction mnemonic, a MACRO–11 directive, or a semicolon) is interpreted during assembly as an implicit .WORD directive, as shown in the example below:

```
.=1440
LABEL: 100,LABEL                ;Stores the value 100 in location 1440
                                ;and the value 1440 in location 1442.
```

NOTE

You should not use this technique to generate .WORD directives because it may not be included in future PDP–11 assemblers.

6.3.3 ASCII Conversion Characters

The single quote (') and the double quote (") characters are unary operators that can appear in any MACRO–11 expression. Used in MACRO–11 expressions, these characters generate a 16-bit expression value.

When the single quote is used, MACRO–11 takes the next character in the expression and converts it from its 7-bit ASCII or 8-bit DEC Multinational character set value to a 16-bit expression value. The high-order byte of the resulting expression value is always zero (0). The 16-bit value is then used as an absolute term within the expression. For example, the statement:

```
MOV     #'A,R0
```

moves the 16-bit binary expression value:

00000000	01000001

into register 0. (01000001_2 is the binary value of ASCII A.)

Thus, the expression 'A results in a value of 101_8.

The single quote (') character must not be followed by a carriage return, null, RUBOUT, line feed, or form feed character; if it is, an error code (A) is generated in the assembly listing. When the double quote is used, MACRO–11 converts the next two characters in the expression to a 16-bit binary expression value from their 7-bit ASCII or 8-bit DEC Multinational values. This 16-bit value is then used as an absolute term within the expression. For example, the statement:

```
MOV     #"AB,R0
```

moves the 16-bit expression value:

01000010	01000001

into register 0. (0100001001000001_2 is the concatenated binary byte values of the ASCII characters A and B.)

Thus, the expression "AB results in a value of 041101_8.

The double quote (") character, like the single quote (') character, must not be followed by a carriage-return, null, RUBOUT, line-feed, or form-feed character; if it is, an error code (A) is generated in the assembly listing.

The DEC Multinational character set is listed in Section A.1.

6.3.4 .ASCII Directive

Format:

```
.ASCII  /string 1/.../string n/
```

where:

string — is a string of 7-bit ASCII or 8-bit DEC Multinational printing characters, plus space and horizontal tab. All nonprinting characters except carriage return and form feed cause an error code (I) if used in a .ASCII string. Carriage return and form feed characters are flagged with an error code (A) because they end the scan of the line, preventing MACRO–11 from detecting the matching delimiter at the end of the character string.

/ . . . / — represent delimiting characters. These delimiters can be any paired printing characters other than the colon (:) and left angle bracket (<), as long as the delimiting character is not contained within the text string itself. The equal sign (=) and the semicolon (;) can be used with caution, as explained below. If the delimiting characters do not match, or if an invalid delimiting character is used, the directive is flagged with an error code (A) in the assembly listing.

The .ASCII directive translates character strings into their 7-bit ASCII or 8-bit DEC Multinational equivalents and stores them in the object module. A nonprinting character can be expressed only by enclosing its equivalent octal value within angle brackets. Each set of angle brackets so used represents a single character. For example, in the following statement:

```
.ASCII  <15>/ABC/<A+2>/DEF/<5><4>
```

the expressions <15>, <A+2>, <5>, and <4> represent the values of nonprinting characters. Each bracketed expression must reduce to eight bits of absolute data or less. The expression cannot contain any global symbols.

Angle brackets can be embedded between delimiting characters in the character string, but angle brackets so used do not take on their usual significance as delimiters for nonprinting characters. For example, the statement:

```
.ASCII  /ABC<expression>DEF/
```

contains a single ASCII character string, and performs no evaluation of the embedded, bracketed expression. This use of the angle brackets is shown in the third example of the .ASCII directive below:

```
.ASCII  /HELLO/         ;Stores the binary representation
                        ;of the letters HELLO in five
                        ;consecutive bytes.
```

```
.ASCII  /ABC/<15><12>/DEF/ ;Stores the binary representation
                           ;of the characters A,B,C,carriage
                           ;return,line feed,D,E,F in eight
                           ;consecutive bytes.

.ASCII  /A<15>B/           ;Stores the binary representation
                           ;of the characters A, <, 1, 5, >,
                           ;and B in six consecutive bytes.
```

The colon (:) character can never be used as a delimiting character. The semicolon (;) and equal sign (=) can be used as delimiting characters in the string, but care must be exercised in so doing because of their significance as a comment indicator and assignment operator, respectively, as illustrated in the examples below:

```
.ASCII ;ABC;/DEF/          ;Stores the binary representation of
                           ;the  characters A, B, C, D, E, and
                           ;F in six consecutive bytes;
                           ;not recommended practice.

.ASCII /ABC/;DEF;          ;Stores the binary representations of
                           ;the characters A, B, and C in three
                           ;consecutive bytes; the characters D,
                           ;E, F, and ; are treated as a comment.

.ASCII /ABC/=DEF=          ;Stores the binary representation of
                           ;the characters A, B, C, D, E, and
                           ;F in six consecutive bytes;
                           ;not recommended practice.
```

An equal sign is treated as an assignment operator when it appears as the first character in the ASCII string, as illustrated by the following example:

```
.ASCII =DEF=               ;The direct assignment operation
                           ;.ASCII=DEF is performed, and a
                           ;syntax error (Q) is generated upon
                           ;encountering the second = sign.
```

6.3.5 .ASCIZ Directive

Format:

```
.ASCIZ  /string 1/.../string n/
```

where:

string — is a string of 7-bit ASCII or 8-bit DEC Multinational printing characters, plus space and horizontal tab. All nonprinting characters except carriage return and form feed cause an error code (I) if used in a .ASCII string. Carriage return and form feed characters are flagged with an error code (A) because they end the scan of the line, preventing MACRO–11 from detecting the matching delimiter at the end of the character string.

/ . . . / represent delimiting characters. These delimiters can be any paired printing characters other than the colon (:) and left angle bracket (<), as long as the delimiting character is not contained within the text string itself. The equal sign (=) and the semicolon (;) can be used with caution, as explained in Section 6.3.4. If the delimiting characters do not match, or if an invalid delimiting character is used, the directive is flagged with an error code (A) in the assembly listing.

The .ASCIZ directive is similar to the .ASCII directive described above, except that a zero byte is automatically inserted as the final character of the string. Thus, when a list or text string has been created with a .ASCIZ directive, a search for the null character in the last byte can effectively determine the end of the string, as reflected in the example below:

```
        CR=15
        LF=12
HELLO:  .ASCIZ  <CR><LF>/MACRO--11 V05.00/<CR><LF>  ;Introductory message
        .EVEN
        .
        .
        .
        MOV     #HELLO,R1       ;Get address of message.
        MOV     #LINBUF,R2      ;Get address of output buffer.
10$:    MOVB    (R1)+,(R2)+     ;Move a byte to output buffer.
        BNE     10$             ;If not null, move another byte.
        .
        .
        .
```

6.3.6 .RAD50 Directive

Format:

```
.RAD50  /string 1/.../string n/
```

where:

string represents a series of characters to be packed. The string must consist of the characters A through Z, 0 through 9, dollar sign ($), period (.) and space ( ). An invalid printing character causes an error flag (Q) to be printed in the assembly listing.

If fewer than three characters are to be packed, the string is packed left-justified within the word, and trailing spaces are assumed.

All nonprinting characters except carriage return and form feed cause an error code (I) if used in a .ASCII string. Carriage return and form feed characters are flagged with an error code (A) because they end the scan of the line, preventing MACRO-11 from detecting the matching delimiter at the end of the character string.

/ . . . / represent delimiting characters. These delimiters can be any paired printing characters other than the colon (:) and left angle bracket (<), as long as the delimiting character is not contained within the text string itself. The equal sign (=) and the semicolon (;) can be used with caution, as explained in Section 6.3.4. If the delimiting characters do not match, or if an invalid delimiting character is used, the directive is flagged with an error code (A) in the assembly listing.

The .RAD50 directive generates data in Radix–50 packed format. Radix–50 form allows three characters to be packed into 16 bits (one word); therefore, any 6-character symbol can be stored in two consecutive words. Examples of .RAD50 directives are shown below:

```
.RAD50 /ABC/     ;Packs ABC into one word.
.RAD50 /AB/      ;Packs AB (SPACE) into one word.
.RAD50 /ABCD/    ;Packs ABC into first word and
                 ;D (SPACE) (SPACE) into second word.
.RAD50 /ABCDEF/ ;Packs ABC into first word, DEF into
                 ;second word.
```

Each character is translated into its Radix–50 equivalent, as indicated in the following table:

Character	Radix-50 Octal Equivalent
(space)	0
A–Z	01–32
$	33
.	34
(undefined)	35
0–9	36–47

The Radix–50 equivalents for characters 1 through 3 (C1,C2,C3) are combined as follows:

Radix–50 value = $((C1*50_8)+C2)*50_8+C3$

For example:

Radix–50 value of ABC = $((1*50_8)+2)*50_8+3 = 3223_8$

Refer to Section A.2 for a table of Radix–50 equivalents.

Angle brackets (<>) must be used in the .RAD50 directive whenever special codes are to be inserted in the text string, as shown in the example below:

```
.RAD50  /AB/<35> ;Stores 3255 in one word.
CHR1=1
CHR2=2
CHR3=3
.
.
.
.RAD50 <CHR1><CHR2><CHR3> ;Equivalent to .RAD50 /ABC/.
```

6.3.7 Temporary Radix–50 Control Operator

Format:

```
^Rccc
```

where:

ccc	represents a maximum of three characters to be converted to a 16-bit Radix–50 value. If more than three characters are specified, any following the third character are ignored. If fewer than three are specified, the trailing characters are assumed to be blanks.

The ^R operator converts its argument to Radix–50 format. This allows up to three characters to be stored in one word. If you use ^R with no argument, MACRO–11 generates a word of 0.

The following example shows how the ^R operator might be used to pack a 3-character file type specifier (MAC) into a single 16-bit word.

```
MOV #^RMAC,FILEXT          ;Store RAD50 MAC as file extension
```

The number sign (#) indicates immediate data (data to be assembled directly into object code). ^R specifies that the characters MAC are to be converted to Radix–50. This value is then stored in location FILEXT.

6.3.8 .PACKED Directive

Format:

```
.PACKED decimal-string[,symbol]
```

where:

decimal-string	represents a decimal number from 0 to 31_{10} digits long. Each digit must be in the range 0 to 9. The number can have a sign, but it is not required and is not counted as a digit in the total of 31_{10}.
symbol	is assigned a value equivalent to the number of decimal digits in the string.

The .PACKED directive generates packed decimal data, four bits per digit (two digits per byte) plus a 4-bit sign designator. The sign designator can have one of three values:

1100_2	Positive
1101_2	Negative
1111_2	Unsigned

Arithmetic and operational properties of packed decimals are similar to those of numeric strings. Figure 6–6 is an example of the .PACKED directive.

Figure 6–6: Example of the .PACKED Directive

```
     1    .LIST BEX
     2 000000    017   .PACKED  0, UOLEN
     3 000001    014   .PACKED +0, POLEN
     4 000002    015   .PACKED -0, NOLEN
     5 000003    037   .PACKED  1, U1LEN
     6 000004    034   .PACKED +1, P1LEN
     7 000005    035   .PACKED -1, N1LEN
     8 000006    001   .PACKED  12, U12LEN
000007    057
     9 000010    001   .PACKED +12, P12LEN
000011    054
    10 000012    001   .PACKED -12, N12LEN
000013    055
    11 000014    001   .PACKED  1234567890, UXLEN
000015    043
000016    105
000017    147
000020    211
000021    017
    12 000022    001   .PACKED +1234567890, PXLEN
000023    043
000024    105
000025    147
000026    211
000027    014
    13 000030    001   .PACKED -1234567890, NXLEN
000031    043
000032    105
000033    147
000034    211
000035    015
    14    .EVEN
    15
    16  000001   .END
Symbol table

NXLEN = 000012    PXLEN = 000012    UXLEN = 000012
NOLEN = 000001    POLEN = 000001    UOLEN = 000001
N1LEN = 000001    P1LEN = 000001    U1LEN = 000001
N12LEN= 000002    P12LEN= 000002    U12LEN= 000002
```

6.4 Radix and Numeric Control Facilities

6.4.1 Radix Control and Unary Control Operators

Any numeric or expression value in a MACRO–11 source program is read as an octal value by default. Occasionally, however, an alternate radix is useful. By using the MACRO–11 facilities described below, you can declare a radix to affect a term or an entire program depending on your needs.

NOTE

When two or more unary operators appear together, modifying the same term, the operators are applied to the term from right to left.

6.4.1.1 .RADIX Directive

Format:

```
.RADIX  n
```

where:

n — represents one of the radices 2, 8, 10, or 16. Any value other than null or one of the acceptable radices is flagged with an error code (A) in the assembly listing. If no argument is specified, the octal default radix is assumed. The argument (n) is always read as a decimal value.

Numbers used in a MACRO–11 source program are initially assumed to be octal values; however, with the .RADIX directive you can declare alternate radices applicable throughout the source program or within specific portions of the program.

Any alternate radix declared in the source program through the .RADIX directive remains in effect until altered by the occurrence of another such directive, for example:

```
.RADIX 10       ;Begins a section of code having a
                ;decimal radix.
   .
   .
   .
.RADIX          ;Reverts to octal radix.
```

In general, macro definitions should not contain or rely on radix settings established with the .RADIX directive. Rather, temporary radix control operators should be used within a macro definition. Where a possible radix conflict exists within a macro definition or source program, specify numeric or expression values using the temporary radix control operators described below.

NOTE

All hexadecimal values used with .RADIX 16 must begin with a digit, which can be 0. For example, the hexadecimal value F3 must be written as 0F3. Otherwise, MACRO–11 assumes the item is a symbolic name, not a hexadecimal number.

6.4.1.2 Temporary Radix Control Operators

Formats:

```
^Bn             ; n is evaluated as a binary number
^Dn             ; n is evaluated as a decimal number
^On             ; n is evaluated as an octal number
^Xn             ; n is evaluated as a hexadecimal number
```

These unary operators establish an alternate radix for a single term. A temporary alternate is useful because, after you have specified a radix for a section of code or have decided to use the default octal radix, you may discover a number of cases where an alternate radix is more convenient or desirable (particularly within macro definitions). Creating a mask word (used to check bit status), for example, might be accomplished best through the use of a binary radix.

An alternate radix can be declared temporarily to meet a localized requirement in the source program. The temporary radix control operator can be used any time regardless of the radix in effect or other radix declarations within the program. Because the operator affects only the term immediately following it, it can be used anywhere a numeric value is valid. The term (or expression) associated with the temporary radix control operator is evaluated during assembly as a 16-bit entity.

The expressions below are representative of the methods of specifying temporary radix control operators:

`^D123`	Decimal Radix
`^O 47`	Octal Radix
`^B 00001101`	Binary Radix
`^O<A+13>`	Octal Radix
`^X0F3`	Hexadecimal Radix

The circumflex and the radix control operator cannot be separated, but the radix control operator and the following term or expression can be separated by spaces or tabs for legibility or formatting. A multielement term or expression that is to be interpreted in an alternate radix should be enclosed within angle brackets, as shown in the last of the four temporary radix control expressions above.

The following example also illustrates the use of angle brackets to delimit an expression that is to be interpreted in an alternate radix. When the temporary radix control operator is used, only numeric values are affected. Any symbols used with the operator are evaluated with respect to the radix in effect at their declaration:

```
        .RADIX 10
A=10
        .WORD ^O<A+10>*10
```

When the temporary radix expression in the `.WORD` directive above is evaluated, it yields the following equivalent statement:

```
        .WORD 180
```

MACRO–11 also allows a temporary radix change to decimal by specifying a number immediately followed by a decimal point (.), as shown below:

```
100.            ;Equivalent to 144(octal)
1376.           ;Equivalent to 2540(octal)
128.            ;Equivalent to 200(octal)
```

The above expression forms are equivalent in function to:

```
^D100
^D1376
^D128
```

NOTE

All hexadecimal values used with ^X must begin with a digit, which can be 0. For example, the hexadecimal value F3 must be written as 0F3. Otherwise, MACRO–11 assumes the item is a symbolic name, not a hexadecimal number.

6.4.2 Numeric Directives and Unary Control Operators

Two storage directives and two numeric control operators are available to simplify the use of the floating-point hardware on the PDP–11. These facilities allow floating-point data to be created in the program, and numeric values to be complemented or treated as floating-point numbers.

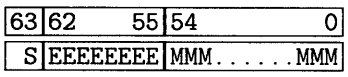
A floating-point number is represented by a string of one or more decimal digits. The string can contain an optional decimal point and can be followed by an optional exponent indicator in the form of the letter E and a signed decimal integer exponent. The number cannot contain embedded blanks, tabs, or angle brackets and cannot be an expression; such a string will result in one or more errors (A and/or Q) in the assembly listing.

The list of numeric representations below contains seven distinct, valid representations of the same floating-point number:

```
3
3.
3.0
3.0E0
3E0
.3E1
300E-2
```

As can be inferred, the list could be extended indefinitely (3000E–3, .03E2, and so on). A leading plus sign is optional (3.0 is considered to be +3.0). A leading minus sign complements the sign bit. No other operators are allowed; for example, 3.0+N is invalid.

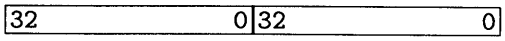
All floating-point numbers are evaluated as 64 bits in the following format:



Sign (1 bit)
Exponent (8 bits)
Mantissa (55 bits)

MACRO–11 returns a value of the appropriate size and precision by means of floating-point directives. The value returned can be truncated or rounded (see Section 6.2.1).

Floating-point numbers are normally rounded. That is, when a floating-point number exceeds the limits of the field in which it is to be stored, the high-order bit of the unretained word is added to the low-order bit of the retained word, as shown below. For example, if the number is to be stored in a 2-word field, but more than 32 bits are needed to express its exact value, the highest bit (32) of the unretained field is added to the least significant bit (0) of the retained field (see illustration below). The `.ENABL FPT` directive is used to enable floating-point truncation; `.DSABL FPT` is used to return to floating-point rounding (see Table 6–3).



Retained field Unretained field

All numeric operands associated with Floating Point Processor instructions are automatically evaluated as single-word, decimal, floating-point values unless a temporary radix control operator is specified. For example, to add (floating) the constant 41040_8 to the contents of floating accumulator zero, the following instruction must be used:

```
ADDF    #^O41040,F0
```

where:

F0	is assumed to represent floating accumulator zero.

Floating-point numbers are described in greater detail in the *PDP–11 Processor Handbook*.

6.4.2.1 One's Complement Operator: ^C

The `^C` unary operator complements an argument as it is evaluated during assembly.

As with the radix control operators such as `^D` and `^O`, the numeric control operator `^C` can be used anywhere in the source program that an expression value is valid. Such a construction is evaluated by MACRO–11 as a 16-bit binary value before being complemented. For example, the following statement:

```
TAG4:   .WORD   ^C151
```

stores the one's complement of the value 151_8 as a 16-bit value in the program. The resulting value expressed in octal form is 177626_8.

Because the ^C construction is a unary operator, the operator and its argument are regarded as a term. Thus, more than one unary operator can be applied to a single term. For example, the following construction:

```
^C^D25
```

complements the value 25_{10} during assembly. The resulting binary value, when expressed in octal form, reduces to 177746_8.

The term created through the use of the temporary numeric control operator can be used alone or in combination with other expression elements. For example, the following construction:

```
^C2+6
```

is equivalent in function to:

```
<^C2>+6
```

This expression is evaluated during assembly as the one's complement of 2, plus the absolute value of 6. When these terms are combined, the resulting expression value generates a carry beyond the most significant bit, leaving 000003_8 as the reduced value.

6.4.2.2 Floating-Point Storage Directives

Format:

```
.FLT2   arg1,arg2,...argn
.FLT4   arg1,arg2,...argn
```

where:

arg1,arg2,...argn	represent one or more floating-point numbers as described in Section 6.4.2. Multiple arguments must be separated by commas.

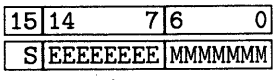
.FLT2 generates two words of storage for each argument, while .FLT4 generates four words of storage for each argument. As in the .WORD directive, the arguments are evaluated and the results stored in the object module.

6.4.2.3 Floating-Point Operator: ^F

The ^F unary operator for numeric control lets you specify an argument that is a 1-word floating-point number. For example, the following statement:

```
A:      MOV   #^F3.7,R0
```

creates a 1-word floating-point number at location A+2 containing the value 3.7 formatted as shown below:



Sign (1 bit)
Exponent (8 bits)
Mantissa (7 bits)

The importance of ordering with respect to unary operators is shown below:

```
^F1.0   = 040200
^F-1.0  = 140200
-^F1.0  = 137600
-^F-1.0 = 037600
```

The value created by the ^F unary operator and its argument is, like ^C and its argument, a term that can be used by itself or in an expression. For example:

```
^C^F6.2
```

is equivalent to:

```
^C<^F6.2>
```

Expressions used as terms or arguments of a unary operator must be explicitly grouped. As illustrated above and in Section 6.4.2.1, when a temporary numeric control operator and its argument are coded as a term within an expression, angle brackets should be used as delimiters to ensure precise evaluation and readability.

6.5 Location Counter Control Directives

The directives used in controlling the value of the current location counter and in reserving storage space in the object program are described in the following sections.

Several MACRO–11 statements (listed below) may allocate an odd number of bytes:

- .BYTE directive
- .BLKB directive
- .ASCII or .ASCIZ directive
- .ODD directive
- .PACKED directive
- A direct assignment statement of the form .=.+expression, which results in the assignment of an odd address value.

In cases that yield an odd address value, the next instruction on a word boundary automatically forces the location counter to an even value, but that instruction is flagged with an error code (B) in the assembly listing.

6.5.1 .EVEN Directive

Format:

```
.EVEN
```

The .EVEN directive ensures that the current location counter contains an even value by adding 1 if the current value is odd. If the current location counter is already even, no action is taken. Any operands following a .EVEN directive are flagged with an error code (Q) in the assembly listing.

The .EVEN directive is used as follows:

```
.ASCIZ /This is a test/
.EVEN           ;Ensures that the next statement will
                ;begin on a word boundary.
.WORD XYZ
```

6.5.2 .ODD Directive

Format:

```
.ODD
```

The .ODD directive ensures that the current location counter contains an odd value by adding 1 if the current value is even. If the current location counter is already odd, no action is taken. Any operands following a .ODD directive are flagged with an error code (Q) in the assembly listing.

6.5.3 .BLKB and .BLKW Directives

Format:

```
.BLKB   exp
.BLKW   exp
```

where:

exp — represents the specified number of bytes or words to be reserved in the object program. Any expression that is defined at assembly time and that reduces to an absolute value is valid. If the expression specified in either of these directives is not an absolute value, the statement is flagged with an error code (A) in the assembly listing. Furthermore, if the expression contains a forward reference (a reference to a symbol that is not previously defined), MACRO-11 generates incorrect object file code and may cause statements following the .BLKB/.BLKW directive to be flagged with phase (P) errors. These directives should not be used without arguments. However, if no argument is present, a default value of 1 is assumed.

The .BLKB directive reserves byte blocks in the object module; the .BLKW directive reserves word blocks. Figure 6–7 illustrates the use of the .BLKB and .BLKW directives.

Figure 6–7: Example of .BLKB and .BLKW Directives

```
 1                      ;+
 2                      ; Illustrate use of .BLKB and .BLKW directives
 3                      ;-
 4 000000                       .PSECT  IMPURE,D,GBL,RW
 5
 6 000000               COUNT:  .BLKW   1               ;Character counter
 7
 8 000002               MESSAG: .BLKB   80.             ;Message text buffer
 9
10 000122               CHRSAV: .BLKB                   ;Saved character
11
12 000123               FLAG:   .BLKB                   ;Flag byte
13
14 000124               MAGPTR: .BLKW                   ;Message buffer pointer
```

The .BLKB directive in a source program has the same effect as the following statement:

```
.=.+expression
```

which adds the value of the expression to the current value of the location counter. The .BLKB directive, however, is easier to interpret in the context of the source code in which it appears and is therefore recommended.

6.5.4 .LIMIT Directive

Format:

```
.LIMIT
```

To know the upper and lower address boundaries of the image is often desirable. When the .LIMIT directive is specified in the source program, MACRO–11 generates the following instruction:

```
.BLKW   2
```

and reserves two storage words in the object module. Later, at link time, the lowest address in the load image (the initial value of SP) is inserted into the first reserved word, and the address of the first free word following the image is inserted into the second reserved word.

During linking, the size of the image is rounded upward to the nearest 2-word boundary.

6.6 Terminating Directive: .END Directive

Format:

```
.END    [exp]
```

where:

exp	represents an optional expression value which, if present, indicates the program-entry point, which is the transfer address where the program begins.

When MACRO–11 encounters a valid occurrence of the .END directive, it terminates the current assembly pass. Any text beyond this point in the current source file, or in additional source files identified in the command line, is ignored.

When an image consisting of several object modules is created, only one object module can be terminated with a .END exp statement (where exp is the starting address). All other object modules must be terminated with a .END statement (where .END has no argument); otherwise, an error message will be issued at link time. If no starting address is specified in any of the object modules, image execution begins at location 1 of the image and immediately faults because of an odd addressing error.

The .END statement must not be used within a macro expansion or a conditional assembly block; if it is so used, it is flagged with an error code (O) in the assembly listing. The .END statement can be used, however, in an immediate conditional statement (see Section 6.9.3).

If the source program input is not terminated with a .END directive, an error code (E) results in the assembly listing.

6.7 Program Sectioning Directives

The MACRO–11 program sectioning directives declare names for program sections (p-sections) and establish certain program section attributes essential to linking.

6.7.1 .PSECT Directive

Format:

```
.PSECT  name,arg1,arg2,...argn
```

where:

name	represents the symbolic name of the program section, as described in Table 6–4.
,	represents any valid separator (comma, tab and/or space).
arg1, arg2,...argn	represent one or more of the valid symbolic arguments defined for use with the .PSECT directive, as described in Table 6–4. The slash separating each pair of symbolic arguments listed in the table indicates that one or the other, but not both, can be specified. Multiple arguments must be separated by a valid separating character. Any symbolic argument specified in the .PSECT directive other than those listed in Table 6–4 will be flagged with an error code (A) in the assembly listing.

Table 6–4: Symbolic Arguments of .PSECT Directive

Argument	Default	Meaning
NAME	Blank	Establishes the program section name, which is specified as one to six Radix–50 characters. If this argument is omitted, a comma must appear in place of the name parameter. The Radix–50 character set is listed in Section A.2.
RO/RW[1]	RW	Defines which type of access is permitted to the program section: RO = Read-Only Access RW = Read/Write Access RT–11 and RSX–11M use only Read/Write access.
I/D[1]	I	Defines the contents of the program section: I = Instructions. If a p-section has the I attribute and the program is overlaid, all calls to the p-section are referenced through a body of overlay code stored in the root. If a concatenated p-section has the I attribute, code is concatenated on even bytes. D = Data. If a p-section has the D attribute, all calls to the p-section are referenced directly. If a concatenated p-section has the D attribute, code is concatenated on the next byte regardless of whether the byte is odd or even.

[1]Where two possible arguments are separated by a slash (/), you can choose one or the other.

Table 6–4 (Cont.): Symbolic Arguments of .PSECT Directive

Argument	Default	Meaning
GBL/LCL[1]	LCL	Defines the scope of the program section, as it will be interpreted at link time: LCL = Local. If an object module contains a local program section, then the storage allocation for that module will remain in the segment containing the module. Many modules can contribute (allocate memory) to this same program section; the memory allocation for each contributing module is either concatenated or overlaid within the segment, depending on the allocation argument of the program section (see CON/OVR below). GBL = Global. If a global program section is used in more than one segment of a program, all references to the p-section are collected across segment boundaries. The program sections are then stored in the segment (of those originally containing the p-sections) that is nearest the root. RT–11 stores the collected p-sections in the root. The GBL/LCL arguments apply only in the case of overlays; in building single-segment nonoverlaid programs, the GBL/LCL arguments have no meaning, because the total memory allocation for the program will go into the root segment of the image.

ABS/REL[1]	REL	Defines the relocatability attribute of the program section:
		ABS = Absolute (non-relocatable). The ABS argument causes the Linker or Task Builder to treat the p-section as an absolute module; therefore, no relocation is required. The program section is assembled and loaded, starting at absolute virtual address 0.
		The location of data in absolute program sections must fall within the virtual memory limits of the segment containing the program section; otherwise, an error results at link time. For example, the following code, although valid during assembly, may generate an error message (A) if virtual location 100000 is outside the segment's virtual address space:
		`.PSECT ALPHA,ABS`
		`.=.+100000`
		`.WORD X`
		REL = Relocatable. The REL argument causes the Linker or Task Builder to treat the p-section as a relocatable module and a relocation bias is added to all location references within the program section making the references absolute.

[1] Where two possible arguments are separated by a slash (/), you can choose one or the other.

Table 6–4 (Cont.): Symbolic Arguments of .PSECT Directive

Argument	Default	Meaning
CON/OVR[1]	CON	Defines the allocation requirements of the program section: CON = Concatenated. All references to one program section are concatenated to determine the total memory space needed for the p-section. OVR = Overlaid. All references to one program section are overlaid; the total memory space needed equaling the largest, individual p-section.
SAV/NOSAV[1]	NOSAV	Determines where the Linker allocates storage for the program section: SAV = Save. The Linker always forces allocation for the program section to the root of the image. NOSAV = No Save. The Linker allocates the program section normally.

[1]Where two possible arguments are separated by a slash (/), you can choose one or the other.

NAME is the only position-dependent argument for the .PSECT directive. If NAME is omitted, a comma must be used in its place. For example, the directive:

```
.PSECT  ,GBL
```

shows a .PSECT directive with a blank name argument and the GBL argument. Default values (see Table 6–4) are assumed for all other unspecified arguments.

The .PSECT directive can be used without a name or arguments (see Section 6.7.1.1).

The .PSECT directive lets you create program sections (see Section 6.7.1.1) and to share code and data among the sections you have created (see Section 6.7.1.2). In declaring the program sections (also called p-sections), you can declare the attributes of the p-sections. This lets you control memory allocation and at the same time increases program modularity. (For a discussion of memory allocation, refer to the applicable system manual—see the Associated Documents section in the Preface.)

MACRO–11 provides for 256_{10} program sections, as listed below:

- One default absolute program section (. ABS.)
- One default relocatable program section (. BLK.)[1]
- 254_{10} named program sections. (You can have more, but only the first 254 appear in the symbol table.)

[1] In RT–11, this program section is unnamed.

For each program section specified or implied, MACRO–11 maintains the following information:

— Program section name

— Contents of the current location counter

— Maximum location counter value encountered

— Program section attributes (described in Table 6–4)

6.7.1.1 Creating Program Sections

The first statement of a source program is always an implied .PSECT directive; this causes MACRO–11 to begin assembling source statements at relocatable zero of the unnamed program section.

The first occurrence of a .PSECT directive with a given name assumes that the current location counter is set at relocatable zero. The scope of this directive then extends until a directive declaring a different program section is specified. Subsequent .PSECT directives cause assembly to resume where the named section previously ended; for example:

```
        .PSECT          ;Declares unnamed relocatable program
A:      .WORD   0       ;section assembled at relocatable
B:      .WORD   0       ;addresses 0 through 5.
C:      .WORD   0
        .PSECT  ALPHA   ;Declares relocatable program section
X:      .WORD   0       ;named ALPHA assembled at relocatable
Y:      .WORD   0       ;addresses 0 through 3.
        .PSECT          ;Returns to unnamed relocatable
D:      .WORD   0       ;program section and continues assem-
                        ;bly at relocatable address 6.
```

A given program section can be defined completely upon encountering its first .PSECT directive. Thereafter, the section can be referenced by specifying its name only or by completely respecifying its attributes. For example, a program section can be declared through the directive:

```
.PSECT  ALPHA,ABS,OVR
```

and later referenced through the equivalent directive:

```
.PSECT  ALPHA
```

which requires no arguments. If arguments are specified, they must be identical to the ones previously declared for the p-section. If the arguments differ, the arguments of the first .PSECT will remain in effect, and an error code (A) will be generated as a warning.

By maintaining separate location counters for each program section, MACRO–11 lets you write statements that are not physically sequential but that can be loaded sequentially following assembly, as shown in the following example.

```
        .PSECT  SEC1,REL,RO     ;Start a relocatable program section
A:      .WORD   0               ;named SEC1 assembled at relocatable
B:      .WORD   0               ;addresses 0 through 5.
C:      .WORD   0
ST:     CLR     A               ;Assemble code at relocatable
        CLR     B               ;addresses 6 through 21(octal).
        CLR     C
        .PSECT  SECA,ABS        ;Start an absolute program section
                                ;named SECA. Assemble code at
        .WORD   .+2,A           ;absolute addresses 0 through 3.
        .PSECT  SEC1            ;Resume relocatable program section
        INC     A               ;SEC1. Assemble code at relocatable
        BR      ST              ;addresses 22 through 27(octal).
```

All labels in an absolute program section are absolute; likewise, all labels in a relocatable section are relocatable. The current location counter symbol (.) is relocatable or absolute when referenced in a relocatable or absolute program section, respectively.

Any labels appearing on a line containing a .PSECT (or .ASECT or .CSECT) directive are assigned the value of the current location counter before the .PSECT (or other) directive takes effect. Thus, if the first statement of a program is:

```
A:      .PSECT ALT,REL
```

the label A is assigned to relocatable address zero of the unnamed program section.

Since it is not known during assembly where relocatable program sections will be loaded, all references to relocatable program sections are assembled as references relative to the base of the referenced section.

In the following example, references to the symbols X and Y are translated into references relative to the base of the relocatable program section named SEN.

```
        .PSECT ENT,ABS
.=.+1000
A:      CLR     X       ;Assembled as CLR base of
                        ;relocatable section + 10(octal).
        JMP     Y       ;Assembled as JMP base of
                        :relocatable section + 6(octal).
        .PSECT  SEN,REL
        MOV     RO,R1
        JMP     A       ;Assembled as JMP 1000.
Y:      HALT
X:      .WORD   0
```

NOTE

In the preceding example, using a constant in conjunction with the current location counter symbol (.) in the form .=1000 would result in an error, because constants are always absolute and are always associated with the program's .ASECT (. ABS.). If the form .=1000 were used, a program section incompatibility would be detected. See Section 3.6 for a discussion of the current location counter.

Thus, MACRO–11 provides the Linker or Task Builder with the necessary information to resolve the linkages between various program sections. Such information is not necessary, however, when an absolute program section is referenced, because all instructions in an absolute program section are associated with an absolute virtual address.

6.7.1.2 Code or Data Sharing

Named relocatable program sections with the arguments GBL and OVR operate in the same manner as FORTRAN COMMON; that is, program sections of the same name with the arguments GBL and OVR from different assemblies are all loaded at the same location at link time. All other program sections (those with the argument CON) are concatenated.

A single symbol could name both an internal symbol and a program section. Considering FORTRAN again, using the same symbolic name is necessary to accommodate the following statement:

```
COMMON  /X/ A,B,C,X
```

where:

X	represents the base of the program section and also the fourth element of that section.

6.7.1.3 Memory Allocation Considerations

MACRO–11 does not generate an error when a module ends at an odd location. You can, therefore, place odd length data at the end of a module. However, when several modules contain object code contributions to the same program section having the concatenate attribute (see Table 6–4; CON/OVR), odd length modules (except the last) may cause succeeding modules to be linked starting at odd locations, thereby making the linked program unexecutable. To avoid this problem, separate code and data from each other and place them in separately named program sections (see Table 6–4; I/D). The Linker or Task Builder can then begin each program section on an even address. Refer to the applicable system manual for further information on memory allocation of tasks (see the Associated Documents section in the Preface).

6.7.2 .ASECT and .CSECT Directives

Format:

```
.ASECT
.CSECT
.CSECT  symbol
```

where:

symbol	represents one or more of the arguments in Table 6–4.

IAS and RSX–11M assembly language programs use the .PSECT and .ASECT directives exclusively, because the .PSECT directive provides all the capabilities of the .CSECT directive defined for other PDP–11 assemblers. MACRO–11 accepts both .ASECT and .CSECT directives, but assembles them as though they were .PSECT directives with the default attributes listed in Table 6–5. Compatibility exists between other MACRO–11

programs and the IAS and RSX-11M Task Builders, because the Task Builders also treat the .ASECT and .CSECT directives like .PSECT directives with the default values listed in Table 6–5.

Table 6–5: Program Section Default Values

	Default Value			
Attribute	**.ASECT**	**.CSECT (named)**	**.CSECT (unnamed)**	**.PSECT**
Name	. ABS.	name	. BLK. [1]	name
Access	RW	RW	RW	RW
Type	I	I	I	I
Scope	GBL	GBL	LCL	LCL
Relocation	ABS	REL	REL	REL
Allocation	OVR	OVR	CON	CON

[1] In RT-11, this program section has no default name.

Note that the statement:

```
.CSECT  JIM
```

is identical to the statement:

```
.PSECT  JIM,GBL,OVR
```

because the .CSECT default values GBL and OVR are assumed for the named program section.

6.7.3 .SAVE Directive

Format:

```
.SAVE
```

The .SAVE directive stores the current program section context on the top of the program section context stack, while leaving the current program section context in effect. If the program section context stack is full when .SAVE is issued, the directive is flagged with an error code (A) in the assembly listing. The program section context stack can handle 16 .SAVEs. The program section context includes the values of the current location counter and the maximum value assigned to the location counter in the current program section.

See Figure 6–8 for an example of .SAVE.

6.7.4 .RESTORE Directive

Format:

```
.RESTORE
```

The .RESTORE directive retrieves the program section context from the top of the program section context stack. If the program section context stack is empty when .RESTORE is issued, the directive is flagged with an error code (A) in the assembly listing. When .RESTORE retrieves a program section, it restores the current location counter to the value it had when the program section was saved.

When saving and restoring program sections, be careful not to store data in a program section for which you have saved but not yet restored the context; when you restore the context, the data will be lost. For example, the .WORD 1000 in the following series of instructions has no effect:

```
.PSECT  A
.SAVE           ;Save context of psect A
.PSECT  A       ;Re-establish psect A
.WORD   1000    ;The effect of this instruction...
.RESTORE        ;gets wiped out by this .RESTORE directive
                ;that restores the old context of psect A
```

See Figure 6–8 for an example of .RESTORE.

Figure 6–8: Example of .SAVE and .RESTORE Directives

```
.MAIN.  MACRO V05.04  Wednesday 03-Jun-87 10:05  Page 1
Example of .SAVE/.RESTORE usage
 1                                      .SBTTL  Example of .SAVE/.RESTORE usage
 2
 3                              ;+
 4                              ; MACRO DS
 5                              ; Define local impure storage
 6                              ;-
 7
 8                                      .MACRO  DS      NAME, SIZE
 9                                      .SAVE                   ;Save the current .PSECT
10                                      .PSECT  IMPURE,D,GBL    ;Store the data in the IMPURE .PSECT
11                              NAME:   .BLKW   SIZE            ;Set aside the space
12                                      .RESTORE                ;Reenter the current .PSECT
13                                      .ENDM
14
15                              ;+
16                              ; SCANSY
17                              ; Scan the hash table for valid entries
18                              ;-
19
20 000000  016701  000000'      SCANSY: MOV     SYMBAS,R1       ;Get base of table
21 000004  010167  000002'              MOV     R1,CURSYM       ;Initialize pointer to table
22 000010  066701  000004'              ADD     SYMSIZ,R1       ;Point past the table
23 000014  010167  000006'              MOV     R1,SYMTOP       ;Save end address
24                              ;
25                              ; Rest of SCANSY routine....
26                              ;
27 000020  000207                       RETURN                  ;Table is scanned, exit.
28
29                              ;+
30                              ; Local data
31                              ;-
32
33 000022                       DS      SYMBAS                  ;Base address of symbol table
34 000022                       DS      CURSYM                  ;Current symbol pointer during scan
35 000022                       DS      SYMSIZ                  ;Size of table, in bytes
36 000022                       DS      SYMTOP                  ;Set to end address of table
37
```

Figure 6–8 Cont'd. on next page

Figure 6–8 (Cont.): Example of .SAVE and .RESTORE Directives

```
38                                      ;+
39                                      ; SSORT
40                                      ; Perform shell sort on symbol table prior to listing
41                                      ;-
42
43 000022  016701  000006'              SSORT:  MOV     SYMTOP,R1       ;Get end of table
44                                      ;
45                                      ; Additional code....
46                                      ;
47          000001                              .END
```

6.8 Symbol Control Directives

The symbol control directives are used to set the type of a given symbol.

6.8.1 .GLOBL Directive

Format:

```
.GLOBL  sym1,sym2,...symn
```

where:

sym1,sym2,...symn	represent valid symbolic names. When multiple symbols are specified, they are separated by any valid separator (comma, space, and/or tab).

A statement line containing a .GLOBL directive can also include a label field and/or a comment field.

The .GLOBL directive defines (and thus provides linkage to) symbols not otherwise defined as global symbols within a module. In defining global symbols, the directive .GLOBL A,B,C is similar to:

```
A==:expression      A==expression      A::
B==:expression  or  B==expression  or  B::
C==:expression      C==expression      C::
```

Because object modules are linked by global symbols, these symbols are vital to a program. The following paragraph, describing the processing of a program from assembly to linking, explains the global's role.

In assembling a source program, MACRO–11 produces a relocatable object module and a listing file containing the assembly listing and symbol table. The Linker or Task Builder joins separately assembled object modules into a single executable image. During linking, object modules are relocated relative to the base of the module and linked by global symbols. Because these symbols will be referenced by other program modules, they must be singled out as global symbols in the defining modules. As shown above, the .GLOBL directive, global assignment operator, or global label operator will define a symbol as global.

All internal symbols appearing within a given program must be defined at the end of assembly pass 1, or they will be assumed to be default global references. Refer to Section 6.2.1 for a description of enabling/disabling of global references.

In the following example, A and B are entry-point symbols. The symbol A has been explicitly defined as a global symbol by means of the .GLOBL directive, and the symbol B has been explicitly defined as a global label by means of the double colon (::). Since the symbol C is not defined as a label within the current assembly, it is an external (global) reference if .ENABL GBL is in effect.

```
;
; Define a subroutine with 2 entry points which calls an
; external subroutine
;
        .PSECT                  ;Declare the unnamed program section.
        .GLOBL  A               ;Define A as a global symbol.
A:      MOV     @(R5)+,R0       ;Define entry point A.
        MOV     #X,R1
X:      JSR     PC,C            ;Call external subroutine C.
        RTS     R5              ;Exit.
B::     MOV     (R5)+,R1        ;Define entry point B.
        CLR     R2
        BR      X
```

External symbols can appear in the operand field of an instruction or MACRO–11 directive as a direct reference, as shown in the examples below:

```
CLR     EXT
.WORD   EXT
CLR     @EXT
```

External symbols can also appear as a term within an expression, as shown below:

```
CLR     EXT+A
.WORD   EXT-2
CLR     @EXT+A(R1)
```

An undefined external symbol cannot be used in the evaluation of a direct assignment statement or as an argument in a conditional assembly directive (see Sections 3.3, 6.9.1, and 6.9.3).

6.8.2 .WEAK Directive

Format:

```
.WEAK sym1,sym2,...symn
```

where:

sym1,sym2,...symn	represent valid symbolic names. When multiple symbols are specified, they are separated by any valid separator (comma, space, and/or tab).

Example:

```
.WEAK   SUB1,SUB2
```

A statement line containing a .WEAK directive can also include a label field and/or a comment field.

The .WEAK directive is used to specify symbols that are either defined externally in another module or defined globally in the current module. This directive suppresses object library searches for specified external symbols.

When the .WEAK directive specifies a symbol that is externally defined, it is considered a global symbol. If the Linker finds the symbol's definition in another module, it uses that definition. If the Linker does not find an external definition, the symbol is given a value of 0. The Linker does not search a library for the global symbol, but if a module brought in from a library for another reason contains the symbol's definition, the Linker uses that definition.

If a symbol that is defined in the current module is specified by the .WEAK directive, the symbol is considered globally defined. However, if the current module is inserted in an object library, the symbol is not inserted in the library's symbol table. Consequently, the module is not found when the library is searched at link time to resolve the symbol.

NOTE

The .WEAK directive is supported only by the RT–11 Librarian (LIBR) and Linker (LINK). Support is not yet implemented in the RSX–11 Task Builder (TKB) or Librarian (LBR).

6.9 Conditional Assembly Directives

Conditional assembly directives allow you to include or exclude blocks of source code during the assembly process, based on the evaluation of stated condition tests within the body of the program.

6.9.1 Conditional Assembly Block Directives

Format:

```
.IF cond,argument(s)   ;Start conditional assembly block.
  .
  .
  .
range                  ;Range of conditional assembly block.
  .
  .
  .
.ENDC                  ;End of conditional assembly block.
```

where:

cond — represents a specified condition that must be met if the block is to be included in the assembly. The conditions that can be tested by the conditional assembly directives are defined in Table 6–6.

, — represents any valid separator (comma, space, and/or horizontal tab).

argument(s) represent(s) the symbolic argument(s) or expression(s) of the specified conditional test. These arguments are thus a function of the condition to be tested (see Table 6–6).

range represents the body of code that is either included in the assembly, or excluded, depending upon whether the condition is met.

.ENDC terminates the conditional assembly block. This directive must be present to end the conditional assembly block.

A condition test other than those listed in Table 6–6, an invalid argument, or a null argument specified in a .IF directive causes that line to be flagged with an error code (A) in the assembly listing.

Table 6–6: Valid Condition Tests for Conditional Assembly Directives

Conditions			
Positive	**Complement**	**Arguments**	**Assemble Block If:**
EQ	NE	Expression	Expression is equal to 0 (or not equal to 0).
GT	LE	Expression	Expression is greater than 0 (or less than or equal to 0).
LT	GE	Expression	Expression is less than 0 (or greater than or equal to 0).
DF	NDF	Symbolic argument	Symbol is defined (or not defined).
B	NB	Macro[1] argument	Argument is blank (or not blank).
IDN	DIF	Two 7-bit ASCII or 8-bit DEC Multinational macro[1] arguments	Arguments are identical (or different). The .IF IDN and .IF DIF conditional directives are not alphabetically case sensitive by default. You can enable these directives to be case sensitive by using the .ENABL option (.ENABL LCM).
P1	P2	–none–	Assembler is in pass 1.[2]
P2	P1	–none–	Assembler is in pass 2.[2]

[1] A macro argument (a form of symbolic argument) is enclosed within angle brackets or delimited by the circumflex construction, as described in Section 7.3. For example,

```
<A,B,C>
^/124/
```

[2] Use P1 and P2 with great care. Most programs do not need them. If used incorrectly, they can cause P (phase) errors during assembly. Before you use P1 or P2, examine your program and make sure you are not trying to use them to disguise some sort of logic error in the way the program is written.

An example of a conditional assembly directive follows:

```
.IF EQ  ALPHA+1          ;Assemble block if ALPHA+1=0
  .
  .
  .
.ENDC
```

The two operators & and ! have special meaning within DF and NDF conditions, in that they are allowed in grouping symbolic arguments.

&	Logical AND operator
!	Logical inclusive OR operator

For example, the conditional assembly statement:

```
.IF DF  SYM1 & SYM2
  .
  .
  .
.ENDC
```

results in the assembly of the conditional block if the symbols SYM1 and SYM2 are both defined. Nested conditional directives take the form:

```
.IF condition1
    .IF condition2
  .
  .
  .
    .ENDC        ;condition2
.ENDC            ;condition1
```

For example, the following conditional directives:

```
.IF DF  SYM1
    .IF DF  SYM2
      .
      .
      .
    .ENDC        ;DF SYM2
.ENDC            ;DF SYM1
```

can govern whether assembly is to occur. In the example above, if the outermost condition is unsatisfied, no deeper level of evaluation of nested conditional statements within the program occurs.

Although indentation is not required, you can indent nested conditionals to improve readability, and you can include comments on .ENDC statements to help you match them to their corresponding conditional assembly directives, as shown above.

Each conditional assembly block must terminate with a .ENDC directive. A .ENDC directive encountered outside a conditional assembly block is flagged with an error code (O) in the assembly listing.

MACRO-11 permits a nesting depth of 16_{10} conditional assembly levels. Any statement that attempts to exceed this nesting level depth is flagged with an error code (O) in the assembly listing.

6.9.2 Subconditional Assembly Block Directives

Formats:

```
.IFF
.IFT
.IFTF
```

Subconditional directives can be placed within conditional assembly blocks to indicate:

- The assembly of an alternate body of code when the condition of the block tests false
- The assembly of a noncontiguous body of code within the conditional assembly block, depending upon the result of the conditional test in entering the block
- The unconditional assembly of a body of code within a conditional assembly block

Subconditional directives are described in detail in Table 6–7. If a subconditional directive appears outside a conditional assembly block, an error code (O) is generated in the assembly listing.

Table 6–7: Subconditional Assembly Block Directives

Subconditional Directive	Function
.IFF	If the condition tested upon entering the conditional assembly block is false, the code following this directive, and continuing up to the next occurrence of a subconditional directive or to the end of the conditional assembly block, is to be included in the program.
.IFT	If the condition tested upon entering the conditional assembly block is true, the code following this directive, and continuing up to the next occurrence of a subconditional directive or to the end of the conditional assembly block, is to be included in the program.
.IFTF	The code following this directive, and continuing up to the next occurrence of a subconditional directive or to the end of the conditional assembly block, is to be included in the program, regardless of the result of the condition tested upon entering the conditional assembly block.

The implied argument of a subconditional directive is the condition test specified upon entering the conditional assembly block, as reflected by the initial directive in the conditional coding examples below. Conditional or subconditional directives in nested conditional assembly blocks are not evaluated if the previous (or outer) condition in the block is not satisfied. Examples 3 and 4 below illustrate nested directives that are not evaluated because of previously unsatisfied conditional coding.

Example 1: Assume that symbol SYM is defined.

```
.IF DF  SYM      ;Tests TRUE, SYM is defined. Assemble
  .              ;the following code.
  .
  .
.IFF             ;Tests FALSE. SYM is defined. Do not
  .              ;assemble the following code.
  .
  .
.IFT             ;Tests TRUE. SYM is defined. Assem-
  .              ;ble the following code.
  .
  .
.IFTF            ;Assemble following code uncondition-
  .              ;ally.
  .
  .
.IFT             ;Tests TRUE. SYM is defined. Assem-
  .              ;ble remainder of conditional assem-
  .              ;bly block.
  .
.ENDC   ;DF SYM
```

Example 2: Assume that symbol X is defined and that symbol Y is not defined.

```
.IF DF  X        ;Tests TRUE, symbol X is defined.
.IF DF  Y        ;Tests FALSE, symbol Y is not defined.
.IFF    ;DF Y    ;Tests TRUE, symbol Y is not defined,
  .              ;assemble the following code.
  .
  .
.IFT    ;DF Y    ;Tests FALSE, symbol Y is not defined.
  .              ;Do not assemble the following code.
  .
  .
.ENDC   ;DF Y
.ENDC   ;DF X
```

Example 3: Assume that symbol A is defined and that symbol B is not defined.

```
.IF DF  A        ;Tests TRUE. A is defined.
                 ;Assemble the following code.
MOV      A,@R1
  .
  .
  .
.IFF   ;DF A     ;Tests FALSE. A is defined. Do not
                 ;assemble the following code.
MOV      R1,RO
  .
  .
  .
.IF NDF B        ;Nested conditional directive is not
  .              ;evaluated.
  .
  .
.ENDC   ;NDF B
.ENDC   ;DF A
```

Example 4: Assume that symbol X is not defined and that symbol Y is defined.

```
.IF DF  X       ;Tests FALSE. Symbol X is not defined.
                ;Do not assemble the following code.
.IF DF  Y       ;Nested conditional directive is not
  .             ;evaluated.
  .
  .
.IFF    ;DF Y   ;Nested subconditional directive is
  .             ;not evaluated.
  .
  .
.IFT    ;DF Y   ;Nested subconditional directive is
  .             ;not evaluated.
  .
  .
.ENDC   ;DF Y
.ENDC   ;DF X
```

6.9.3 Immediate Conditional Assembly Directive

Format:

```
.IIF    cond,arg,statement
```

where:

cond	represents a valid condition test defined for conditional assembly blocks in Table 6–6.
,	represents any valid separator (comma, space, and/or tab), unless cond is B or NB; in that case, a comma must be used unless the argument is enclosed in angle brackets or delimited by the circumflex construction (see Table 3–3).
arg	represents the argument associated with the immediate conditional directive; an expression, symbolic argument, or macro argument (see Table 6–6).
,	represents the separator between the conditional argument and the statement field. If the preceding argument is an expression, then a comma must be used; otherwise, a comma, space, and/or tab can be used.
statement	represents the specified statement to be assembled if the condition is satisfied.

An immediate conditional assembly directive lets you write a 1-line conditional assembly block. The use of this directive requires no terminating .ENDC statement and the condition to be tested is completely expressed within the line containing the directive.

For example, the immediate conditional statement:

```
.IIF    DF FOO,BEQ ALPHA
```

generates the code:

```
BEQ     ALPHA
```

if the symbol FOO is defined within the source program.

As with the .IF directive, a condition test other than those listed in Table 6–6, an invalid argument, or a null argument specified in a .IIF directive results in an error code (A) in the assembly listing.

6.10 File Control Directives

The MACRO–11 file control directives are used to add file names to macro library lists and to insert a source file into the source file being currently used.

6.10.1 .LIBRARY Directive

Format:

```
.LIBRARY string
```

where:

string	represents a delimited string that is the file specification of a macro library.

The .LIBRARY directive adds a file name to a macro library list that is searched. A library list is searched whenever a .MCALL or an undefined op code is encountered within a MACRO–11 program. The libraries that make up the list are searched in the reverse order in which they were specified to the MACRO–11 assembler.

If any information was omitted from the macro library argument, default values are assumed. The default library device and file type for MACRO–11/RT–11 are DK: and .MLB, and for other systems they are SY: and .MLB.

The .LIBRARY directive is used as follows:

```
.LIBRARY  /DB1:[SMITH]USERLIB/
.LIBRARY  ?DK:SYSDEF.MLB?
.LIBRARY  \CURRENT.MLB\
```

MACRO–11 searches all macro libraries if it finds an unknown symbol in the op code field and the auto-mcall option has been previously enabled by .ENABL MCL.

NOTE

If you are using MACRO–11 with the RT–11 operating system, the device handler for the device the .LIBRARY file resides on must already be loaded, either explicitly with the KMON LOAD command, or implicitly by reference to the device on the original MACRO–11 command line. The maximum number of .LIBRARY files that you can specify is limited to twelve minus the number of files specified in the MACRO–11 command line. Up to eight files can be specified on a MACRO–11/RT–11 command line, so at least four slots are available for .LIBRARY files.

6.10.2 .INCLUDE Directive

Format:

```
.INCLUDE string
```

where:

string	represents a delimited string that is the file specification of a macro source file.

The .INCLUDE directive inserts a source file within the source file currently being used. When this directive is encountered, an implicit .PAGE directive is issued, status of the current source file is stacked, and the source file specified by the directive is read into memory. When the end of the specified source file is reached, an implicit .PAGE directive is issued, the original source file status is popped from the stack, and assembly resumes at the line following the directive. A source file can also be inserted within a source file that has already been specified by the .INCLUDE directive. In this case, the status of the original source file and the first source file specified by the .INCLUDE directive are stacked, and the second specified source file is read into memory. When the end of the second source file is reached, the status of the first specified source file is popped from the stack, and assembly resumes at the line following the directive. When the end of the first specified source file is reached, the status of the original source file is popped from the stack, and assembly of that file is started again at the line following the .INCLUDE directive. An implicit .PAGE directive precedes and follows each included source file. The maximum nesting level of source files specified by the .INCLUDE directive is five.

If any information is omitted from the source file argument, default values are assumed. The default source file device and file type for MACRO-11/RT-11 are DK: and .MAC, and for other systems they are SY: and .MAC.

The .INCLUDE directive is used as follows:

```
.INCLUDE        /DR3:[1,2]MACROS/       ;File MACROS.MAC
.INCLUDE        ?DK:SYSDEF?
.INCLUDE        \CURRENT.MAC\
```

NOTE

If you are using MACRO-11 with an RT-11 operating system, the device handler for the device that the .INCLUDE file resides on must already be loaded, either explicitly with the KMON LOAD command, or implicitly by reference to the device on the original MACRO-11 command line.

Part IV

Chapter 7
Macro Directives

This chapter tells you how to use MACRO–11's macro directives to define and write macros. Macro directives let you:

- Define macros
- Call macros
- Test and substitute macro arguments
- Test macro attributes
- Report error conditions
- Perform counted or indefinite repeat loops
- Call macros from libraries
- Delete macro definitions

Each function is described in its own section of this chapter. Table 7–1 gives an alphabetical list of all directives described in this chapter and the associated section reference. Also refer to Section B.3 for a complete list of all MACRO–11 directives.

Table 7–1: Directives in Chapter 7

Directive	Function	Section Reference
.ENDM	Terminates a macro definition.	7.1.2
.ENDR	Terminates a counted or indefinite repeat block.	7.7
.ERROR	Writes a message to the listing file to flag invalid macro arguments or conditions.	7.5
.IRP	Creates an indefinite repeat block.	7.6.1
.IRPC	Creates an indefinite repeat block for character string arguments.	7.6.2
.MACRO	Begins a macro definition.	7.1.1
.MCALL	Calls a previously-defined macro from a library.	7.8
.MDELETE	Deletes a macro definition from MACRO–11's macro symbol table.	7.9
.MEXIT	Prematurely terminates execution of a macro.	7.1.3
.NARG	Returns number of macro arguments.	7.4.1
.NCHR	Returns number of characters in an argument.	7.4.2

Table 7–1 (Cont.): Directives in Chapter 7

Directive	Function	Section Reference
.NTYPE	Returns addressing mode of an argument.	7.4.3
.PRINT[1]	Writes a message to the listing file to flag invalid macro arguments or conditions, and generates a (P) error.	7.5
.REPT	Creates a counted repeat block.	7.7

[1]MACRO–11's .PRINT directive is not the same as the RT–11 monitor .PRINT request; be careful not to confuse the two. Under RT–11, if you .MCALL .PRINT, you will get the RT–11 monitor .PRINT request; otherwise, you will get MACRO–11's .PRINT directive.

7.1 Defining Macros

By using macros, you can use a single line to insert a sequence of lines into a source program.

A macro definition is headed by a .MACRO directive (see Section 7.1.1) followed by the source lines. The source lines may optionally contain dummy arguments. If such arguments are used, each one is listed in the .MACRO directive.

A macro call (see Section 7.3) is the statement you use to call the macro into the source program. It consists of the macro name followed by the real arguments needed to replace any dummy arguments used in the macro.

Macro expansion is the insertion of the macro source lines into the main program. Included in this insertion is the replacement of the dummy arguments by the real arguments.

Macro directives provide the means to define macros and control macro expansions. Only one directive is allowed per source line. Each directive may have a blank operand field or one or more operands. Valid operands differ with each directive. This chapter describes the macro directives available in MACRO–11 and their arguments.

7.1.1 .MACRO Directive

Format:

```
[label:] .MACRO  name, dummy argument list
```

where:

label — represents an optional statement label.

name — represents the user-assigned symbolic name of the macro. This name can be any valid symbol and can be used as a label elsewhere in the program.

represents any valid separator (comma, space, and/or tab).

dummy argument list — represents a number of valid symbols (see Section 3.2.2) that can appear anywhere in the body of the macro definition, even as a label. These dummy symbols can be used elsewhere in the program with no conflict of definition. Multiple dummy arguments specified in this directive can be separated by any valid separator. The detection of a duplicate or an invalid symbol in a dummy argument list terminates the scan and causes an error code (A) to be generated.

The first statement of a macro definition must be a .MACRO directive.

A comment can follow the dummy argument list in a .MACRO directive, as shown below:

```
.MACRO  ABS  A,B        ;Defines macro ABS with two arguments.
```

Although it is acceptable for a label to appear on a .MACRO directive, this practice is discouraged, especially in the case of nested macro definitions, because invalid labels or labels constructed with the concatenation character will cause the macro directive to be ignored. This may result in improper termination of the macro definition.

7.1.2 .ENDM Directive

Format:

```
.ENDM   [name]
```

where:

name — represents an optional argument specifying the name of the macro being terminated by the directive.

Example:

```
.ENDM           ;Terminates the current
                ;macro definition.

.ENDM  ABS      ;Terminates the current
                ;macro definition named ABS.
```

The final statement of every macro definition must be a .ENDM directive.

If specified, the macro name in the .ENDM statement must match the name specified in the corresponding .MACRO directive. Otherwise, the statement is flagged with an error code (A) in the assembly listing. In either case, the current macro definition is terminated. Specifying the macro name in the .ENDM statement permits MACRO–11 to detect missing .ENDM statements or improperly nested macro definitions.

The .ENDM directive must not have a label. If a valid label is attached, the label is ignored; if an invalid label is attached, the directive is ignored.

The .ENDM directive can be followed by a comment field, as shown below:

```
.MACRO  TYPMSG MESSGE    ;Type a message.
JSR     R5,TYPMSG
.WORD   MESSGE
.ENDM                    ;End of TYPMSG macro.
```

You can also use the .ENDM directive to terminate indefinite repeat blocks (see Section 7.6) and repeat blocks (see Section 7.7).

7.1.3 .MEXIT Directive

Format:

```
.MEXIT
```

The .MEXIT directive terminates a macro expansion before the end of the macro is encountered. This directive is also valid within repeat blocks (see Sections 7.6 and 7.7). It is most useful in nested macros. The .MEXIT directive terminates the current macro as though a .ENDM directive had been encountered. A .MEXIT also terminates any pending .IF directives.

Using the .MEXIT directive bypasses the complexities of nested conditional directives and alternate assembly paths, as shown in the following example:

```
.MACRO ALTR N,A,B
   .
   .
   .
.IF EQ N          ;Start conditional assembly block.
   .
   .
   .
.MEXIT            ;Terminate macro expansion.
.ENDC             ;End conditional assembly block.
   .
   .
   .
.ENDM             ;Normal end of macro.
```

In an assembly where the dummy symbol N is replaced by 0 (zero) (see Table 6–6), the .MEXIT directive would assemble the conditional block and terminate the macro expansion. When macros are nested, a .MEXIT directive exits to the next higher level of macro expansion. A .MEXIT directive encountered outside a macro definition is flagged with an error code (O) in the assembly listing.

7.1.4 MACRO Definition Formatting

A form feed character within a macro definition causes a page eject during the assembly of the macro definition. However, no page eject is done when the macro is expanded.

Conversely, when the .PAGE directive is used in a macro definition, it is ignored during the assembly of the macro definition, but a page eject is performed when that macro expansion is listed.

7.2 Calling Macros

Format:

```
[label:]  name  real arguments
```

where:

label	represents an optional statement label.
name	represents the name of the macro, as specified in the .MACRO directive (see Section 7.1.1).
real arguments	represent symbolic arguments which replace the dummy arguments listed in the .MACRO directive. When multiple arguments occur, they are separated by any valid separator. Arguments to the macro call are treated as character strings, their usage is determined by the macro definition.

A macro must be defined with the .MACRO directive (see Section 7.1.1) before the macro can be called and expanded within the source program.

When a macro name is the same as a user label, the appearance of the symbol in the operator field designates the symbol as a macro call; the appearance of the symbol in the operand field designates it as a label, as shown below:

```
ABS:    MOV     (R0),R1         ;ABS is defined as a label.
          .
          .
          .
        BR      ABS             ;ABS is considered to be a label.
          .
          .
          .
        ABS     #4,ENT,LAR      ;ABS is a macro call.
```

You can also assign a value to a symbol that has the same name as a macro, as illustrated in this example:

```
        ABS =   100             ;ABS is a user symbol.
          .
          .
          .
        ABS     #4,ENT,LAR      ;ABS is a macro call.
```

7.3 Arguments in Macro Definitions and Macro Calls

Multiple arguments within a macro definition or macro call must be separated by one of the valid separating characters described in Section 3.1.1. Macro definition arguments (dummy) and macro call arguments (real) normally maintain a strict positional relationship. That is, the first real argument in a macro call corresponds with the first dummy argument in a macro definition. Only the use of keyword arguments in a macro call can override this correspondence (see Section 7.3.6).

For example, the following macro definition and its associated macro call contain multiple arguments:

```
.MACRO  REN A,B,C
 .
 .
 .
REN     ALPHA,BETA,<C1,C2>
```

Arguments which themselves contain separating characters must be enclosed in paired angle brackets. For example, the macro call:

```
REN     <MOV X,Y>,#44,WEV
```

uses the entire expression:

```
MOV     X,Y
```

to replace all occurrences of the symbol `A` in the macro definition. Real arguments within a macro call are considered to be character strings and are treated as a single entity during the macro expansion.

The circumflex (^) construction allows angle brackets to be passed as part of the argument. For example, this construction could have been used in the above macro call, as follows:

```
REN     ^/<MOV X,Y>/,#44,WEV
```

passing the character string `<MOV X,Y>` as an argument.

Because of the use of the circumflex (^) shown above, you must be careful when passing an argument beginning with a unary operator (`^O`, `^D`, `^B`, `^R`, `^F` ....). These arguments must be enclosed in angle brackets (as shown below) or MACRO–11 will read the character following the circumflex as a delimiter.

```
REN     <^O 411>,X,Y
```

The following macro call:

```
REN     #44,WEV^/MOV X,Y/
```

contains only two arguments (`#44` and `WEV^/MOV X,Y/`), because the circumflex is a unary operator (see Section 3.1.3) and it is not preceded by an argument separator.

As shown in the examples above, spaces can be used within bracketed argument constructions to increase the legibility of such expressions.

When 8-bit DEC Multinational character set (MCS) characters are used in argument strings, they must be enclosed in angle brackets (< >) or the argument delimiter (/) must be preceded by a circumflex (^). The following are valid uses of the MCS characters in the argument string:

```
<This string can contain MCS characters>

^/This string can contain MCS characters/
```

7.3.1 Macro Nesting

Macro nesting occurs where the expansion of one macro includes a call to another. The depth of nesting allowed depends upon the amount of dynamic memory used by the source program being assembled.

To pass an argument containing valid argument delimiters to nested macros, enclose the argument in the macro definition within angle brackets, as shown in the coding sequence below. This extra set of angle brackets for each level of nesting is required in the macro definition, not in the macro call.

```
.MACRO  LEVEL1 DUM1,DUM2
LEVEL2  <DUM1>
LEVEL2  <DUM2>
.ENDM

.MACRO  LEVEL2 DUM3
DUM3
ADD     #10,40
MOV     R0,(R1)+
.ENDM
```

A call to the LEVEL1 macro, as shown below, for example:

```
LEVEL1  <MOV X,R0>,<MOV R2,R0>
```

causes the following macro expansion to occur:

```
MOV     X,R0
ADD     #10,R0
MOV     R0,(R1)+
MOV     R2,R0
ADD     #10,R0
MOV     R0,(R1)+
```

When macro definitions are nested, the inner definition cannot be called until the outer macro has been called and expanded. For example, in the following coding:

```
.MACRO  LV1 A,B
   .
   .
   .
.MACRO  LV2 C
   .
   .
   .
.ENDM
.ENDM
```

the LV2 macro cannot be called and expanded until the LV1 macro has been expanded. Likewise, any macro defined within the LV2 macro definition cannot be called and expanded until LV2 has also been expanded.

7.3.2 Special Characters in Macro Arguments

If an argument does not contain spaces, tabs, semicolons, or commas, it can include special characters without enclosing them in a bracketed construction. For example:

```
.MACRO  PUSH ARG
MOV     ARG,-(SP)
.ENDM
   .
   .
   .
PUSH    X+3(%2)
```

generates the following code:

```
MOV     X+3(%2),-(SP)
```

7.3.3 Passing Numeric Arguments as Symbols

If the unary operator backslash (\) precedes an argument, the macro treats that argument as a numeric value in the current program radix. The ASCII characters representing this value are inserted in the macro expansion, and their function is defined in the context of the resulting code. The backslash operator cannot take a forward reference (the argument must be defined at the time it is used), and the argument cannot be a relocatable symbol.

The following example illustrates the use of the backslash operator:

```
 1                      .LIST   ME
 2                ;+
 3                ; Example of the use of the backslash (\) operator
 4                ;-
 5
 6                      .MACRO  RESERV X
 7                      .BLKW   X
 8                      .ENDM
 9
10                ;Note difference in the way the macro gets expanded when backslash
11                ;is used and when it is not.  (In this case the resulting binary
12                ;code is the same.)
13
14        000010  SIZE=10
15 000000               RESERV  SIZE            ;Call macro without backslash on argument
   000000               .BLKW   SIZE
16
17 000020               RESERV  \SIZE           ;Call macro with backslash on argument
   000020               .BLKW   10
18
19        000001        .END
```

Another, more complicated, example is given below:

```
        .MACRO INC A,B
        CON     A,\B            ;B is treated as a number in current
B=B+1                           ;program radix.
        .ENDM
        .MACRO CON A,B
A'B:    .WORD   4
        .ENDM
          .
          .
          .
C=0     INC     X,C
```

The above macro call (INC) would thus expand to:

```
XO:     .WORD   4
```

In this expanded code, the label XO: results from the concatenation of two real arguments. The single quote (') character in the label A'B: concatenates the real arguments X and 0 as they are passed during the expansion of the macro. This type of argument construction is described in more detail in Section 7.3.7.

A subsequent call to the same macro would generate the following code:

```
X1:     .WORD 4
```

and so on, for later calls. The two macro definitions are necessary, because the symbol associated with dummy argument B (that is, C) cannot be updated in the CON macro definition, because the character 0 (zero) has replaced C in the argument string (INC X, C). In the CON macro definition, the number that is passed is treated as a string argument. (Where the value of the real argument is 0 (zero), only a single 0 character is passed to the macro expansion.)

Passing numeric values in this manner is useful in identifying source listings. For example, versions of programs created through conditional assemblies of a single source program can be identified through such coding as that shown below. Assume, for example, that the symbol ID in the macro call (IDT) has been equated elsewhere in the source program to the value 6.

```
.MACRO IDT  SYM         ;Assume that the symbol ID takes
.IDENT /V01.'SYM/       ;on a unique 2-digit value.
.ENDM                   ;Where V01 is the update
    .                   ;version of the program.
    .
    .

IDT     \ID
```

The above macro call would then expand to:

```
.IDENT /V01.6/
```

where 6 is the numeric value of the symbol ID.

7.3.4 Number of Arguments in Macro Calls

A macro can be defined with or without arguments. If more arguments appear in the macro call than in the macro definition, an error code (Q) is generated in the assembly listing. If fewer arguments appear in the macro call than in the macro definition, missing arguments are assumed to be null values. The conditional directives .IF B and .IF NB (see Table 6–6) can be used within the macro to detect missing arguments. The number of arguments can also be determined by using the .NARG directive (Section 7.4.1).

7.3.5 Creating Local Symbols Automatically

A label is often required in an expanded macro. In the conventional macro facilities thus far described, a label must be explicitly specified as an argument with each macro call. You must be careful in issuing subsequent calls to the same macro in order to avoid duplicating labels. This concern can be eliminated through a feature

of MACRO–11 that creates a unique symbol where a label is required in an expanded macro.

MACRO–11 can automatically create local symbols of the form `n$`, where `n` is an integer in the range 30000_{10} through 65535_{10}, inclusive. Such local symbols are created by MACRO–11 in numerical order, as shown below:

```
30000$
30001$
  .
  .
  .
65534$
65535$
```

This automatic generation occurs on each call of a macro whose definition contains a dummy argument preceded by the question mark (?) character, as shown in the macro definition below:

```
        .MACRO ALPHA, A,?B      ;Contains dummy argument B preceded by
                                ;question mark.
        TST     A
        BEQ     B
        ADD     #5,A
B:
        .ENDM
```

A local symbol is created automatically by MACRO–11 only when a real argument of the macro call is either null or missing, as shown in Example 1 below. If the real argument is specified in the macro call, however, MACRO–11 inhibits the generation of a local symbol and normal argument replacement occurs, as shown in Example 2 below. (Examples 1 and 2 are both expansions of the `ALPHA` macro defined above.)

Example 1: Create a Local Symbol for the Missing Argument

```
        ALPHA   R1      ;Second argument is missing.
        TST     R1
        BEQ     30000$  ;Local symbol is created.
        ADD     #5,R1
30000$:
```

Example 2: Do Not Create a Local Symbol

```
        ALPHA   R2,XYZ  ;Second argument XYZ is specified.
        TST     R2
        BEQ     XYZ     ;Normal argument replacement occurs.
        ADD     #5,R2
XYZ:
```

Automatically created local symbols are restricted to the first 16_{10} arguments of a macro definition.

Automatically created local symbols resulting from the expansion of a macro, as described above, do not establish a local symbol block in their own right.

When a macro has several arguments earmarked for automatic local symbol generation, substituting a specific label for one such argument risks assembly errors because

MACRO–11 constructs its argument substitution list at the point of macro invocation. Therefore, the appearance of a label, the .ENABL LSB directive, or the .PSECT directive, in the macro expansion will create a new local symbol block. The new local symbol block could leave local symbol references in the previous block and their symbol definitions in the new one, causing error codes in the assembly listing. Furthermore, a later macro expansion that creates local symbols in the new block may duplicate one of the symbols in question, causing an additional error code (P) in the assembly listing.

7.3.6 Keyword Arguments

Format:

```
name=string
```

where:

name	represents the dummy argument.
string	represents the real symbolic argument.

The keyword argument cannot contain embedded argument separators unless delimited as described in Section 7.3.

Macros can be defined with, and/or called with, keyword arguments. When a keyword argument appears in the dummy argument list of a macro definition, the specified string becomes the default real argument at macro call. When a keyword argument appears in the real argument list of a macro call, however, the specified string becomes the real argument for the dummy argument that matches the specified name, whether or not the dummy argument was defined with a keyword. If a match fails, the entire argument specification is treated as the next positional real argument.

The DEC Multinational character set can be used in keyword arguments if enclosed in angle brackets (<>).

A keyword argument can be specified anywhere in the dummy argument list of a macro definition and is part of the positional ordering of argument. A keyword argument can also be specified anywhere in the real argument list of a macro call but, in this case, does not affect the positional ordering of the arguments.

```
 1                      .LIST   ME
 2              ;
 3              ; Define a macro having keywords in dummy argument
 4              ; list
 5              ;
 6                      .MACRO  TEST CONTRL=1,BLOCK,ADDRES=TEMP
 7                      .WORD   CONTRL
 8                      .WORD   BLOCK
 9                      .WORD   ADDRES
10                      .ENDM
11
12
13              ;
14              ; Now call several times
15              ;
```

```
16
17 000000                        TEST    A,B,C
   000000       000000G         .WORD   A
   000002       000000G         .WORD   B
   000004       000000G         .WORD   C
18
19 000006                        TEST    ADDRES=20,BLOCK=30,CONTRL=40
   000006       000040          .WORD   40
   000010       000030          .WORD   30
   000012       000020          .WORD   20
20
21 000014                        TEST    BLOCK=5
   000014       000001          .WORD   1
   000016       000005          .WORD   5
   000020       000000G         .WORD   TEMP
22
23 000022                        TEST    CONTRL=5,ADDRES=VARIAB
   000022       000005          .WORD   5
   000024       000000          .WORD
   000026       000000G         .WORD   VARIAB
24
25 000030                        TEST
   000030       000001          .WORD   1
   000032       000000          .WORD
   000034       000000G         .WORD   TEMP
26
27 000036                        TEST    ADDRES=JACK!JILL
   000036       000001          .WORD   1
   000040       000000          .WORD
   000042       000000C         .WORD   JACK!JILL
28
29
30      000001          .END
```

7.3.7 Concatenation of Macro Arguments

The single quote or apostrophe character (') operates as a valid delimiting character in macro definitions. A single quote that precedes and/or follows a dummy argument in a macro definition is removed, and the substitution of the real argument occurs at that point. For example, in the following statements:

```
        .MACRO DEF A,B,C
A'B:    .ASCIZ  /C/
        .BYTE   ''A,''B
        .ENDM
```

when the macro DEF is called through the statement:

```
        DEF     X,Y,<MACRO-11>
```

it expands as follows:

```
XY:     .ASCIZ  /MACRO-11/
        .BYTE   'X,'Y
```

During expansion of the first line, the scan for the first argument terminates upon finding the first single quote (') character. Since A is a dummy argument, the single quote (') is removed. The scan then resumes with B; B is also noted as another dummy

argument. The two real arguments X and Y are then concatenated to form the label XY:. The third dummy argument is noted in the operand field of the .ASCIZ directive, causing the real argument MACRO–11 to be substituted in this field.

When the arguments of the .BYTE directive are evaluated during expansion of the second line, the scan begins with the first single quote (') character. Since it is neither preceded nor followed by a dummy argument, this single quote remains in the macro expansion. The scan then encounters the second single quote, which is followed by a dummy argument and is therefore discarded. The scan of argument A is terminated upon encountering the comma (,). The third single quote is neither preceded nor followed by a dummy argument and again remains in the macro expansion. The fourth (and last) single quote is followed by another dummy argument and is likewise discarded. (Four single quote characters were necessary in the macro definition to generate two single quote characters in the macro expansion.)

7.4 Macro Attribute Directives: .NARG, .NCHR, and .NTYPE

MACRO–11 has three directives that let you determine certain attributes of macro arguments: .NARG, .NCHR, and .NTYPE. The use of these directives permits selective modifications of a macro expansion, depending on the nature of the arguments being passed. These directives are described below.

7.4.1 .NARG Directive

Format:

```
[label:] .NARG symbol
```

where:

label	represents an optional statement label.
symbol	represents any valid symbol. This symbol is equated to the number of nonkeyword arguments in the macro call currently being expanded. If a symbol is not specified, the .NARG directive is flagged with an error code (A) in the assembly listing.

The .NARG directive determines the number of nonkeyword arguments in the macro call currently being expanded. Hence, the .NARG directive can appear only within a macro definition; if it appears elsewhere, an error code (O) is generated in the assembly listing.

An example of the .NARG directive is shown in Figure 7–1.

Figure 7–1: Example of .NARG Directive

```
                                .TITLE  NARG
                                .LIST   ME
                        ;+
                        ; Example of the .NARG directive
                        ;-
                        .MACRO  NULL    NUM
                                .NARG   SYM
                                .IF EQ  SYM
                                .MEXIT
                                .IFF
                                .REPT   NUM
                                NOP
                                .ENDR
                                .ENDC
                        .ENDM
000000                          NULL
                000000          .NARG   SYM
                                .IF EQ  SYM
                                .MEXIT
                                .IFF
                                .REPT
                                NOP
                                .ENDR
                                .ENDC

000000                          NULL    6
                000001          .NARG   SYM
                                .IF EQ  SYM
                                .MEXIT
                                .IFF
                000006          .REPT   6
                                NOP
                                .ENDR
        000000  000240          NOP
        000002  000240          NOP
        000004  000240          NOP
        000006  000240          NOP
        000010  000240          NOP
        000012  000240          NOP
                                .ENDC

                000001          .END
```

7.4.2 .NCHR Directive

Format:

```
[label:] .NCHR symbol,<string>
```

where:

label	represents an optional statement label.
symbol	represents any valid symbol. This symbol is equated to the number of characters in the specified character string. If a symbol is not specified, the .NCHR directive is flagged with an error code (A) in the assembly listing.
	represents any valid separator (comma, space, and/or tab).
<string>	represents a string of 7-bit ASCII or 8-bit DEC Multinational printing characters. If the character string contains a valid separator (comma, space, and/or tab), the whole string must be enclosed within angle brackets (<>) or be delimited by the circumflex (^) construction (see Section 7.3). If the delimiting characters do not match or if the ending delimiter cannot be detected because of a syntactical error in the character string (thus prematurely terminating its evaluation), the .NCHR directive is flagged with an error code (A) in the assembly listing.

The .NCHR directive, which can appear anywhere in a MACRO–11 program, determines the number of characters in a specified character string. This directive is useful in calculating the length of macro arguments.

An example of the .NCHR directive is shown in Figure 7–2.

Figure 7–2: Example of .NCHR Directive

```
 1                              .TITLE  NCHR
 2
 3                              .LIST   ME
 4                      ;+
 5                      ; Illustrate the .NCHR directive
 6                      ;-
 7
 8                      .MACRO  STRING  MESSAG
 9                              .NCHR   $$$, MESSAG
10                              .WORD   $$$
11                              .ASCII  /MESSAG/
12                              .EVEN
13                      .ENDM
14
15 000000                      MSG1:   STRING  <Hello>
           000005                       .NCHR   $$$, Hello
   000000  000005                       .WORD   $$$
   000002     110                       .ASCII  /Hello/
   000003     145
   000004     154
   000005     154
   000006     157
                                        .EVEN
16
17         000001                       .END
```

7.4.3 .NTYPE Directive

Format:

```
[label:] .NTYPE symbol,aexp
```

where:

label	represents an optional statement label.
symbol	represents any valid symbol. This symbol is equated to the 6-bit addressing mode of the following expression (aexp). If a symbol is not specified, the .NTYPE directive is flagged with an error code (A) in the assembly listing.
,	represents any valid separator (comma, space, and/or tab).
aexp	represents any valid address expression, as used with an op code. If no argument is specified, an error code (A) will appear in the assembly listing.

The .NTYPE directive determines the addressing mode of a specified macro argument. Hence, the .NTYPE directive can appear only within a macro definition; if it appears elsewhere, it is flagged with an error code (O) in the assembly listing.

An example of a .NTYPE directive in a macro definition is shown in Figure 7–3.

Figure 7–3: Example of .NTYPE Directive in Macro Definition

```
 1                              .TITLE  NTYPE
 2
 3                              .LIST   ME
 4                      ;+
 5                      ; Illustrate the .NTYPE directive
 6                      ;-
 7
 8                      .MACRO  SAVE    ARG
 9                              .NTYPE  $$$, ARG
10                      .IF EQ  $$$&70
11                              MOV     ARG,-(SP)       ;Save in register mode
12                      .IFF
13                              MOV     #ARG,-(SP)      ;Save in non-register mode
14                      .ENDC
15                      .ENDM
16
17 000000                              SAVE    R1
           000001                       .NTYPE  $$$, R1
                        .IF EQ  $$$&70
   000000  010146                      MOV     R1,-(SP)        ;Save in register mode
                        .IFF
                                       MOV     #R1,-(SP)       ;Save in non-register mode
                        .ENDC
18
19 000002                              SAVE    TEMP
           000067                       .NTYPE  $$$, TEMP
                        .IF EQ  $$$&70
                                       MOV     TEMP,-(SP)      ;Save in register mode
                        .IFF
   000002  012746                      MOV     #TEMP,-(SP)     ;Save in non-register mode
           000006'
                        .ENDC
20
21 000006  000000       TEMP:  .WORD    0
22
23         000001               .END
```

For additional information concerning addressing modes, refer to Chapter 5 and Section B.2.

7.5 .ERROR and .PRINT Directives

Format:

```
[label:] .ERROR [expr]     ;text
```

where:

label	represents an optional statement label.
expr	represents an optional expression whose value is output when the .ERROR directive is encountered during assembly.
;	denotes the beginning of the text string.
text	represents the message associated with the .ERROR directive. The text can be 7-bit ASCII or 8-bit DEC Multinational characters.

The .ERROR directive writes a message to the listing file during assembly pass 2. A common use of this directive is to warn you about a rejected or erroneous macro call or an invalid set of conditions in a conditional assembly. If the listing file is not specified, the .ERROR messages are written to the command output device.

Upon encountering a .ERROR directive anywhere in a source program, MACRO–11 writes a single line containing:

1. An error code (P)
2. The sequence number of the .ERROR directive statement
3. The value of the current location counter
4. The value of the expression, if one is specified
5. The source line containing the .ERROR directive.

For example, the following line tests an argument to be sure its value is at least 100, and writes a message if it is not:

```
.IIF LT <A-100> .ERROR  A     ;Invalid macro argument
```

If A had a value of 76, a line in the following form would be written to the listing file:

```
          Seq.  Loc.        Exp.
          No.   No.         Value                          Text

P         512  005642      000076  .ERROR  A       ;Invalid macro argument
```

The .PRINT[1] directive is identical in function to the .ERROR directive, except that it is not flagged with the error code (P).

[1] MACRO–11's .PRINT directive is not the same as the RT–11 monitor .PRINT request; be careful not to confuse the two. Under RT–11, if you .MCALL .PRINT, you will get the RT–11 monitor .PRINT request; otherwise, you will get MACRO–11's .PRINT directive.

7.6 Indefinite Repeat Block Directives: .IRP and .IRPC

An indefinite repeat block is similar to a macro definition with only one dummy argument. At each expansion of the indefinite repeat range, this dummy argument is replaced with successive elements of a real argument list. Since the repeat directive and its associated range are coded inline within the source program, this type of macro definition and expansion does not require calling the macro by name, as required in the expansion of the conventional macros previously described in this chapter.

An indefinite repeat block can appear either within or outside another macro definition, indefinite repeat block, or repeat block. The rules for specifying indefinite repeat block arguments are the same as for specifying macro arguments (see Section 7.3).

7.6.1 .IRP Directive

Format:

```
[label:] .IRP sym,<argument list>
          .
          .
          .
        (range of indefinite repeat block)
          .
          .
          .
         .ENDR
```

where:

label — represents an optional statement label.

Although it is valid for a label to appear on a .IRP directive, this practice is discouraged, especially in the case of nested macro definitions, because invalid labels or labels constructed with the concatenation character will cause the macro directive to be ignored. This may result in improper termination of the macro definition.

This also applies to .IRPC and .REPT.

sym — represents a dummy argument that is replaced with successive real arguments from within the angle brackets. If no dummy argument is specified, the .IRP directive is flagged with an error code (A) in the assembly listing.

, — represents any valid separator (comma, space, and/or tab).

<argument list> — represents a list of real arguments enclosed within angle brackets that is to be used in the expansion of the indefinite repeat range. A real argument can consist of one or more 7-bit ASCII or 8-bit DEC Multinational characters; multiple arguments must be separated by any valid separator (comma, space, and/or tab). If no real arguments are specified, no action is taken.

range	represents the block of code to be repeated once for each occurrence of a real argument in the list. The range can contain other macro definitions, repeat ranges and/or the .MEXIT directive (see Section 7.1.3).
.ENDR	indicates the end of the indefinite repeat block range. You can also terminate an indefinite repeat block with .ENDM.

The .IRP directive replaces a dummy argument with successive real arguments specified in an argument string. This replacement process occurs during the expansion of an indefinite repeat block range.

Use the .MEXIT directive to leave a .IRP loop if you want to exit the loop before its normal completion.

An example of the .IRP directive is shown in Figure 7–4.

7.6.2 .IRPC Directive

Format:

```
[label:] .IRPC   sym,<string>
          .
          .
          .
        (range of indefinite repeat block)
          .
          .
          .
         .ENDR
```

where:

label	represents an optional statement label (see discussion in Section 7.6.1).
sym	represents a dummy argument that is replaced with successive real arguments from within the angle brackets. If no dummy argument is specified, the .IRPC directive is flagged with an error code (A) in the assembly listing.
,	represents any valid separator (comma, space, and/or tab).
<string>	represents a list of 7-bit ASCII or 8-bit DEC Multinational characters, enclosed within angle brackets, to be used in the expansion of the indefinite repeat range. Although the angle brackets are required only when the string contains separating characters, their use is recommended for legibility.
range	represents the block of code to be repeated once for each occurrence of a character in the list. The range can contain macro definitions, repeat ranges, and/or the .MEXIT directive (see Section 7.1.3).
.ENDR	indicates the end of the indefinite repeat block range. You can also terminate an indefinite repeat block with .ENDM.

The .IRPC directive does single character substitution, rather than argument substitution. On each iteration of the indefinite repeat range, the dummy argument is replaced with successive characters in the specified string.

Use the .MEXIT directive to leave a .IRPC loop, if you want to exit the loop before its normal completion.

An example of the .IRPC directive is shown in Figure 7–4.

Figure 7–4: Example of .IRP and .IRPC Directives

```
 1                                      .TITLE  IRPTST
 2
 3                                      .LIST   ME
 4                              ;+
 5                              ; Illustrate the .IRP and .IRPC directives
 6                              ; by creating a pair of RAD50 tables
 7                              ;-
 8
 9 000000                       REGS:   .IRP    REG,<PC,SP,R5,R4,R3,R2,R1,R0>
10                                      .RAD50  /REG/
11                                      .ENDR
   000000  062170                       .RAD50  /PC/
   000002  074500                       .RAD50  /SP/
   000004  072770                       .RAD50  /R5/
   000006  072720                       .RAD50  /R4/
   000010  072650                       .RAD50  /R3/
   000012  072600                       .RAD50  /R2/
   000014  072530                       .RAD50  /R1/
   000016  072460                       .RAD50  /R0/
12
13 000020                       REGS2:  .IRPC   NUM,<76543210>
14                                      .RAD50  /R'NUM/
15                                      .ENDR
   000020  073110                       .RAD50  /R7/
   000022  073040                       .RAD50  /R6/
   000024  072770                       .RAD50  /R5/
   000026  072720                       .RAD50  /R4/
   000030  072650                       .RAD50  /R3/
   000032  072600                       .RAD50  /R2/
   000034  072530                       .RAD50  /R1/
   000036  072460                       .RAD50  /R0/
16
17          000001                      .END
```

7.7 Repeat Block Directive: .REPT, .ENDR

Format:

```
[label:] .REPT   exp
           .
           .
           .
         (range of repeat block)
           .
           .
           .
         .ENDR
```

where:

label	represents an optional statement label (see discussion in Section 7.6.1).
exp	represents any valid expression. This value controls the number of times the block of code is to be assembled within the program. When the expression value is less than or equal to zero, the repeat block is not assembled. If this expression is not an absolute value, the .REPT statement is flagged with an error code (A) in the assembly listing.
range	represents the block of code to be repeated. The repeat block can contain macro definitions, indefinite repeat blocks, other repeat blocks and/or the .MEXIT directive (see Section 7.1.3).
.ENDR	indicates the end of the repeat block range. You can also terminate a repeat block with .ENDM.

The .REPT directive duplicates a block of code, a certain number of times, in line with other source code.

Use the .MEXIT directive to leave a .REPT loop, if you want to exit the loop before its normal completion.

7.8 Macro Library Directive: .MCALL

Format:

```
.MCALL  arg1,arg2,...argn
```

where:

arg1,arg2,...argn	represent the symbolic names of the macro definitions required in the assembly of the source program. The names must be separated by any valid separator (comma, space, and/or tab).

The .MCALL directive identifies any system and/or user-defined macro definitions that are not defined within the source program but which are required to assemble the program.

The .MCALL directive must appear before the first occurrence of a call to any externally defined macro if:

- Auto-Mcall mode is disabled (the default)
- The name of the macro being called is the same as one of MACRO's permanent symbols or directives, such as SUB, .ERROR, or .PRINT. Otherwise, MACRO will use the permanent symbol or directive instead of the macro from the library.

The /ML switch (see Section 8.1.3) under RSX-11M and the /LIBRARY qualifier (see Section 8.2.2) under IAS and RT-11, used with an input file specification, indicate to MACRO-11 that the file is a macro library. Additional macro libraries to be searched can also be specified in the MACRO-11 program itself, using the MACRO-11 .LIBRARY directive. See Section 6.10.1 for a description of the .LIBRARY directive. When a macro call is encountered in the source program, MACRO-11 first searches the user macro

library for the named macro definitions and, if necessary, continues the search with the system macro library.

You can specify any number of user-supplied libraries[1] . For multiple library files, the search for the named macros begins with the last such file specified. The files are searched in reverse order until the required macro definitions are found, finishing, if necessary, with a search of the system macro library.

If any named macro is not found upon completion of the search, the .MCALL statement is flagged with an error code (U) in the assembly listing. Furthermore, a statement elsewhere in the source program that attempts to expand such an undefined macro is flagged with an error code (O) in the assembly listing.

The command strings to MACRO–11, through which file specifications are supplied, are described in detail in the applicable system manual (see the Associated Documents section in the Preface).

7.9 Macro Deletion Directive: .MDELETE

Format:

```
.MDELETE name1,name2,...namen
```

where:

name1,name2,...namen	represent valid macro names. When multiple names are specified, they are separated by any valid separator (comma, space, and/or tab).

The .MDELETE directive deletes the definitions of the specified macro(s), freeing virtual memory. If references are made to deleted macros, the referencing line is flagged with an op code (O) error.

An example of the .MDELETE directive is shown below.

```
.MDELETE    .EXIT,EXIT$S
```

[1] The number is restricted under RT–11. See Section 6.10.1.

Chapter 8
IAS/RSX–11M/RSX–11M–PLUS Operating Procedures

MACRO–11 assembles one or more ASCII source files containing MACRO–11 statements into a single relocatable binary object file. This binary object file contains the table of contents listing, the assembly listing, and the symbol table listing. An optional cross-reference listing of symbols and macros is available. A sample assembly listing is provided in Appendix H.

8.1 RSX–11M/RSX–11M–PLUS Operating Procedures

On RSX–11M and RSX–11M–PLUS systems, two command languages are available: the Monitor Console Routine (MCR) and the DIGITAL Command Language (DCL). When you log onto the system, you are given either MCR or DCL as the default command language. Your default command language is contained in your account file.

By pressing CTRL/C (echoed as ^C) at the monitor prompt, you can see the explicit prompt for the command language you are currently using:

```
> ^C
MCR>

> ^C
DCL>
```

You can switch from one command language to the other. To switch from DCL to MCR, type the following command:

```
DCL> SET TERMINAL MCR
```

To switch from MCR to DCL, type the following command:

```
MCR> SET /DCL=TI:
```

In addition to switching from one command language to the other, you can type a DCL command from a terminal set to MCR, and an MCR command from a terminal set to DCL, as shown below:

```
MCR> DCL cmd-string

DCL> MCR cmd-string
```

8.1.1 Running MACRO–11 Under RSX–11M/RSX–11M–PLUS

The following sections describe those MACRO–11 operating procedures that apply to both the Monitor Console Routine and the DIGITAL Command Language. You can use any of the four methods shown below to run MACRO–11:

- Direct MACRO–11 call
- Single assembly
- Install, run immediately, and remove on exit
- Indirect command processor

8.1.1.1 Direct MACRO–11 Call

MCR Format:

```
MCR> MAC
MAC> cmd-string
```

When you call MACRO-11 directly, the Monitor Console Routine (MCR) accepts `MAC` as input and runs MACRO–11. Since a command string is not present with the MCR line, MACRO–11 then asks for input with the prompting sequence `MAC>` and waits for command string input. After the assembly of the specified files has been completed, MACRO–11 again asks for command string input with the `MAC>` prompting sequence. This process repeats until you press CTRL/Z.

DCL Format:

```
DCL>  MACRO[/qualifier(s)]
File(s)?  filespec[/qualifiers]...
```

DCL accepts MACRO as input and runs MACRO–11. In addition, you can include the qualifiers contained in Table 8–3. Since no file specifications are included in the DCL command line, MACRO–11 asks for input with the `File(s)?` prompt. You can then enter the name of one or more source files plus any of the qualifiers listed in Table 8–4. When you press RETURN, MACRO–11 does the assembly.

8.1.1.2 Single Assembly

MCR Format:

```
MCR> MAC cmd-string
```

DCL Format:

```
DCL>  MACRO cmd-string
```

When you do a single assembly, no prompting from MACRO–11 occurs, since the command line includes the command string input. MACRO–11 assembles the source files in the command string and exits when finished.

8.1.1.3 Install, Run Immediately, and Remove on Exit

Format:

```
>RUN $MAC
MAC>cmd-string
```

Use this method when MACRO–11 is not permanently installed in the system. On RSX–11M, the system must be generated for this type of call support. MAC is run from the system directory. MACRO–11 asks for command string input. The command string must have the MCR format, even if run from a DCL terminal. When MACRO–11 exits, it is removed from the system.

If the system has the "flying install" feature, the `RUN $` calling format is not needed.

8.1.1.4 Indirect Command Processor

MCR Formats:

```
MCR>MAC
MAC>@filespec
```

or:

```
MCR>MAC @filespec
```

or:

```
MAC>RUN $MAC[/UIC=[g,m]]
MAC>@filespec
```

These commands use the indirect command processor, which effectively substitutes "@filespec" for the "cmd-string" input used in the other methods. In the commands shown above, the indirect command processor passes commands to MACRO–11. The file specified as `@filespec` contains MACRO–11 command strings. After this file is opened, command lines are read from the file until the end-of-file is detected. Three nested levels of indirect files are permitted in MACRO–11.

MCR and DCL Format:

```
DCL> @filespec
```

These forms use the indirect command processor to pass commands to the command language. This is the only form you can use with DCL. The indirect command file `@filespec` must contain one of the command lines to run MACRO–11 as listed in the other methods.

NOTE

MACRO–11 can be terminated by entering a CTRL/Z any time a request for command string input is pending.

8.1.2 Default RSX–11 File Specifications

MACRO–11 accepts as input or creates as output up to six types of files. When using the MACRO–11 assembler, you should keep in mind the default device, directory, name, and types listed in Table 8–1. Table 8–1 lists the default values for each file specification.

Table 8–1: RSX–11 File Specification Default Values

	Default Values			
File	**Device**	**Directory**	**Filename**	**Type**
Object file	Your default volume	Current	None	.OBJ
Listing file	Device used for object file	Directory used in object file	None	.LST
Source	Your default volume	Current; used for source 1 or device of last source file specified	None	.MAC
User macro library	Your default volume	Current, if macro file is specified first; if not, directory of last source file	None	.MLB
System macro library	Library device	Library [1,1]	RSXMAC	.SML
Indirect command file	Your default volume	Current	None	.CMD

8.1.3 MCR Command String Format

In response to the MAC> prompting sequence printed by MACRO–11, type the output and input file specifications in the form shown below:

```
MAC> object,listing=src1,src2,...,srcn
```

where:

object	represents the binary object (output) file.
listing	represents the assembly listing (output) file containing the table of contents, the assembly listing, and the symbol table.
=	separates output file specifications from input file specifications.
src1,src2,...srcn	represent the ASCII source (input) files containing the MACRO–11 source program or the user-supplied macro library files to be assembled.

Only two output file specifications in the command string are recognized by MACRO–11; any more than two output files are ignored. No limit is set on the number of source input files. If the entire command string is longer than 80 characters and less than or equal to 132 characters, a hyphen can be placed at the end of the first line as a continuation character.

A null specification in either of the output file specification fields signifies that the associated output file is not desired. A null specification in the input file field, however, is an error condition, resulting in the error message *MAC—Illegal filename* on the command output device (see Section 8.5). The absence of both the device name (`dev:`) and the name of the file (`filename.type`) from a file specification is the equivalent of a null specification.

NOTE

When no listing file is specified, any errors encountered in the source program are printed on the terminal from which MACRO–11 was started. When the `/NL` switch is used in the listing file specification without an argument, the errors and symbol table are written to the file specified.

Each file specification contains the following information:

```
filespec /switch:value ...
```

where:

filespec	is the standard file specification.
/switch	represents an ASCII name identifying a switch option. This switch option can be specified in three forms, as shown below, depending on the function desired:

/switch	Enables the specified switch action.
/noswitch	Negates the specified switch action.
/–switch	Negates the specified switch action.

In addition, the switch identifier can be accompanied by ASCII character strings, octal numbers, or decimal numbers. The default assumption for a numeric value is octal. Decimal values must be followed by a decimal point (.).

Any numeric value preceded by a number sign (#) is regarded as an explicit octal declaration; this option is provided for command line documentation and ready identification of octal values.

Also, any numeric value can be preceded by a plus sign (+) or a minus (–) sign. The positive specification is the default assumption. If an explicit octal declaration is specified (#), the sign indicator, if included, must precede the number sign.

All switch values must be preceded by a colon (:).

The switch specifications are interpreted in the context of the program to which they apply. The switch options applicable to MACRO–11 are described in Table 8–2.

If MACRO–11 detects a syntax error in the command string, MACRO–11 writes the error message *MAC—Command syntax error* to the command output device, followed by a copy of the entire command string.

At assembly time, you may want to override certain MACRO–11 directives appearing in the source program or to provide MACRO–11 with information establishing how certain files are to be handled during assembly. You can do so through one or more switches, which can be selectively included as additional parameters in each file specification. The available switches for MACRO–11 file specifications under RSX–11M/RSX–11M–PLUS are listed in Table 8–2.

Table 8–2: RSX–11 File Specification Switches for MACRO–11

Switch	Function
/LI:arg /NL:arg	Listing control switches; these options accept ASCII switch values (arg) which are equivalent in function and name to the arguments for the .LIST and .NLIST directives you can include in your source program (see Section 6.1.1). Arguments that you specify with the /LI:arg and /NL:arg switches override any arguments that you may have specified with the .LIST and .NLIST directives and remain in effect for the entire assembly process.
/EN:arg /DS:arg	Function control switches; these options accept ASCII switch values (arg) which are equivalent in function and name to the arguments for the .ENABL and .DSABL directives you can include in your source program (see Section 6.2.1). Arguments that you specify with the /EN:arg and /DS:arg switches override any arguments that you may have specified with the .ENABL and .DSABL directives and remain in effect for the entire assembly process.
/ML	The /ML switch, which takes no accompanying switch values, identifies an input file as a macro library file. As noted in Section 7.8, any macro that is defined externally must be identified by a .MCALL directive before it can be retrieved from a macro library file and assembled with the user program. In locating macro definitions, MACRO–11 performs a fixed search algorithm, beginning with the last specified user macro file, continuing in reverse order with each such specified file, and terminating, if necessary, with a search of the system macro library file. If a required macro definition is not found upon completion of the search, an error code (U) is written in the assembly listing. Therefore, a user macro library file must be specified in the command line or by using the MACRO–11 .LIBRARY directive (see Section 6.10.1) prior to the source file(s) that use macros defined in the library file. MACRO–11 does not prescan the command line for macro libraries; when a new source file is needed, MACRO–11 parses the next input file specification. If that file specification contains the /ML switch, it is appended to the front of the library file list. As a result, a user macro library file must be specified in the command line prior to the source files which require it, in order to resolve macro definitions.
/SP	Spool listing output (default value).
/NOSP	Do not spool output.
/CR:[arg]	Produce a cross-reference listing (see Section 8.3).

Switches for the object file are limited to /EN and /DS; when specified, they apply throughout the entire command string. Switch options for the listing file are limited to /LI, /NL, /SP, /CR, and /NOSP. Switches for input files are limited to /ML, /EN, and /DS; the option /ML applies only to the file immediately preceding the option so specified, whereas the /EN and /DS options, as noted above, are also applicable to subsequent files in the command string.

Do not specify the same switch more than once following a file specification. If you do, the values included with any duplicate switch specification override any previously specified values. If you want to include two or more values for the same switch, separate them by colons, as shown below:

```
/LI:SRC:MEB
```

8.1.4 DCL Operating Procedures

RSX-11M/RSX-11M-PLUS indicates its readiness to accept a command by prompting with the DCL prompt. In response to the prompt, enter the command string in one of the formats shown below:

```
> MACRO[/qualifiers]
FILE?  filespec[/qualifiers][,filespec[/qualifiers]...]
```

or:

```
[DCL]> MACRO[/qualifiers] filespec[/qualifiers][,filespec[/qualifiers]...]
```

where:

qualifiers	affect either the entire command string (command qualifiers) or the filespec (parameter qualifiers). See Table 8–3 for a description of the command qualifiers and Table 8–4 for a description of the parameter qualifier.
filespec	is the standard file specification shown in Section 8.4.

Use a comma (,) to separate file specifications. MACRO-11 concatenates all the files and then performs the assembly.

Table 8–3: RSX–11 DCL Command Qualifiers

Qualifier	Function
/[NO]CROSS_REFERENCE	Suppresses or generates a cross-reference listing (see Section 8.3). When the cross-reference is generated, a listing file is also generated, whether or not the /LIST qualifier is present in the command string. The default is /NOCROSS_REFERENCE.

Table 8–3 (Cont.): RSX–11 DCL Command Qualifiers

Qualifier	Function
/DISABLE:arg /ENABLE:arg /DISABLE:(arg,arg...) /ENABLE:(arg,arg...)	Overrides the .DISABLE or .ENABLE assembler directives in the source program. When more than one argument is entered, arguments must be enclosed in parentheses and separated by commas. You can specify any of the following arguments with the /DISABLE or /ENABLE qualifier: ABSOLUTE — If enabled, MACRO–11 assembles all relative addresses (address mode 67) as absolute addresses (address mode 37). The default is Disabled. AUTO_MCALL — If enabled, MACRO–11 searches all known macro libraries for a macro definition that matches any undefined symbols appearing in the op code field of a MACRO–11 statement. The default is Disabled. If MACRO–11 finds an unknown symbol in the op code field, it either declares an undefined symbol (U) error, or declares the symbol as an external symbol, depending upon the GLOBAL argument described below. BINARY — If enabled, MACRO–11 produces absolute binary output in FILES–11 format. The default is Disabled. CARD_FORMAT — If enabled, MACRO–11 treats columns 73 through the end of the line as comments. The default is Disabled. CASE_MATCH — If enabled, MACRO–11 makes the conditional assembly directives .IF IDN and .IF DIF alphabetically case sensitive. The default is not case sensitive. GLOBAL — If disabled, MACRO–11 flags all undefined symbol references with an error code (U) on the assembly listing. The default is Enabled; MACRO–11 treats all symbols that are undefined at the end of assembly pass 1 as default global references.

Table 8–3 (Cont.): RSX–11 DCL Command Qualifiers

Qualifier	Function	
	LOCAL	If enabled, MACRO–11 treats all symbols as local symbols. When enabled, all global symbols are flagged with the undefined symbol (U) error message. The default is Disabled.
	LOWER_CASE	If disabled, MACRO–11 converts all lowercase ASCII input to uppercase. The default is Enabled.
	REGISTER_DEFINITIONS	If disabled, MACRO–11 ignores the normal register definitions. The default is Enabled.
	TRUNCATION	If enabled, MACRO–11 performs floating-point truncation. If disabled, MACRO–11 performs floating-point rounding. The default is Disabled.
/[NO]LIST[:filespec]	Specifies whether or not MACRO–11 should create and print a listing file. You can include /LIST as a qualifier for either a command or a file specification. If /LIST qualifies the command, the listing file is both entered in your directory and printed on the line printer. If you do not include a file specification, the listing file has a .LST file type and is named after the last file named in the MACRO command. The listing file cannot be a library file. (The LINK command and all other language commands use the name of the first file named in the command as the default file name.) If /LIST qualifies a file specification, the file is entered in your directory but is not printed on the line printer. The listing file is named after the file it qualifies. The default is /NOLIST.	
/[NO]OBJECT[:filespec]	Specifies whether or not MACRO–11 should create an object module. If you do not include a file specification in the command line, MACRO–11 creates an object file with the same file name as the source file and a .OBJ extension. The default is /OBJECT.	
/[NO]SHOW:arg /[NO]SHOW:(arg,arg...)	Overrides any .LIST and .NLIST assembler directives that may be included in the source file. You can use any of the following arguments with the /SHOW qualifier:	
	BINARY	Controls the listing of macro expansion binary code.

Table 8–3 (Cont.): RSX–11 DCL Command Qualifiers

Qualifier	Function	
	CALLS	Controls listing of macro calls and repeat range expansions.
	COMMENTS	Controls listing of comments.
	CONDITIONALS	Controls listing of unsatisfied conditional coding.
	CONTENTS	Controls listing of the table of contents during assembly pass 1.
	COUNTER	Controls listing of the current location counter field.
	DEFINITIONS	Controls listing of macro definitions and repeat range expansions.
	EXPANSIONS	Controls listing of macro expansions.
	EXTENSIONS	Controls listing of binary expansions.
	LISTING_DIRECTIVES	Controls listing of listing control directives without arguments, that is, directives that alter the listing level counter.
	OBJECT_BINARY	Controls listing of the generated binary code.
	SEQUENCE_NUMBERS	Controls listing of source line sequence numbers.
	SOURCE	Controls listing of source lines.
	SYMBOLS	Controls listing of the symbol table resulting from the assembly.
/[NO]WIDE	When set to /WIDE, the listing is printed in 132-column format. When set to /NOWIDE, the listing is printed in 80-column format. The default is /NOWIDE.	

Table 8–4: RSX–11 DCL Parameter Qualifier

Qualifier	Function
/LIBRARY	Specifies that an input file is a macro library file. The assembler processes the files listed in the command line in reverse order. Therefore, a library file cannot be the last file in the command line.

8.1.5 MACRO–11 Command String Examples

Example 1:

The following commands assemble the source file FILNAM.MAC into a relocatable object module named FILNAM.OBJ:

```
MCR> MAC FILNAM=FILNAM

DCL> MACRO
FILE? FILNAM

DCL> MACRO FILNAM
```

Example 2:

The following commands assemble the source file FILNAM.MAC and produce an object file with the name TESTA.OBJ:

```
MCR> MAC TESTA=FILNAM

DCL> MACRO/OBJECT:TESTA FILNAM
```

Example 3:

The following commands concatenate and assemble the source files named FILNAM.MLB, TESTA.MAC, SPAN3.MAC, and SHELL.MAC and create an object file named SHELL.OBJ:

```
MCR> MAC SHELL=FILNAM/ML,TESTA,SPAN3,SHELL

DCL> MACRO FILNAM/LIBRARY,TESTA,SPAN3,SHELL
```

Example 4: The following commands produce an object module and an assembly listing. Any .LIST TTM or .LIST COM directives in the source file are ignored. The listing produced by this command includes no comments and is printed in wide format:

```
MCR> MAC FILNAM,FILNAM/NL:TTM:COM=FILNAM

DCL> MACRO/LIST/NOSHOW:COMMENTS/WIDE FILNAM
```

8.2 IAS MACRO–11 Operating Procedures

The following sections describe those MACRO–11 operating procedures that apply exclusively to the IAS system.

8.2.1 Running MACRO–11 Under IAS

The MACRO command used under IAS assembles one or more ASCII source files containing MACRO–11 statements into a relocatable binary object file. MACRO–11 also produces an assembly listing followed by a symbol table listing. A cross-reference listing can also be produced by means of the /CROSSREFERENCE qualifier (see Section 8.3 below).

You can call MACRO–11 directly from the terminal (interactive mode) or from a batch file (batch mode). For interactive mode, use the MACRO command, which can be issued whenever the IAS Program Development System (PDS) is at command level, a condition signified by the appearance of the prompt:

```
PDS>
```

For batch mode, use the $MACRO command.

When the assembly is completed, MACRO–11 terminates operations and returns control to PDS. (Refer to the *IAS User's Guide* for further information about interactive and batch mode operations.)

8.2.2 IAS Command String

Formats:

Interactive Mode:

```
PDS>  MACRO qualifiers        filespec /LIBRARY +...
```

or:

```
PDS>  MACRO qualifiers
FILES?   filespec /LIBRARY        +...
```

Batch Mode:

```
$MACRO qualifiers        filespec /LIBRARY +...
```

where:

filespec — is the specification of an input file (see Section 8.4) that contains MACRO–11 source program code. When the program consists of multiple files, a plus sign (+) must be used to separate each file specification from the next. The "wild card" form of a file specification is not allowed.

/LIBRARY — specifies that an input file is a macro library file. Library files hold the definitions of externally defined macros. As noted in Section 7.8, an externally defined macro must be identified in a .MCALL directive before it can be retrieved and assembled with your program. When MACRO–11 encounters a .MCALL directive, a search begins for the definitions of the macros listed.

The search order is important, because a macro might have two different definitions in library files LIB1 and LIB2. For example, if you need the definition in LIB1, you must place LIB1 after LIB2 in the command line, because MACRO–11 searches the last file specified in the command line first, then moves backwards through the given files until all have been searched.

If a macro's definition is not found in any of the files named by the user, MACRO–11 automatically searches the system macro library; if the definition is still not found, an error code (U) is generated in the assembly listing.

qualifiers — specifies one or more of the following:

/OBJECT[:filespec] — produces an object file as specified by `filespec` (see Section 8.4). The default is a file with the same filename as the last named source file and a `.OBJ` extension. `/OBJECT` is always the default condition.

/NOOBJECT — does not produce an object file.

/LIST[:filespec] — produces an assembly listing file according to `filespec` (see Section 8.4). If `filespec` is not specified, the listing is printed on the line printer. The default in interactive mode is `/NOLIST` and in batch mode is `/LIST`.

/NOLIST — does not produce a listing file. The default in interactive mode is `/NOLIST` and in batch mode is `/LIST`.

When no listing file is specified, any errors encountered in the source program are displayed at the terminal from which MACRO–11 was initiated.

/CROSSREFERENCE[:arg1...arg4]

produces a cross-reference listing. `Arg1` through `arg4` are described in Section 8.3. This qualifier can be abbreviated to `/C`.

A MACRO–11 command string can be specified by using any one of the three formats shown above for the interactive and batch modes. In interactive mode, if the input file specification (`filespec`) does not begin on the same line as the MACRO command and its qualifiers, PDS prints the following prompting message:

```
FILES?
```

then waits for you to specify the input file(s).

In batch mode, the `$MACRO` command and its arguments must appear on the same line unless the PDS line continuation symbol (–) is used.

8.2.3 IAS Indirect Command Files

Format:

```
@filespec
```

where:

@ — specifies that the name that follows is an indirect file.

filespec — is the file specification (see Section 8.4) of a file that contains a command string. The default extension for the file name is `.CMD`.

You can use the indirect command file facility of PDS with MACRO–11 command strings. Create an ASCII file that contains the desired command strings (or portions thereof) in the forms shown in Section 8.2.2. When an indirect command file reference

is used in a MACRO–11 command string, the contents of the specified file are taken as all or part of the command string.

An indirect command file reference must always be the rightmost entry in the command (see Section 8.2.4 for examples).

8.2.4 IAS Command String Examples

The following examples show typical PDS MACRO–11 command strings.

Example 1:

```
PDS>  MACRO /NOLIST
FILES?  A+BOOT.MAC;3
```

In this example, the source files A.MAC and BOOT.MAC;3 are assembled to produce an object file called BOOT.OBJ. No listing is produced.

Example 2:

Where the indirect command file `TEST.CMD` contains the command string:

```
MACRO/OBJECT:MYFILE  A+B
```

the command:

```
PDS> @TEST
```

assembles the two files `A.MAC` and `B.MAC` into an object file called `MYFILE.OBJ`.

Example 3:

Where the indirect command file `IND02.CMD` contains the command string segment:

```
ATEST/LIBRARY+BTEST+SRT1.021
```

the command:

```
PDS> MACRO/LIST:DK1:TST    @IND02
```

assembles the files `BTEST.MAC` and `SRT1.021`, using the macro library file `ATEST.MAC` to produce an object file named `SRT1.OBJ`. A listing file named `TST.LST` is placed on disk unit 1.

Example 4:

```
$MACRO/LIST:DKO:MICR/NOOBJECT  -
LIB1/LIBRARY+MICR.MAC;002
```

In this example, the library file is assembled with the file `MICR.MAC;002`. The program listing file named `MICR.LST` is placed on disk unit 0.

8.3 Cross-Reference Processor (CREF)

The CREF processor is used to produce a listing that includes cross-references to symbols that appear in the source program. The cross-reference listing is appended to the assembly listing. Such cross-references are helpful in debugging and in reading long programs.

A cross-reference listing can include up to four sections:

- User-defined symbols
- Macro symbols
- Register symbols
- Permanent symbols

To generate a cross-reference listing, specify the /CR switch in the MACRO–11 command string. Optional arguments can also be specified. The form of the switch is:

/CR [: { SYM / MAC / REG / PST / SEC / ERR }]

where:

SYM	specifies user-defined symbols (default).
MAC	specifies macro symbols (default).
REG	specifies register symbols.
PST	specifies permanent symbols.
SEC	specifies program sections.
ERR	specifies error lines (default).

If you want to generate listings for user-defined and macro symbols only, use /CR. No argument is necessary.

However, if an argument is specified, only that type of cross-reference listing is generated. For example:

```
/CR:SYM
```

produces a cross-reference listing of user-defined symbols only. No listing of macro symbols is generated. Thus, to produce all six types of cross-reference listings, you must specify all six arguments; the order in which they are specified is not significant. Use a colon to separate arguments, for example:

```
/CR:REG:SYM:MAC:PST:SEC:ERR
```

The CREF processor (CRF) is more fully described in the Utilities Reference Manual supplied with your system.

Figure 8–1 illustrates a complete cross-reference listing. In the listing, references are made in the form *page-line*. To make the listing more informative, the CREF processor uses the following signs:

=	somewhere in the source program the symbol listed is defined by a direct assignment statement.
*	destructive reference; the value of the symbol is changed (its previous contents destroyed) by the program instruction at the line number marked by the asterisk (*).
#	symbol definition; the symbol is defined by a direct assignment statement, a colon sign (:), or a double colon sign (::) at the line number marked by the number sign (#).

Figure 8–1: Sample IAS CREF Listing

```
R5OUNP     CREATED BY  MACRO  ON 4-AUG-87 AT 12:17      PAGE 1
SYMBOL CROSS REFERENCE                                   CREF   V02
SYMBOL  VALUE           REFERENCES
R5OUNP    000000 RG     #2-42
SYMBOL  = ******  G      2-38       2-43       2-51
TABLE     000062 R      2-66      #2-70

R5OUNP     CREATED BY  MACRO  ON 4-AUG-87 AT 12:17      PAGE 2
REGISTER SYMBOL CROSS REFERENCE                          CREF   V02
SYMBOL          REFERENCES
R0              *2-49      *2-64      *2-65       2-66
R1              *2-44       2-49
R2              *2-66
R3              *2-45      *2-47       2-65
R4               2-42      *2-43      *2-44       2-51      *2-53
SP              *2-42      *2-53

R5OUNP     CREATED BY  MACRO  ON 4-AUG-87 AT 12:17      PAGE 3
PERMANENT SYMBOL TABLE CROSS REFERENCE                   CREF   V02
SYMBOL          REFERENCES
BNE             2-52
CALL            2-46      2-48      2-50
CLR             2-64
CMP             2-51
DIV             2-65
MOV             2-42      2-43      2-44      2-45      2-47      2-49
                2-53
MOVB            2-66
RETURN          2-54      2-67
.BYTE           2-70      2-71      2-72      2-73      2-74
.END            2-76
.GLOBL          2-38
.IDENT          1-2
.NLIST          2-69
.PSECT          2-40
.SBTTL          2-25
.TITLE          1-1
```

Figure 8–1 Cont'd. on next page

Figure 8–1 (Cont.): Sample IAS CREF Listing

```
R5OUNP     CREATED BY  MACRO  ON 4-AUG-87 AT 12:17      PAGE 4
SECTION CROSS REFERENCE                                 CREF   V02
SECTION NAME    REFERENCES
                 0-0
PUREI            2-40
. ABS.          #0-0
```

8.4 IAS/RSX–11M/RSX–11M–PLUS File Specification

Format:

```
dev:[g,m]name.ext;ver
```

where:

dev: is the name of the device where the desired file resides. A device name consists of two characters followed by a 1- or 2-digit device unit number (octal) and a colon (for example, DP1:, DK0:, DT3:). The default device is specified in Table 8–1. The default device under IAS is established initially by the system manager for each user and can be changed through the SET command.

[g,m] is the User File Directory (UFD) code. This code consists of a group number (octal), a comma (,) and an owner (member) number (octal) all enclosed in brackets ([]). An example of a UFD code is: [200,30].

The default UFD is equivalent to the User Identification Code (UIC) given at login time. Under IAS, the UFD can be changed through the SET DEFAULT command.

name is a 1- to 9-character alphanumeric filename. There is no default.

.ext is a 1- to 3-character alphanumeric filename extension or type that is preceded by a period (.). An extension is normally used to identify the nature of the file. Default values depend on the context of the file specification and are as follows:

.CMD	Indirect command (input) file
.LST	A listing (print format) file
.MAC	MACRO–11 source module (input file)
.OBJ	MACRO–11 object module (output file)
.CRF	Intermediate CREF input file created by MACRO–11

;ver is an octal number between 1 and 77777 that is used to differentiate between versions of the same file. This number is prefixed by a semicolon (;).

For input files, the default value is the highest version number of the file that exists.

For output files, the default value is the highest version number of the file that exists increased by 1. If no version number exists, the value 1 is used.

This is the general form for a file specification in IAS/RSX-11M/RSX-11M-PLUS systems. Detailed information is provided in the applicable system user's guide or operating procedures manual (see the Associated Documents section in the Preface).

8.5 MACRO-11 Error Messages Under IAS/RSX-11M/RSX-11M-PLUS

MACRO-11 writes an error message to the command output device when one of the error conditions described below is detected. MACRO-11 writes below the error message the command line that caused the error. If the error is a .INCLUDE or a .LIBRARY directive file error, MACRO-11 writes both the source line and the command line that caused the error.

```
MAC -- Error message
MACRO-11 source line
MACRO-11 command line
```

These error messages reflect operational problems and should not be confused with the error codes (see Appendix D) produced by MACRO-11 during assembly.

All the error messages listed below, with the exception of the *MAC—Command I/O error* message, terminate the current assembly; MACRO-11 then attempts to restart by reading another command line. In the case of a command I/O error, however, MACRO-11 exits, since it is unable to obtain additional command line input.

MAC—Command file/open failure

Either the file from which MACRO-11 is reading a command could not be opened initially or between assemblies; or the indirect command file specified as @filename in the MACRO-11 command line could not be opened. See *MAC—Open failure on input file.*

MAC—Command I/O error

An error was returned by the file system during MACRO-11's attempt to read a command line. This is an unconditionally fatal error, causing MACRO-11 to exit. No MACRO-11 restart is attempted when this message appears.

MAC—Command syntax error

An error was detected in the syntax of the MACRO-11 command line.

MAC—Illegal filename

Neither the device name nor the filename was present in the input file specification (the input file specification was null), or a wild card convention (asterisk) was employed in an input or output file specification.

Wildcard options (*) are not permitted in MACRO-11 file specifications.

MAC—Illegal switch

An invalid switch was specified for a file, an invalid value was specified with a switch, or an invalid use of a switch was detected by MACRO-11.

MAC—.INCLUDE directive file error

The file specified in the .INCLUDE statement either does not exist or is invalid, the device specified in the command line is not available, or the .INCLUDE stacking depth exceeds five.

MAC—Indirect command syntax error

The name of the indirect command file (@filename) specified in the MACRO–11 command line is syntactically incorrect.

MAC—Indirect file depth exceeded

An attempt to exceed the maximum allowable number of nested indirect command files has occurred. (Three levels of indirect command files are permitted in MACRO–11.)

MAC—Insufficient dynamic memory

There is not enough physical memory available for MACRO–11 to page its symbol table. Reinstall MACRO–11 in a larger partition, or see Section F.3.

MAC—Invalid format in macro library

The library file has been corrupted, or it was not produced by the Librarian utility program (LBR).

MAC—I/O error on input file

In reading a record from a source input file or macro library file, the file system detected an error; for example, a line containing more than 132_{10} characters was encountered. This message may also indicate that a device problem exists or that either a source file or a macro library file has been corrupted with incorrect data.

MAC—I/O error on macro library file

Same meaning as *MAC—I/O error on input file*, except that the file is a macro library file and not a source input file.

MAC—I/O error on output file

The file system detected an error while writing a record to the object output file or the listing output file. This message may also indicate that a device problem exists or that the device is full.

MAC—I/O error on work file

A read or write error occurred on the work file used to store the symbol table. This error is most likely caused by a problem on the device or by an attempt to write to a full device.

MAC—.LIBRARY directive file error

The file specified in the .LIBRARY statement either does not exist or is invalid, the file specification in the .LIBRARY directive is for a nonrandom access device, the device specified in the command line is not available, or the .LIBRARY stacking depth exceeds the maximum depth allowed.

MAC—Open failure on input file

One of the following conditions exists:

- The specified device does not exist.
- The volume is not mounted.
- A problem exists with the device.
- The specified directory file does not exist.
- The specified file does not exist.
- You do not have access privilege to the file directory or to the file itself.

MAC—Open failure on output file

One of the following conditions exists:

- The specified device does not exist.
- The volume is not mounted.
- A problem exists with the device.
- The specified directory file does not exist.
- You do not have access privilege to the file directory.
- The volume is full, or the device is write protected.
- There is insufficient space for File Control Blocks.

MAC—64K storage limit exceeded

64K words of work file memory are available to MACRO–11. This message indicates that the assembler has generated so many symbols (about 13,000 to 14,000) that it has run out of space. Either the source program is too large to start with, or it contains a condition that leads to excessive size, such as a macro expansion that recursively calls itself without a terminating condition.

Chapter 9
RSTS/RT–11 Operating Procedures

9.1 MACRO–11 Under RSTS

The only way a MACRO–11 program can run on a RSTS system is through either the RT–11 or RSX run-time systems.

9.1.1 RT–11 Through RSTS

There are two ways to run MACRO–11 under the RT–11 run-time system on RSTS:

- Use the RT–11 Emulator. This is done by typing `SW RT11`. The terminal will respond with the RT–11 prompt (a dot printed by the keyboard monitor). You can then use the RT–11 commands (see Section 9.2).
- Type the command `RUN $MACRO.SAV`. The terminal will respond with an asterisk (*) prompt. You can then enter a command string of the form:

```
objfil,lstfil=src1,...src6
```

where:

objfil	is an object (output) file with the default extension `.OBJ`.
lstfil	is a listing (output) file with the default extension `.LST`.
src1,...src6	are source (input) files with the default extension `.MAC`. Six input files are allowed in this command.

9.1.2 RSX Through RSTS

To run MACRO–11 under the RSX run-time system on RSTS, type the command: `RUN $MAC.TSK`. The terminal will display:

```
MAC>
```

In response, enter a command string of the form:

```
objfil,lstfil=src1,...srcn
```

where:

objfil	is an object (output) file with the default extension `.OBJ`.
lstfil	is a listing (output) file with the default extension `.LST`.
src1,...srcn	are source (input) files with the default extension `.MAC`.

NOTE

You can use other RSTS commands to call the RT–11 and RSX run-time systems, but they are site dependent and so are not mentioned here.

9.2 Running MACRO–11 Under RT–11

The following sections describe those MACRO–11 operating procedures that apply only to the RT–11 system. Table 9–1 lists the default file specifications for RT–11.

Table 9–1: RT–11 Default File Specification Values

	Default		
File	**Device**	**Filename**	**Type**
Object	DK:	Must specify	.OBJ
Listing	Same as for object file	Must specify	.LST
CREF	Logical device name CF:, if it has been defined; otherwise, DK:	CREF	.TMP
Work	Logical device name WF:, if it has been defined; otherwise, DK:	WRK	.TMP
First source	DK:	Must specify	.MAC
Additional source	Same as for preceding source file	Must specify	.MAC
System macro library	System device SY:	SYSMAC	.SML
User macro library	DK: if first file; otherwise, same as for preceding source file	Must specify	.MLB

9.2.1 RT–11 Command String (CSI) Format

To call the MACRO–11 assembler from the system device, respond to the system prompt (a dot printed by the keyboard monitor) by typing:

```
.R MACRO
```

When the assembler responds with an asterisk (*), it is ready to accept command string (CSI) input.

Format:

```
dev:obj,dev:list,dev:cref/s:arg=dev:src1,src2,...,dev:srcn/s:arg
```

where:

dev:	is any valid RT–11 device for output; any file-structured device for input. If `dev:` is omitted, `DK:` is assumed.
obj	is the file specification of the binary object file that the assembly process produces; the device for this file should not be `TT:` or `LP:`.
list	is the file specification of the assembly and symbol listing that the assembly process produces.
cref	is the file specification of the CREF temporary cross-reference file that the assembly process produces. Omission of `dev:cref` does not preclude a cross-reference listing, however. If you specify `/C` without a CREF filename, MACRO–11 uses a default name for the CREF temporary file on logical device name `CF:`, if it has been defined, or on `DK:`.
/s:arg	is a set of file specification options and arguments (see Table 9–2).
src1,src2,...srcn	represent the ASCII source (input) files containing the MACRO–11 source program or the user-supplied macro library files to be assembled. You can specify as many as six source files.

The following command string calls for an assembly that uses one source file plus the system macro library to produce an object file `BINF.OBJ` and a listing. The listing goes directly to the line printer.

```
*DK:BINF.OBJ,LP:=DK:SRC.MAC
```

All output file specifications are optional. The system does not produce an output file (except for the CREF temporary file, if you include the `/C` option), unless the command string contains a specification for that file.

The system determines the file type of an output file specification by its position in the command string, as determined by the number of commas in the string. For example, to omit the object file, you must begin the command string with a comma. The following command produces a listing, including a cross-reference table, but not a binary object file.

```
*,LP:/C=SRC1,SRC2
```

Notice that you need not include a comma after the final output file specification in the command string.

Table 9–1 lists the default values for each file specification.

Some assemblies need more symbol table space than available memory can contain. When this occurs, the system automatically creates a temporary work file called `WRK.TMP` to provide extended symbol table space.

MACRO–11 writes `WRK.TMP` to the logical name `WF:`, if it has been defined. Otherwise, MACRO–11 puts the work file on `DK:`. To assign the logical name `WF:` to a device, enter the following command:

```
.ASSIGN dev: WF
```

where:

dev:	is the file-structured device that will hold `WRK.TMP`.

The default size of WRK.TMP is 200_8 blocks. You can increase the size to a maximum of 400_8 blocks with a customization patch. Refer to the file CUSTOM.TXT on your RT–11 distribution kit.

9.2.2 RT–11 CSI Command Line Options

At assembly time, you may need to override certain MACRO directives appearing in the source programs. You may also need to direct MACRO–11 on the handling of certain files during assembly. You can satisfy these needs by using the switches described in Table 9–2.

Table 9–2: File Specification Options

Option	Explanation
/L:arg /N:arg	Listing control options; these options accept ASCII values (arg) which are equivalent in function and name to the arguments for the .LIST and .NLIST directives you can include in your source program (see Section 6.1.1). Arguments that you specify with the /LI:arg and /NL:arg options override any arguments that you may have specified with the .LIST and .NLIST directives and remain in effect for the entire assembly process.
/E:arg /D:arg	Function control options; these options accept ASCII values (arg) which are equivalent in function and name to the arguments for the .ENABL and .DSABL directives you can include in your source program (see Section 6.2.1). Arguments that you specify with the /E:arg and /D:arg options override any arguments that you may have specified with the .ENABL and .DSABL directives and remain in effect for the entire assembly process.
/M	Indicates input file is a MACRO library file. When the assembler encounters a .MCALL directive in the source code, it searches macro libraries according to their order of appearance in the command string, starting from the right. When it locates a macro record whose name matches that given in the .MCALL, it assembles the macro as indicated by that definition. Thus, if two or more macro libraries contain definitions of the same macro name, the macro library that appears rightmost in the command string takes precedence. Consider the following command string: `*(output file specification)=ALIB/M,BLIB/M,XIZ` Assume that each of the two macro libraries, ALIB.MLB and BLIB.MLB, contains a macro called .BIG, but with different definitions. Then, if source file XIZ contains a macro call .MCALL .BIG, the system includes the definition of .BIG in the program as it appears in the macro library BLIB. If the command string does not include the standard system macro library SYSMAC.SML, the system automatically includes it as the first source file in the command string. Therefore, if macro library ALIB.MLB contains a definition of a macro called .READ, that definition of .READ overrides the standard .READ macro definition in SYSMAC.SML.
/C:arg	Controls contents of cross-reference table.

The /M option affects only the source file to which it is appended. The other options affect the entire command string.

9.2.3 RT–11 Digital Command Language (DCL) Format

You can enter the MACRO DCL command in response to the monitor prompt (.) to run MACRO–11 under RT–11.

Format:

```
                 [ /CROSSREFERENCE[:type[...:type]] ]
                 | /DISABLE:type[...:type]          |
                 | /ENABLE:type[...:type]           |
MACRO            | /LIST[:filespec]                 |  [SP] filespecs  [/LIBRARY]
                 |   /ALLOCATE:size                 |
                 | /[NO]OBJECT[:filespec]           |
                 |   /ALLOCATE[:size]               |
                 | /[NO]SHOW:type[...:type]         |
                 [                                  ]
```

where:

/ALLOCATE:size — reserves space for output file; a size of –1 reserves the largest possible space.

/CROSSREFERENCE[:type[...:type]] — produces CREF listing; *type* can be:

C	Control section names
E	Error codes
M	Macro names
P	Permanent names
R	Register symbols
S	user-defined symbols
blank	equivalent to :E:M:S

/DISABLE:type[...:type]] — specifies .DSABL directives; *type* can be:

ABS	Produces absolute binary output
AMA	Assembles absolute addresses as relative addresses
CDR	Treats source columns beyond 72 as a comment
DBG	Writes internal symbol director (ISD) records
FPT	Truncates floating point
GBL	Assumes undefined symbols are globals
LC	Accepts lowercase characters in source programs
LSB	Defines local symbol block
MCL	Enables or disables automatic .MCALL
PNC	Enables or disables binary output
REG	Defines default register mnemonics

/ENABLE:type[...:type]] — specifies .ENABL directives; *type* can be any of the types listed under /DISABLE.

/LIBRARY — identifies a macro library file.

/LIST[:filespec]	writes program listing to the printer or to `filespec`.
[NO]OBJECT[:filespec]	[does not] generate a `.OBJ` file; output filespec defaults to input filespec.
[NO]SHOW:type[...:type]	specifies MACRO–11 `.LIST` and `.NLIST` directives; *type* can be:

BEX	Extended binary code
BIN	Generated binary code
CND	Unsatisfied conditionals and `.IF` and `.ENDC` statements
COM	Comments
LOC	Location counter
MC	Macro calls, repeat range expansions
MD	Macro definitions, repeat range expansions
ME	Macro expansions
MEB	Macro expansions, binary code
SEQ	Source line sequence numbers
SRC	Source code
SYM	Symbol table
TOC	Table of contents
TTM	Wide or narrow listing format

9.3 Cross-Reference (CREF) Table Generation Option

A cross-reference (CREF) table lists all or a subset of the symbols in a source program, identifying the statements that define and use symbols.

9.3.1 Obtaining a Cross-Reference Table

To obtain a CREF table you must include the `/C:arg` option in the command string. Usually you include the `/C:arg` option with the assembly listing file specification, but it can appear anywhere on the command line.

If the command string does not include a CREF file specification but does include `/C`, MACRO–11 automatically writes a temporary file `CREF.TMP` to logical name `CF:`, if it has been defined. Otherwise, MACRO–11 uses `DK:`. If you want to use a device other than `DK:` for the temporary CREF workfile, include the `dev:cref` field in the command string, or assign the logical name `CF:` to the device you want to use.

A complete CREF listing contains the following sections:

- A cross reference of program symbols—labels used in the program and symbols followed by an operator.
- A cross reference of register symbols—`R0`, `R1`, `R2`, `R3`, `R4`, `R5`, `SP`, and `PC`.
- A cross reference of MACRO symbols—symbols defined by `.MACRO` and `.MCALL` directives.
- A cross reference of permanent symbols—all operation mnemonics and assembler directives.

- A cross reference of program sections—the names you specify as operands of .CSECT or .PSECT directives.
- A cross reference of errors—all flagged errors from the assembly, grouped and listed by type.

You can include any or all of these sections on the cross-reference listing by specifying the appropriate arguments with the /C option. These arguments are listed and described in Table 9–3.

Table 9–3: /C Option Arguments

Argument	CREF Section
S	User defined symbols
R	Register symbols
M	MACRO symbolic names
P	Permanent symbols including instructions and directives
C	Control and program sections
E	Error code grouping

NOTE

Specifying /C with no arguments is equivalent to specifying /C:S:M:E. That special case excepted, you must explicitly request each CREF section by including its arguments. No cross-reference file is written if you omit the /C option, even if the command string includes a CREF file specification.

9.3.2 Handling Cross-Reference Table Files

When you request a cross-reference listing with the /C option, MACRO–11 generates a temporary file CREF.TMP and writes this file to logical device name CF:, if it is defined. Otherwise, MACRO–11 writes CREF.TMP to DK:.

If the device MACRO–11 attempts to use for CREF.TMP is write-protected, or if it contains insufficient free space for the temporary file, you can specify another device for the file in your command string. To use another device, you can specify a third output file in the command string; that is, include a dev:cref specification for the CREF temporary file in addition to the file specifications for the binary and listing files. (You must still include the /C option to control the form and content of the listing. The dev:cref specification is ignored if the /C option is not also present in the command string.)

MACRO–11 then uses dev:cref instead of CF:CREF.TMP or DK:CREF.TMP. In any case, CREF deletes the file automatically after producing the CREF listing.

For example, with the following command string MACRO–11 uses RK2:TEMP.TMP as the temporary CREF file:

```
* ,LP:,RK2:TEMP.TMP=SOURCE/C
```

Another way to assign an alternative device for the CREF.TMP file is to assign the logical name CF: to the device you want to use for CREF.TMP, prior to running MACRO–11:

```
.ASSIGN dev: CF
```

This method is convenient if you intend to do several assemblies, as it relieves you from having to include a dev:cref specification for the CREF file in each command string. If you enter the ASSIGN dev: CF command, and later include a cref file specification in a command string, the specification in the command string prevails for that assembly only.

The system lists requested cross-reference tables following the MACRO assembly listing. Each table begins on a new page.

The system prints symbols and also symbol values, control sections, and error codes, if applicable, beginning at the left margin of the page. References to each symbol are listed on the same line, left-to-right across the page. The system lists references in the form *P–L;* where *P* is the page on which the symbol, control section, or error code appears, and *L* is the line number on the page.

A number sign (#) next to a reference indicates a symbol definition. An asterisk (*) next to a reference indicates a destructive reference—an operation that alters the contents of the addressed location.

9.3.3 MACRO–11 Error Messages Under RT–11

MACRO–11 writes an error message to the command output device when one of the error conditions described below is detected. MACRO–11 writes below the error message the command line that caused the error. If the error is a .INCLUDE or a .LIBRARY directive file error, MACRO–11 writes both the source line and the command line that caused the error.

```
?MACRO-s-Error message
MACRO-11 source line
MACRO-11 command line
```

The s in the error message represents the letter code that indicates the severity level of the error.

These error messages reflect operational problems and should not be confused with the error codes (see Appendix D) produced by MACRO–11 during assembly.

Message and Meaning	How to Respond
?MACRO-F-Device full <dev:>	
The output volume does not have enough room for an output file specified in the command string.	• Delete unnecessary files from the output volume, perhaps transferring them to a backup volume. • Use another volume with more space. • Specify an explicit output file size by using the /ALLOCATE option or include the file size in square brackets as part of the output file specification. • Consolidate free space on the volume by using the monitor's SQUEEZE command. • Refer to other techniques for gaining file space in the *RT-11 System Message Manual.*
?MACRO-F-File not found <dev:filnam.typ>	
An input file in the command line is not on the specified device.	Correct any file specification errors in the command line and enter it again.
?MACRO-F-.INCLUDE directive file error	
1. The file specified in the .INCLUDE statement does not exist or is invalid. 2. The device specified in the command line is not available or its handler is not loaded. 3. The .INCLUDE stacking depth exceeds five.	1. Check for a typing error in the command line. Use file specifications that are valid with the .INCLUDE directive. 2. Enter the command line again, specifying an available device, or load the device handler. 3. Make sure that the .INCLUDE stacking depth does not exceed five.
?MACRO-F-Insufficient memory	
MACRO-11 lacks the minimum amount of memory (16K words) necessary to run.	• Use the SHOW command to find out what device handlers are loaded, then use the UNLOAD command to remove those that are not necessary. After unloading any unnecessary handlers, you may need to unload, then reload, handlers that you plan to use so that free space is concatenated. Be careful not to unload any handler being used by a foreground or system job.

Message and Meaning	How to Respond
	• Terminate and unload the foreground job or a system job. • If you are using the FB monitor, SET USR SWAP (see the *RT-11 System User's Guide*) to allow USR swapping. • Create a new monitor with SYSGEN (see the *RT-11 System Generation Guide*) containing only those features that you absolutely need. • If you have extended memory available, use VBGEXE to run MACRO-11.
?MACRO-F-Internal error MACRO-11 detected an unexpected condition while checking its internal tables.	This error should not occur. If you get this error, please send an SPR to DIGITAL along with a method of reproducing the problem.
?MACRO-F-Invalid command The command line contains a syntax error or specifies more than six input files.	Correct and retype the command line.
?MACRO-F-Invalid device The device specified in the command line is not on the system.	Install the device or substitute another.
?MACRO-F-Invalid macro library The library file has been corrupted, or it was not produced by the RT-11 librarian, LIBR.	Obtain a new copy of SYSMAC.SML from your distribution kit. If you have modified SYSMAC.SML, carefully check the procedures you used.
?MACRO-F-Invalid option: /x The specified option was not recognized by the program.	Check for a typing error in the command line. Use only a valid listing control or a functional control (or CREF) option.
?MACRO-F-I/O error on <dev:filnam.typ> A hardware error occurred during a read from or write to the specified file.	• Be sure the device is on line and write enabled. • Refer to other procedures for recovery from hard error conditions listed in the *RT-11 System Message Manual*.

Message and Meaning	How to Respond
?MACRO-F-I/O error on workfile	
MACRO failed to read, write, or open its work file WRK.TMP, possibly because of a hard error condition.	• Be sure the device is on line and write enabled. • Be sure there is enough contiguous free space on the output volume to accommodate the workfile. If not, use the monitor's SQUEEZE command, or delete unnecessary files. • Refer to other procedures for recovery from hard error conditions listed in the *RT-11 System Message Manual.*
?MACRO-F-.LIBRARY directive file error	
1. The file specified in the .LIBRARY directive does not exist or is invalid. 2. The file specification in the .LIBRARY directive is for a non-random-access device. 3. The device specified in the command line is not available. 4. The .LIBRARY stacking depth exceeds the maximum depth allowed.	1. Check for a typing error in the command line. Use file specifications that are valid with the .LIBRARY directive. 2. Make sure that the file specification used in the .LIBRARY directive is for a random-access device. 3. Enter the command line again, specifying an available device. 4. Make sure that the .LIBRARY stacking depth does not exceed the maximum depth allowed.
?MACRO-F-Protected file already exists <dev:filnam.typ>	
An attempt was made to create a file having the same name as an existing protected file.	Use the monitor UNPROTECT command to change the protection level of the existing file, or use a different name to create the new file.
?MACRO-F-Storage limit exceeded (64K)	
MACRO's virtual symbol table can store symbols and macros up to 64K words (400_8 blocks) in any combination. The program contains more than 64K of one or both of these elements.	Check the program logic for a condition that leads to excessive size, such as a macro expansion that recursively calls itself without a terminating condition. If necessary, reduce the requirements of the source program by segmenting it into separate modules, and assemble each separately.

Message and Meaning	How to Respond
?MACRO-F-Workfile space exceeded	
The size required by MACRO–11's virtual symbol table has exceeded the amount of space available in the temporary workfile.	• Increase the size of the workfile by patching location WRKSIZ. (Refer to the file CUSTOM.TXT on your distribution kit.) The default size of the workfile is 200_8 blocks; it can be patched to a maximum size of 400_8 blocks. • Check the program logic for a condition that leads to excessive size, such as a macro expansion that recursively calls itself without a terminating condition. You may also have a missing .ENDM or .ENDR statement. If necessary, reduce the requirements of the source program by segmenting it into separate modules, and assemble each separately.
?MACRO-W-I/O error on CREF file: CREF aborted	
Not enough space was available to perform the operation, or an I/O error occurred while the CREF work file was being written. CREF processing is terminated, but the assembly will continue.	• Delete unnecessary files from the output volume, perhaps transferring them to a backup volume. • Use another volume with more space. • Include the CREF workfile specification in the MACRO–11 command line, and include the file size in square brackets as part of the file specification. • Consolidate free space on the volume by using the monitor's SQUEEZE command. • Refer to other techniques for gaining file space in the *RT–11 System Message Manual.*

Appendix A
MACRO–11 Character Sets

A.1 DEC Multinational Character Set

Empty positions are reserved for future standardizations.

Table A–1: DEC Multinational Character Set

Left Byte Octal	Right Byte Octal	Hex	Decimal	Character	Remarks
000000	000	00	0	NUL	Null; tape feed; CTRL/@
000400	001	01	1	SOH	Start of heading; SOM, start of message; CTRL/A
001000	002	02	2	STX	Start of text; EOA, end of address; CTRL/B
001400	003	03	3	ETX	End of text; EOM, end of message; CTRL/C
002000	004	04	4	EOT	End of transmission (END); shuts off TWX terminals; CTRL/D
002400	005	05	5	ENQ	Enquiry (ENQRY); WRU; CTRL/E
003000	006	06	6	ACK	Acknowledge; RU; CTRL/F
003400	007	07	7	BEL	Rings the bell; CTRL/G
004000	010	08	8	BS	Backspace; FEO, format effector; backspaces some terminals; CTRL/H
004400	011	09	9	HT	Horizontal tab; CTRL/I
005000	012	0A	10	LF	Line feed or Line space (new line); CTRL/J
005400	013	0B	11	VT	Vertical tab (VTAB); CTRL/K
006000	014	0C	12	FF	Form feed to top of next page (PAGE); CTRL/L
006400	015	0D	13	CR	Carriage return to beginning of line; CTRL/M
007000	016	0E	14	SO	Shift out; changes ribbon color to red; CTRL/N
007400	017	0F	15	SI	Shift in; changes ribbon color to black; CTRL/O
010000	020	10	16	DLE	Data link escape; DC0; CTRL/P
010400	021	11	17	DC1	Device control 1; turns transmitter (READER) on; XON; CTRL/Q
011000	022	12	18	DC2	Device control 2; turns punch or auxiliary on; TAPE; AUX ON; CTRL/R
011400	023	13	19	DC3	Device control 3; turns transmitter (READER) off; XOFF; CTRL/S

Table A–1 (Cont.): DEC Multinational Character Set

Left Byte Octal	Right Byte Octal	Hex	Decimal	Character	Remarks
012000	024	14	20	DC4	Device control 4; turns punch or auxiliary off; AUX OFF; CTRL/T
012400	025	15	21	NAK	Negative acknowledge; ERR; ERROR; CTRL/U
013000	026	16	22	SYN	Synchronous file (SYNC); CTRL/V
013400	027	17	23	ETB	End of transmission block; LEM, logical end of medium; CTRL/W
014000	030	18	24	CAN	Cancel (CANCL); CTRL/X
014400	031	19	25	EM	End of medium; CTRL/Y
015000	032	1A	26	SUB	Substitute; CTRL/Z
015400	033	1B	27	ESC	Escape; CTRL/[
016000	034	1C	28	FS	File separator; CTRL/\
016400	035	1D	29	GS	Group separator; CTRL/]
017000	036	1E	30	RS	Record separator; CTRL/^
017400	037	1F	31	US	Unit separator; CTRL/_
020000	040	20	32	SP	Space
020400	041	21	33	!	Exclamation mark
021000	042	22	34	"	Double quote
021400	043	23	35	#	Number sign
022000	044	24	36	$	Dollar sign
022400	045	25	37	%	Percent sign
023000	046	26	38	&	Ampersand
023400	047	27	39	'	Single quote; apostrophe; accent acute
024000	050	28	40	(	Left parenthesis
024400	051	29	41	)	Right parenthesis
025000	052	2A	42	*	Asterisk
025400	053	2B	43	+	Plus sign
026000	054	2C	44	,	Comma
026400	055	2D	45	-	Minus sign or hyphen
027000	056	2E	46	.	Period
027400	057	2F	47	/	Slash
030000	060	30	48	0	Number zero
030400	061	31	49	1	Number one
031000	062	32	50	2	Number two
031400	063	33	51	3	Number three
032000	064	34	52	4	Number four
032400	065	35	53	5	Number five
033000	066	36	54	6	Number six
033400	067	37	55	7	Number seven
034000	070	38	56	8	Number eight
034400	071	39	57	9	Number nine
035000	072	3A	58	:	Colon
035400	073	3B	59	;	Semicolon
036000	074	3C	60	<	Left angle bracket
036400	075	3D	61	=	Equal sign

Table A–1 (Cont.): DEC Multinational Character Set

Left Byte Octal	Right Byte Octal	Hex	Decimal	Character	Remarks
037000	076	3E	62	>	Right angle bracket
037400	077	3F	63	?	Question mark
040000	100	40	64	@	At sign
040400	101	41	65	A	Uppercase A
041000	102	42	66	B	Uppercase B
041400	103	43	67	C	Uppercase C
042000	104	44	68	D	Uppercase D
042400	105	45	69	E	Uppercase E
043000	106	46	70	F	Uppercase F
043400	107	47	71	G	Uppercase G
044000	110	48	72	H	Uppercase H
044400	111	49	73	I	Uppercase I
045000	112	4A	74	J	Uppercase J
045400	113	4B	75	K	Uppercase K
046000	114	4C	76	L	Uppercase L
046400	115	4D	77	M	Uppercase M
047000	116	4E	78	N	Uppercase N
047400	117	4F	79	O	Uppercase O
050000	120	50	80	P	Uppercase P
050400	121	51	81	Q	Uppercase Q
051000	122	52	82	R	Uppercase R
051400	123	53	83	S	Uppercase S
052000	124	54	84	T	Uppercase T
052400	125	55	85	U	Uppercase U
053000	126	56	86	V	Uppercase V
053400	127	57	87	W	Uppercase W
054000	130	58	88	X	Uppercase X
054400	131	59	89	Y	Uppercase Y
055000	132	5A	90	Z	Uppercase Z
055400	133	5B	91	[	Left square bracket
056000	134	5C	92	\	Backslash
056400	135	5D	93	]	Right square bracket
057000	136	5E	94	^	Circumflex; appears as up arrow (↑) on some terminals
057400	137	5F	95	_	Underscore; appears as left arrow (←) on some terminals
060000	140	60	96	`	Accent grave
060400	141	61	97	a	Lowercase a
061000	142	62	98	b	Lowercase b
061400	143	63	99	c	Lowercase c
062000	144	64	100	d	Lowercase d
062400	145	65	101	e	Lowercase e
063000	146	66	102	f	Lowercase f
063400	147	67	103	g	Lowercase g
064000	150	68	104	h	Lowercase h

Table A–1 (Cont.): DEC Multinational Character Set

Left Byte Octal	Right Byte Octal	Hex	Decimal	Character	Remarks
064400	151	69	105	i	Lowercase i
065000	152	6A	106	j	Lowercase j
065400	153	6B	107	k	Lowercase k
066000	154	6C	108	l	Lowercase l
066400	155	6D	109	m	Lowercase m
067000	156	6E	110	n	Lowercase n
067400	157	6F	111	o	Lowercase o
070000	160	70	112	p	Lowercase p
070400	161	71	113	q	Lowercase q
071000	162	72	114	r	Lowercase r
071400	163	73	115	s	Lowercase s
072000	164	74	116	t	Lowercase t
072400	165	75	117	u	Lowercase u
073000	166	76	118	v	Lowercase v
073400	167	77	119	w	Lowercase w
074000	170	78	120	x	Lowercase x
074400	171	79	121	y	Lowercase y
075000	172	7A	122	z	Lowercase z
075400	173	7B	123	{	Left brace
076000	174	7C	124	|	Vertical bar
076400	175	7D	125	}	Right brace
077000	176	7E	126	~	Tilde
077400	177	7F	127	DEL	Delete, Rubout
100000	200	80	128		Reserved
100400	201	81	129		Reserved
101000	202	82	130		Reserved
101400	203	83	131		Reserved
102000	204	84	132	IND	Index
102400	205	85	133	NEL	Next line
103000	206	86	134	SSA	Start selected area
103400	207	87	135	ESA	End selected area
104000	210	88	136	HTS	Horizontal tab set
104400	211	89	137	HTJ	Horizontal tab justify
105000	212	8A	138	VTS	Vertical tab set
105400	213	8B	139	PLD	Partial line down
106000	214	8C	140	PLU	Partial line up
106400	215	8D	141	RI	Reverse index
107000	216	8E	142	SS2	Single shift G2
107400	217	8F	143	SS3	Single shift G3
110000	220	90	144	DCS	Device control string
110400	221	91	145	PU1	Private use 1
111000	222	92	146	PU2	Private use 2
111400	223	93	147	STS	Set transmit state
112000	224	94	148	CCH	Cancel character
112400	225	95	149	MW	Message waiting

Table A–1 (Cont.): DEC Multinational Character Set

Left Byte Octal	Right Byte Octal	Hex	Decimal	Character	Remarks
113000	226	96	150	SPA	Start protected area
113400	227	97	151	EPA	End protected area
114000	230	98	152		Reserved
114400	231	99	153		Reserved
115000	232	9A	154		Reserved
115400	233	9B	155	CSI	Control sequence introduction
116000	234	9C	156	ST	String terminator
116400	235	9D	157	OSC	Operating system command
117000	236	9E	158	PM	Privacy message
117400	237	9F	159	APC	Application program command
120000	240	A0	160		Reserved
120400	241	A1	161	¡	Inverted exclamation mark
121000	242	A2	162	¢	Cent sign
121400	243	A3	163	£	British pound
122000	244	A4	164		Reserved
122400	245	A5	165	¥	Japanese yen
123000	246	A6	166		Reserved
123400	247	A7	167	§	Section sign
124000	250	A8	168	¤	General currency
124400	251	A9	169	©	Copyright
125000	252	AA	170	ª	Feminine ordinal
125400	253	AB	171	«	Double open angle bracket
126000	254	AC	172		Reserved
126400	255	AD	173		Reserved
127000	256	AE	174		Reserved
127400	257	AF	175		Reserved
130000	260	B0	176	°	Degree
130400	261	B1	177	±	Plus or minus
131000	262	B2	178	²	Superscript 2
131400	263	B3	179	³	Superscript 3
132000	264	B4	180		Reserved
132400	265	B5	181	µ	Micro
133000	266	B6	182	¶	Pilcrow
133400	267	B7	183	·	Middle dot
134000	270	B8	184		Reserved
134400	271	B9	185	¹	Superscript 1
135000	272	BA	186	º	Masculine ordinal
135400	273	BB	187	»	Double close angle bracket
136000	274	BC	188	¼	One-fourth
136400	275	BD	189	½	One-half
137000	276	BE	190		Reserved
137400	277	BF	191	¿	Inverted question mark
140000	300	C0	192	À	Uppercase A grave
140400	301	C1	193	Á	Uppercase A acute
141000	302	C2	194	Â	Uppercase A circumflex

Table A–1 (Cont.): DEC Multinational Character Set

Left Byte Octal	Right Byte Octal	Hex	Decimal	Character	Remarks
141400	303	C3	195	Ã	Uppercase A tilde
142000	304	C4	196	Ä	Uppercase A umlaut
142400	305	C5	197	Å	Uppercase A ring
143000	306	C6	198	Æ	Uppercase AE diphthong
143400	307	C7	199	Ç	Uppercase C cedilla
144000	310	C8	200	È	Uppercase E grave
144400	311	C9	201	É	Uppercase E acute
145000	312	CA	202	Ê	Uppercase E circumflex
145400	313	CB	203	Ë	Uppercase E umlaut
146000	314	CC	204	Ì	Uppercase I grave
146400	315	CD	205	Í	Uppercase I acute
147000	316	CE	206	Î	Uppercase I circumflex
147400	317	CF	207	Ï	Uppercase I umlaut
150000	320	D0	208		Reserved
150400	321	D1	209	Ñ	Uppercase N tilde
151000	322	D2	210	Ò	Uppercase O grave
151400	323	D3	211	Ó	Uppercase O acute
152000	324	D4	212	Ô	Uppercase O circumflex
152400	325	D5	213	Õ	Uppercase O tilde
153000	326	D6	214	Ö	Uppercase O umlaut
153400	327	D7	215	Œ	Uppercase OE ligature
154000	330	D8	216	Ø	Uppercase O slash
154400	331	D9	217	Ù	Uppercase U grave
155000	332	DA	218	Ú	Uppercase U acute
155400	333	DB	219	Û	Uppercase U circumflex
156000	334	DC	220	Ü	Uppercase U umlaut
156400	335	DD	221	Ÿ	Uppercase Y umlaut
157000	336	DE	222		Reserved
157400	337	DF	223	ß	German small sharp s
160000	340	E0	224	à	Lowercase a grave
160400	341	E1	225	á	Lowercase a acute
161000	342	E2	226	â	Lowercase a circumflex
161400	343	E3	227	ã	Lowercase a tilde
162000	344	E4	228	ä	Lowercase a umlaut
162400	345	E5	229	å	Lowercase a ring
163000	346	E6	230	æ	Lowercase ae diphthong
163400	347	E7	231	ç	Lowercase c cedilla
164000	350	E8	232	è	Lowercase e grave
164400	351	E9	233	é	Lowercase e acute
165000	352	EA	234	ê	Lowercase e circumflex
165400	353	EB	235	ë	Lowercase e umlaut
166000	354	EC	236	ì	Lowercase i grave
166400	355	ED	237	í	Lowercase i acute
167000	356	EE	238	î	Lowercase i circumflex
167400	357	EF	239	ï	Lowercase i umlaut

Table A–1 (Cont.): DEC Multinational Character Set

Left Byte Octal	Right Byte Octal	Hex	Decimal	Character	Remarks
170000	360	F0	240		Reserved
170400	361	F1	241	ñ	Lowercase n tilde
171000	362	F2	242	ò	Lowercase o grave
171400	363	F3	243	ó	Lowercase o acute
172000	364	F4	244	ô	Lowercase o circumflex
172400	365	F5	245	õ	Lowercase o tilde
173000	366	F6	246	ö	Lowercase o umlaut
173400	367	F7	247	œ	Lowercase oe ligature
174000	370	F8	248	ø	Lowercase o slash
174400	371	F9	249	ù	Lowercase u grave
175000	372	FA	250	ú	Lowercase u acute
175400	373	FB	251	û	Lowercase u circumflex
176000	374	FC	252	ü	Lowercase u umlaut
176400	375	FD	253	ÿ	Lowercase y umlaut
177000	376	FE	254		Reserved
177400	377	FF	255		Reserved

A.2 Radix–50 Character Set

Table A–2: Radix–50 Character Set

Character	Octal Equivalent	Radix-50 Equivalent
Space	040	000
A–Z	101–132	001–032
$	044	033
.	056	034
Unused		035
0–9	060–071	036–047

The maximum Radix–50 octal value is therefore:

$47 * 50^2 + 47 * 50 + 47 = 174777$

Table A–3 provides a convenient means of translating between the ASCII character set and its Radix–50 equivalents. For example, given the ASCII string X2B, the Radix–50 equivalent is (arithmetic is performed in octal):

```
X=113000
2=002400
B=000002
X2B=115402
```

Table A–3: Radix–50 Character Equivalents

Single Character or First Character		Second Character		Third Character	
Space	000000	Space	000000	Space	000000
A	003100	A	000050	A	000001
B	006200	B	000120	B	000002
C	011300	C	000170	C	000003
D	014400	D	000240	D	000004
E	017500	E	000310	E	000005
F	022600	F	000360	F	000006
G	025700	G	000430	G	000007
H	031000	H	000500	H	000010
I	034100	I	000550	I	000011
J	037200	J	000620	J	000012
K	042300	K	000670	K	000013
L	045400	L	000740	L	000014
M	050500	M	001010	M	000015
N	053600	N	001060	N	000016
O	056700	O	001130	O	000017
P	062000	P	001200	P	000020

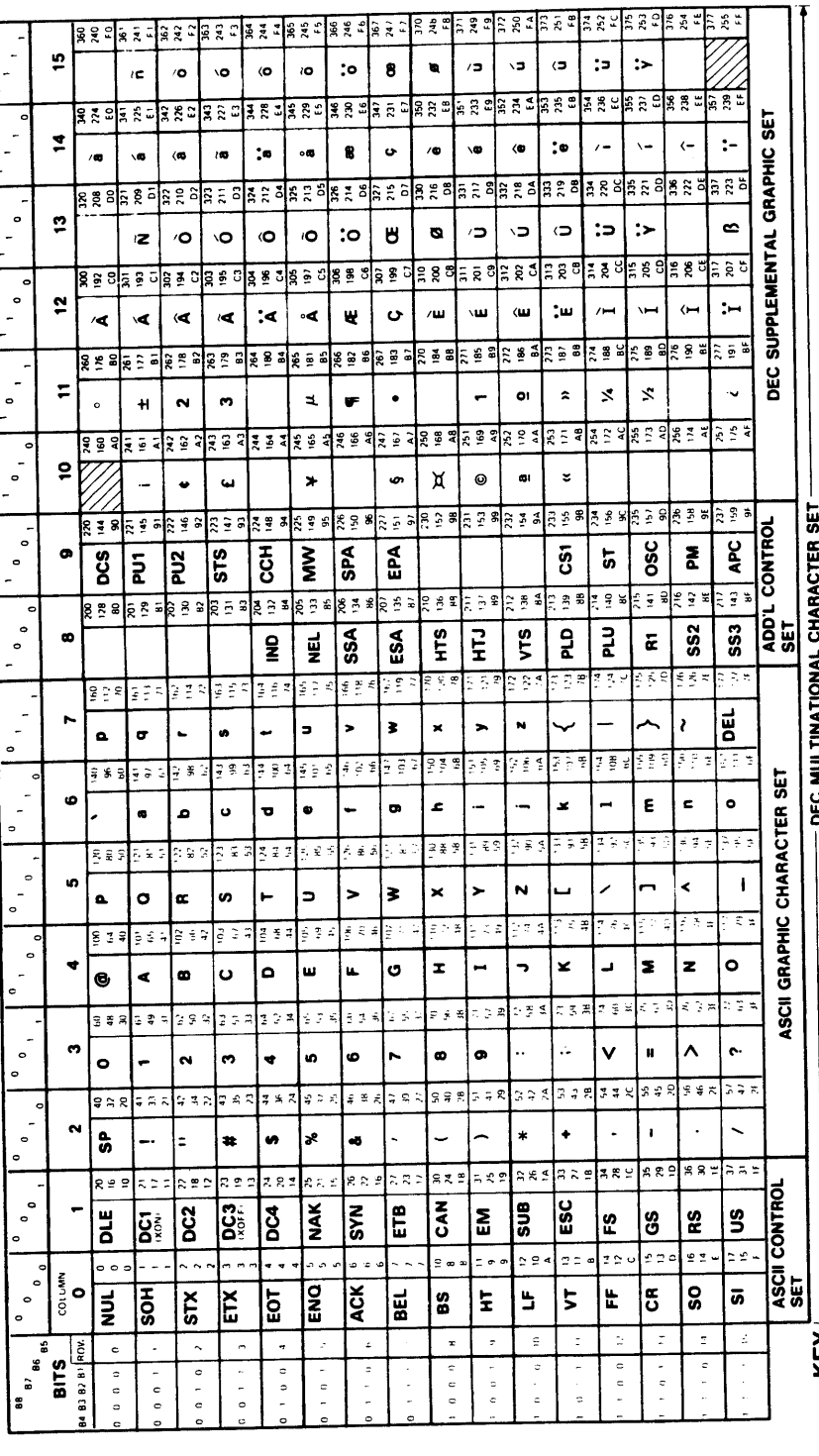
Table A–3 (Cont.): Radix–50 Character Equivalents

Single Character or First Character		Second Character		Third Character	
Q	065100	Q	001250	Q	000021
R	070200	R	001320	R	000022
S	073300	S	001370	S	000023
T	076400	T	001440	T	000024
U	101500	U	001510	U	000025
V	104600	V	001560	V	000026
W	107700	W	001630	W	000027
X	113000	X	001700	X	000030
Y	116100	Y	001750	Y	000031
Z	121200	Z	002020	Z	000032
$	124300	$	002070	$	000033
.	127400	.	002140	.	000034
Unused	132500	Unused	002210	Unused	000035
0	135600	0	002260	0	000036
1	140700	1	002330	1	000037
2	144000	2	002400	2	000040
3	147100	3	002450	3	000041
4	152200	4	002520	4	000042
5	155300	5	002570	5	000043
6	160400	6	002640	6	000044
7	163500	7	002710	7	000045
8	166600	8	002760	8	000046
9	171700	9	003030	9	000047

A.3 DEC Multinational Character Set

Figure A–1 contains the DEC multinational character set; empty positions are reserved for future standardizations.

Figure A–1: DEC Multinational Character Set



Appendix B
MACRO–11 Assembly Language and Assembler Directives

B.1 Special Characters

Character	Function
:	Label terminator
=	Direct assignment operator
%	Register term indicator
TAB	Item terminator or field terminator
SP	Item terminator or field terminator
#	Immediate expression indicator
@	Deferred addressing indicator
(	Initial register indicator
)	Terminal register indicator
, (comma)	Operand field separator
;	Comment field indicator
+	Arithmetic addition operator or autoincrement indicator
-	Arithmetic subtraction operator or autodecrement indicator
*	Arithmetic multiplication operator
/	Arithmetic division operator
&	Logical AND operator
!	Logical OR operator
"	Double ASCII character indicator
' (single quote)	Single ASCII character indicator or concatenation indicator
.	Assembly location counter
<	Initial argument indicator
>	Terminal argument indicator
^	Universal unary operator or argument indicator
\	Macro call numeric argument indicator
vertical tab	Source line terminator

B.2 Summary of Address Mode Syntax

Format[1]	Address Mode: Name	Address Mode: Number	Meaning
R	Register	0n	Register R contains the operand.
@R or (ER)	Register Deferred	1n	Register R contains the address of the operand.
(ER)+	Autoincrement	2n	The contents of the register specified as (ER) are incremented after being used as the address of the operand.
@(ER)+	Autoincrement Deferred	3n	The register specified as (ER) contains the pointer to the address of the operand; the register (ER) is incremented after use.
-(ER)	Autodecrement	4n	The contents of the register specified as (ER) are decremented before being used as the address of the operand.
@-(ER)	Autodecrement Deferred	5n	The contents of the register specified as (ER) are decremented before being used as the pointer to the address of the operand.
E(ER)	Index	6n	The expression E, plus the contents of the register specified as (ER), form the address of the operand.
@E(ER)	Index Deferred	7n	The expression E, plus the contents of the register specified as (ER), yield a pointer to the address of the operand.
E	Immediate	27	The expression E is the operand itself.
@ E	Absolute	37	The expression E is the address of the operand.
E	Relative	67	The address of the operand E, relative to the instruction, follows the instruction.
@E	Relative Deferred	77	The address of the operand is pointed to by E, whose address, relative to the instruction, follows the instruction.

[1] Symbols used in the table:
n is an integer, 0 to 7, representing a register number.
R is a register expression.
E is an expression.
ER is a register expression or an expression whose value is in the range 0 to 7.

B.3 Assembler Directives

The MACRO–11 assembler directives are summarized in the following table. For a detailed description of each directive, refer to the appropriate sections in the body of the manual.

Form	Reference	Operation
'	6.3.3 7.3.7	Followed by one ASCII character, a single quote (apostrophe) generates a word which contains the 7-bit ASCII representation of the character in the low-order byte and zero in the high-order byte. Single quote is also used as a concatenation indicator in the expansion of macro arguments.
"	6.3.3	Followed by two ASCII characters, a double quote generates a word which contains the 7-bit ASCII representation of the two characters. The first character is stored in the low-order byte; the second character is stored in the high-order byte.
^Bn	6.4.1.2	A temporary radix control, causes the value n to be treated as a binary number.
^Cexpr	6.4.2.1	A temporary numeric control, causes the expression's value to be one's complemented.
^Dn	6.4.1.2	A temporary radix control, causes the value n to be treated as a decimal number.
^Fn	6.4.2.3	A temporary numeric control, causes the value n to be treated as a 16-bit floating-point number.
^On	6.4.1.2	A temporary radix control, causes the value n to be treated as an octal number.
^Rccc	6.3.7	Converts ccc to Radix–50 form.
^Xn	6.4.1.2	A temporary radix control, causes the value n to be treated as a hexadecimal number. The value n must begin with a digit, which may be 0.
.ASCII /string/	6.3.4	Generates a block of data containing the ASCII equivalent of the character string (enclosed in delimiting characters), one character per byte.
.ASCIZ /string/	6.3.5	Generates a block of data containing the ASCII equivalent of the character string (enclosed in delimiting characters), one character per byte, with a zero byte terminating the specified string.
.ASECT	6.7.2	Begins or resumes the absolute program section.
.BLKB exp	6.5.3	Reserves a block of storage space whose length in bytes is determined by the specified expression.

Form	Reference	Operation
.BLKW exp	6.5.3	Reserves a block of storage space whose length in words is determined by the specified expression.
.BYTE exp1,exp2,...	6.3.1	Generates successive bytes of data; each byte contains the value of the corresponding specified expression.
.CROSS sym1,sym2,...	6.2.2	Enables the cross-reference listing for the specified symbol list. If a symbol list is not specified, this directive reenables the cross-reference listing for all symbols in the program.
.CSECT [name]	6.7.2	Begins or resumes named or unnamed relocatable program section. This directive is provided for compatibility with other PDP-11 assemblers.
.DSABL arg	6.2.1	Disables the function specified by the argument.
.ENABL arg	6.2.1	Enables the function specified by the argument.
.END [exp]	6.6	Indicates the logical end of the source program. The optional argument specifies the transfer address where program execution is to begin.
.ENDC	6.9.1	Indicates the end of a conditional assembly block.
.ENDM [name]	7.1.2	Indicates the end of the current repeat block, indefinite repeat block, or macro definition. The optional name, if used, must be identical to the name specified in the macro definition.
.ENDR	7.7	Indicates the end of the current repeat block. This directive is provided for compatibility with other PDP-11 assemblers.
.ERROR exp;text	7.5	A user-called error directive, causes output to the listing file or the command output device containing the optional expression and the statement containing the directive.
.EVEN	6.5.1	Ensures that the current location counter contains an even address by adding 1 if it is odd.
.FLT2 arg1,arg2,...	6.4.2.2	Generates successive 2-word floating-point equivalents for the floating-point numbers specified as arguments.
.FLT4 arg1,arg2,...	6.4.2.2	Generates successive 4-word floating-point equivalents for the floating-point numbers specified as arguments.
.GLOBL sym1,sym2,...	6.8.1	Defines the listed symbol(s) as global symbol(s).

Form	Reference	Operation
.IDENT /string/	6.1.4	Provides a means of labeling the object module with the program version number. The version number is the Radix–50 string appearing between the paired delimiting characters.
.IF cond,arg1,arg2,...	6.9.1	Begins a conditional assembly block of source code, which is included in the assembly only if the stated condition is met with respect to the specified argument(s).
.IFF	6.9.2	Appears only within a conditional assembly block, indicating the beginning of a section of code to be assembled if the condition upon entering the block tests false.
.IFT	6.9.2	Appears only within a conditional assembly block, indicating the beginning of a section of code to be assembled if the condition upon entering the block tests true.
.IFTF	6.9.2	Appears only within a conditional assembly block, indicating the beginning of a section of code to be assembled unconditionally.
.IIF cond,arg, statement	6.9.3	Acts as a 1-line conditional assembly block where the condition is tested for the specified argument. The statement is assembled only if the condition tests true.
.INCLUDE filespec	6.10.2	Inserts a specified source file within the source file currently being used.
.IRP sym,<arg1,arg2,...>	7.6.1	Indicates the beginning of an indefinite repeat block in which the specified symbol is replaced with successive elements of the real argument list enclosed within angle brackets.
.IRPC sym,<string>	7.6.2	Indicates the beginning of an indefinite repeat block in which the specified symbol takes on the value of successive characters, optionally enclosed within angle brackets.
.LIBRARY filespec	6.10.1	Adds a specified file name to a macro library list that is searched.
.LIMIT	6.5.4	Reserves two words into which the Linker or Task Builder inserts the low and high addresses of the task image.

Form	Reference	Operation
.LIST [arg]	6.1.1	Without an argument, the .LIST directive increments the listing level count by 1. With an argument, this directive does not alter the listing level count, but formats the assembly listing according to the specified argument.
.MACRO name,arg1,arg2,...	7.1.1	Indicates the start of a macro definition having the specified name and the following dummy arguments.
.MCALL arg1,arg2,...	7.8	Specifies the symbolic names of the user or system macro definitions required in the assembly of the current user program, but which are not defined within the program.
.MDELETE name1,name2,...	7.9	Deletes the definitions of the specified macro(s), freeing virtual memory.
.MEXIT	7.1.3	Causes an exit from the current macro expansion or indefinite repeat block.
.NARG symbol	7.4.1	Appearing only within a macro definition, equates the specified symbol to the number of arguments in the macro call currently being expanded.
.NCHR symbol,<string>	7.4.2	Appearing anywhere in a source program, equates the specified symbol to the number of characters in the specified string.
.NLIST [arg]	6.1.1	Without an argument, decrements the listing level count by 1. With an argument, this directive suppresses that portion of the listing specified by the argument.
.NOCROSS sym1,sym2,...	6.2.2	Disables the cross-reference listing for the listed symbols. If a symbol list is not specified, this directive disables the cross-reference listing for all symbols in the program.
.NTYPE symbol,aexp	7.4.3	Appearing only within a macro definition, equates the symbol to the 6-bit addressing mode of the specified address expression.
.ODD	6.5.2	Ensures that the current location counter contains an odd address by adding 1 if it is even.
.PACKED	6.3.8	Causes a decimal number of 31_{10} digits or less to be packed two digits per byte.
.PAGE	6.1.5	Causes the assembly listing to skip to the top of the next page and to increment the page count.

Form	Reference	Operation
.PRINT exp;text	7.5	User-called message directive; causes output to the listing file or the command output device containing the optional expression and the statement containing the directive.
.PSECT name,att1,...	6.7.1	Begins or resumes a named or attn unnamed program section having the specified attributes.
.RAD50 /string/	6.3.6	Generates a block of data containing the Radix-50 equivalent of the character string enclosed within delimiting characters.
.RADIX n	6.4.1.1	Alters the current program radix to n, where n is 2, 8, 10, or 16.
.REM comment-character	6.1.6	Allows a programmer to insert a block of comments into a MACRO-11 source program without having to precede the comment lines with the comment character (;).
.REPT exp	7.7	Begins a repeat block; causes the section of code up to the next .ENDM or .ENDR directive to be repeated the number of times specified as exp.
.RESTORE	6.7.4	Retrieves a previously .SAVEd program section context from the top of the program section context stack leaving the current program section in effect.
.SAVE	6.7.3	Stores the current program section context on the top of the program section context stack leaving the current program section in effect.
.SBTTL string	6.1.3	Causes the specified string to be printed as part of the assembly listing page header. The string component of each .SBTTL directive is collected into a table of contents at the beginning of the assembly listing.
.TITLE string	6.1.2	Assigns the first six Radix-50 characters in the string as an object module name and causes the string to appear on each page of the assembly listing.
.WEAK sym1,sym2,...	6.8.2	Specifies symbols that are defined either externally in another module or globally in the current module.
.WORD exp1,exp2,...	6.3.2	Generates successive words of data; each word contains the value of the corresponding specified expression.

Appendix C
Permanent Symbol Table

The mnemonics for the PDP–11 operation (op) codes and MACRO–11 assembler directives are stored in the Permanent Symbol Table. The Permanent Symbol Table contains the symbols that are automatically recognized by MACRO–11.

For a detailed description of the op codes, see the *PDP–11 Processor Handbook.*

C.1 Op Codes

Instruction Mnemonic	Octal Value	Operation
ADC	005500	Add Carry
ADCB	105500	Add Carry (Byte)
ADD	060000	Add Source To Destination
ASH	072000	Shift Arithmetically
ASHC	073000	Arithmetic Shift Combined
ASL	006300	Arithmetic Shift Left
ASLB	106300	Arithmetic Shift Left (Byte)
ASR	006200	Arithmetic Shift Right
ASRB	106200	Arithmetic Shift Right (Byte)
BCC	103000	Branch If Carry Is Clear
BCS	103400	Branch If Carry Is Set
BEQ	001400	Branch If Equal
BGE	002000	Branch If Greater Than Or Equal
BGT	003000	Branch If Greater Than
BHI	101000	Branch If Higher
BHIS	103000	Branch If Higher Or Same
BIC	040000	Bit Clear
BICB	140000	Bit Clear (Byte)
BIS	050000	Bit Set
BISB	150000	Bit Set (Byte)

Instruction Mnemonic	Octal Value	Operation
BIT	030000	Bit Test
BITB	130000	Bit Test (Byte)
BLE	003400	Branch If Less Than Or Equal
BLO	103400	Branch If Lower
BLOS	101400	Branch If Lower Or Same
BLT	002400	Branch If Less Than
BMI	100400	Branch If Minus
BNE	001000	Branch If Not Equal
BPL	100000	Branch If Plus
BPT	000003	Breakpoint Trap
BR	000400	Branch Unconditional
BVC	102000	Branch If Overflow Is Clear
BVS	102400	Branch If Overflow Is Set
CALL	004700	Jump To Subroutine (JSR PC,xxx)
CALLR	000100	Jump (JMP addr)
CCC	000257	Clear All Condition Codes
CLC	000241	Clear C Condition Code Bit
CLN	000250	Clear N Condition Code Bit
CLR	005000	Clear Destination
CLRB	105000	Clear Destination (Byte)
CLV	000242	Clear V Condition Code Bit
CLZ	000244	Clear Z Condition Code Bit
CMP	020000	Compare Source To Destination
CMPB	120000	Compare Source To Destination (Byte)
COM	005100	Complement Destination
COMB	105100	Complement Destination (Byte)
DEC	005300	Decrement Destination
DECB	105300	Decrement Destination (Byte)
DIV	071000	Divide
EMT	104000	Emulator Trap
FADD	075000	Floating Add

Instruction Mnemonic	Octal Value	Operation
FDIV	075030	Floating Divide
FMUL	075020	Floating Multiply
FSUB	075010	Floating Subtract
HALT	000000	Halt
INC	005200	Increment Destination
INCB	105200	Increment Destination (Byte)
IOT	000004	Input/Output Trap
JMP	000100	Jump
JSR	004000	Jump To Subroutine
MARK	006400	Mark
MED6X	076600	PDP-11/60 Maintenance
MFPI	006500	Move From Previous Instruction Space
MFPS	106700	Move From PS (LSI-11, LSI-11/23, LSI-11/2)
MFPT	000007	Move From Processor Type
MOV	010000	Move Source To Destination
MOVB	110000	Move Source To Destination (Byte)
MTPI	006600	Move To Previous Instruction Space
MTPS	106400	Move To PS (LSI-11, LSI-11/23, LSI-11/2)
MUL	070000	Multiply
NEG	005400	Negate Destination
NEGB	105400	Negate Destination (Byte)
NOP	000240	No Operation
RESET	000005	Reset External Bus
RETURN	000207	Return From Subroutine (RTS PC)
ROL	006100	Rotate Left
ROLB	106100	Rotate Left (Byte)
ROR	006000	Rotate Right
RORB	106000	Rotate Right (Byte)
RTI	000002	Return From Interrupt (permits trace trap)
RTS	000200	Return From Subroutine
RTT	000006	Return From Interrupt (inhibits trace trap)

Instruction Mnemonic	Octal Value	Operation
SBC	005600	Subtract Carry
SBCB	105600	Subtract Carry (Byte)
SCC	000277	Set All Condition Code Bits
SEC	000261	Set C Condition Code Bit
SEN	000270	Set N Condition Code Bit
SEV	000262	Set V Condition Code Bit
SEZ	000264	Set Z Condition Code Bit
SOB	077000	Subtract One And Branch
SUB	160000	Subtract Source From Destination
SWAB	000300	Swap Bytes
SXT	006700	Sign Extend
TRAP	104400	Trap
TST	005700	Test Destination
TSTB	105700	Test Destination (Byte)
TSTSET	007200	Test Destination And Set Low Bit
WAIT	000001	Wait For Interrupt
WRTLCK	007300	Read/Lock Destination. Write/Unlock R0 Into Destination
XOR	074000	Exclusive OR

C.2 Commercial Instruction Set (CIS) Op Codes

Every operation listed in the CIS table has two instruction mnemonics. The suffix I, attached to every second mnemonic, indicates that the addresses are inline. CIS instructions take no arguments.

Instruction Mnemonic	Octal Value	Operation
ADDN	076050	Add Numeric
ADDNI	076150	Add Numeric
ADDP	076070	Add Packed
ADDPI	076170	Add Packed
ASHN	076056	Arithmetic Shift Numeric
ASHNI	076156	Arithmetic Shift Numeric
ASHP	076076	Arithmetic Shift Packed
ASHPI	076176	Arithmetic Shift Packed
CMPC	076044	Compare Character String
CMPCI	076144	Compare Character String
CMPN	076052	Compare Numeric
CMPNI	076152	Compare Numeric
CMPP	076072	Compare Packed
CMPPI	076172	Compare Packed
CVTLN	076057	Convert Long To Numeric
CVTLNI	076157	Convert Long To Numeric
CVTLP	076077	Convert Long To Packed
CVTLPI	076177	Convert Long To Packed
CVTNP	076055	Convert Numeric To Packed
CVTNPI	076155	Convert Numeric To Packed
CVTPN	076054	Convert Packed To Numeric
CVTPNI	076154	Convert Packed To Numeric
DIVP	076075	Divide Decimal
DIVPI	076175	Divide Decimal
LOCC	076040	Locate Character
LOCCI	076140	Locate Character
L2Dn[1]	07602n	Load 2 Descriptors @(Rn)+

[1] n = 0 to 7.

Instruction Mnemonic	Octal Value	Operation
L3Dn[1]	07606n	Load 3 Descriptors @(Rn)+
MATC	076045	Match Character
MATCI	076145	Match Character
MOVC	076030	Move Character
MOVCI	076130	Move Character
MOVRC	076031	Move Reverse Justified Character
MOVRCI	076131	Move Reverse Justified Character
MOVTC	076032	Move Translated Character
MOVTCI	076132	Move Translated Character
MULP	076074	Multiply Decimal
MULPI	076174	Multiply Decimal
SCANC	076042	Scan Character
SCANCI	076142	Scan Character
SKPC	076041	Skip Character
SKPCI	076141	Skip Character
SPANC	076043	Span Character
SPANCI	076143	Span Character
SUBN	076051	Subtract Numeric
SUBNI	076151	Subtract Numeric
SUBP	076071	Subtract Packed
SUBPI	076171	Subtract Packed

[1] n = 0 to 7.

C.3 Floating-Point Processor Op Codes

Instruction Mnemonic	Octal Value	Operation
ABSD	170600	Make Absolute Double
ABSF	170600	Make Absolute Floating
ADDD	172000	Add Double
ADDF	172000	Add Floating
CFCC	170000	Copy Floating Condition Codes
CLRD	170400	Clear Double
CLRF	170400	Clear Floating
CMPD	173400	Compare Double
CMPF	173400	Compare Floating
DIVD	174400	Divide Double
DIVF	174400	Divide Floating
LDCDF	177400	Load And Convert From Double To Floating
LDCFD	177400	Load And Convert From Floating To Double
LDCID	177000	Load And Convert Integer To Double
LDCIF	177000	Load And Convert Integer To Floating
LDCLD	177000	Load And Convert Long Integer To Double
LDCLF	177000	Load And Convert Long Integer To Floating
LDD	172400	Load Double
LDEXP	176400	Load Exponent
LDF	172400	Load Floating
LDFPS	170100	Load FPPs Program Status
MFPD	106500	Move From Previous Data Space
MODD	171400	Multiply And Integerize Double
MODF	171400	Multiply And Integerize Floating
MTPD	106600	Move To Previous Data Space
MULD	171000	Multiply Double
MULF	171000	Multiply Floating
NEGD	170700	Negate Double
NEGF	170700	Negate Floating

Instruction Mnemonic	Octal Value	Operation
SETD	170011	Set Double Mode
SETF	170001	Set Floating Mode
SETI	170002	Set Integer Mode
SETL	170012	Set Long Integer Mode
SPL	000230	Set Priority Level
STA0	170005	Diagnostic Floating Point
STB0	170006	Diagnostic Floating Point
STCDF	176000	Store And Convert From Double To Floating
STCDI	175400	Store And Convert From Double To Integer
STCDL	175400	Store And Convert From Double To Long Integer
STCFD	176000	Store And Convert From Floating To Double
STCFI	175400	Store And Convert From Floating To Integer
STCFL	175400	Store And Convert From Floating To Long Integer
STD	174000	Store Double
STEXP	175000	Store Exponent
STF	174000	Store Floating
STFPS	170200	Store FPPs Program Status
STST	170300	Store FPPs Status
SUBD	173000	Subtract Double
SUBF	173000	Subtract Floating
TSTD	170500	Test Double
TSTF	170500	Test Floating

C.4 MACRO–11 Directives

The MACRO–11 directives that follow are described in greater detail in Appendix B.

Directive	Function
.ASCII	Translates character string to ASCII equivalents.
.ASCIZ	Translates character string to ASCII equivalents; inserts zero byte as last character.
.ASECT	Begins absolute program section (provided for compatibility with other PDP–11 assemblers).
.BLKB	Reserves byte block in accordance with value of specified argument.
.BLKW	Reserves word block in accordance with value of specified argument.
.BYTE	Generates successive byte data in accordance with specified arguments.
.CROSS	Enables cross-reference listing for specified symbols; enables cross-reference for all symbols.
.CSECT	Begins relocatable program section (provided for compatibility with other PDP–11 assemblers).
.DSABL	Disables specified function.
.ENABL	Enables specified function.
.END	Defines logical end of source program.
.ENDC	Defines end of conditional assembly block.
.ENDM	Defines end of macro definition, repeat block, or indefinite repeat block.
.ENDR	Defines end of current repeat block (provided for compatibility with other PDP–11 assemblers).
.ERROR	Outputs diagnostic message to listing file or command output device.
.EVEN	Word aligns the current location counter.
.FLT2	Generates two words of storage for each floating-point argument.
.FLT4	Generates four words of storage for each floating-point argument.
.GLOBL	Declares global attribute for specified symbol(s).
.IDENT	Labels object module with specified program version number.
.IF	Begins conditional assembly block.
.IFF	Begins subconditional assembly block (if conditional assembly block test is false).
.IFT	Begins subconditional assembly block (if conditional assembly block test is true).
.IFTF	Begins subconditional assembly block (whether conditional assembly block test is true or false).

Directive	Function
.IIF	Assembles immediate conditional assembly statement (if specified condition is satisfied).
.INCLUDE	Inserts specified source file within source file currently being used.
.IRP	Begins indefinite repeat block; replaces specified symbol with specified successive real arguments.
.IRPC	Begins indefinite repeat block; replaces specified symbol with value of successive characters in specified string.
.LIBRARY	Adds a specified file name to a macro library list that is searched.
.LIMIT	Reserves two words of storage for high and low addresses of task image.
.LIST	Controls listing level count and format of assembly listing.
.MACRO	Denotes start of macro definition.
.MCALL	Identifies required macro definition(s) for assembly.
.MDELETE	Deletes the definitions of the specified macro(s).
.MEXIT	Exits from current macro definition or indefinite repeat block.
.NARG	Equates specified symbol to the number of nonkeyword arguments in the macro expansion.
.NCHR	Equates specified symbol to the number of characters in the specified character string.
.NLIST	Controls listing level count and suppresses specified portions of the assembly listing.
.NOCROSS	Disables cross-reference listing for specified symbols; disables cross-reference listing for all symbols.
.NTYPE	Equates specified symbols to the addressing mode of the specified argument.
.ODD	Byte aligns the current location counter.
.PACKED	Generates packed decimal data, two digits per byte.
.PAGE	Advances form to top of next page.
.PRINT	Prints specified message on command output device.
.PSECT	Begins specified program section having specified attributes.
.RAD50	Generates data block having Radix–50 equivalents of specified character string.
.RADIX	Changes current program radix to specified radix.
.REM	Inserts a block of comments into a MACRO–11 source program without having to precede comment lines with the comment character (;).
.REPT	Begins repeat block and replicates it according to the value of the specified expression.

Directive	Function
.RESTORE	Stores the current program section context on the top of the program section context stack.
.SAVE	Retrieves the program section from the top of the program section context stack.
.SBTTL	Prints specified subtitle text as the second line of the assembly listing page header.
.TITLE	Prints specified title text as object module name in the first line of the assembly listing page header.
.WEAK	Specifies symbols that are either defined externally in another module or are defined globally in the current module.
.WORD	Generates successive word data in accordance with specified arguments.

Appendix D
Error Messages

An error code is printed as the first character in a source line containing an error. This error code identifies the error condition detected during the processing of the line. For example:

```
Q    26 000236 010102 MOV     R1,R2,A
```

The extraneous argument A in the MOV instruction above causes the line to be flagged with a Q (syntax) error.

Error Code	Meaning	
A	Assembly error. Because many different conditions produce this error message, the directives which may yield a general assembly error have been categorized below to reflect these error conditions:	
	CATEGORY 1: INVALID ARGUMENT SPECIFIED	
	.ENABL/.DSABL	Table 6–3 contains a list of the valid arguments for this directive.
	.IF/.IIF	An invalid conditional test (see Table 6–6), an invalid argument expression value, or no conditional argument is specified in the directive.
	.IRP/.IRPC	No dummy argument is specified in the directive.
	.LIST/.NLIST	Table 6–2 contains a list of the valid arguments for this directive.
	.MACRO	There is an invalid or duplicate symbol in the dummy argument list.
	.NARG/.NCHR .NTYPE	No symbol is specified in the directive.
	.PSECT	Other than a valid argument (see Table 6–4) is specified with the directive, or the attribute arguments of a previously declared program section change (see Section 6.7.1.1).
	.RADIX	A value other than 2, 8, 10, or 16 is specified as a new radix.
	.TITLE	Program name is not specified in the directive, or first non-blank character following the directive is a non-Radix–50 character.

Error Code	Meaning
	CATEGORY 2: UNMATCHED DELIMITER/INVALID ARGUMENT CONSTRUCTION
.ASCII/.ASCIZ .RAD50/.IDENT	Character string or argument string delimiters do not match, or an invalid character is used as a delimiter, or an invalid argument construction is used in the directive.
.NCHR	Character string delimiters do not match, or an invalid character is used as a delimiter in the directive.

CATEGORY 3: GENERAL ADDRESSING ERRORS

This type of error results from one of several possible conditions:

- Permissible range of a branch instruction (from -128_{10} to $+127_{10}$ words) has been exceeded.
- A statement makes invalid use of the current location counter. For example, a `.=expression` statement attempts to force the current location counter to cross program section (`.PSECT`) boundaries.
- A statement contains an invalid address expression:

  In cases where an absolute address expression is required, specifying a global symbol, a relocatable value, or a complex relocatable value (see Section 3.9) results in an invalid address expression. For example, this error occurs with `.BLKB/.BLKW/.REPT` if other than an absolute value or an expression which reduces to an absolute value is specified with the directive.

  If an undefined symbol is made a default global reference by the `.ENABL GBL` directive (see Section 6.2.1) during pass 1, any attempt to redefine the symbol during pass 2 will result in an invalid address expression.

  In cases where a relocatable address expression is required, either a relocatable or absolute value is permissible, but a global symbol or a complex relocatable value in the statement results in an invalid address expression.
- Multiple expressions are not separated by a comma. This condition causes the next symbol to be evaluated as part of the current expression.
- `.SAVE`—The stack is full when the `.SAVE` directive is issued.
- `.RESTORE`—The stack is empty when the `.RESTORE` directive is issued.

Error Code	Meaning
	CATEGORY 4: INVALID FORWARD REFERENCE
	This type of error results from either of two possible conditions:
	• A global assignment statement (`symbol==expression` or `symbol==:expression`) contains a forward reference to another symbol.
	• An expression defining the value of the current location counter contains a forward reference.
B	Bounding error. Instructions or word data are being assembled at an odd address. The location counter is incremented by 1.
	Insert a `.EVEN` statement before the statement that generates the error.
D	Doubly-defined symbol referenced. Reference was made to a symbol which is defined more than once.
	Remove one of the definitions or rename one of the symbols to something else.
E	End directive not found. When the end-of-file is reached during source input and the `.END` directive has not yet been encountered, MACRO–11 generates this error code, ends assembly pass 1, and proceeds with assembly pass 2.
	Put a `.END` directive at the end of the program.
	This error is also caused by assembler stack overflow. In this case MACRO–11 places a question mark (?) into the line at the point where the overflow occurred.
I	Invalid character detected. Invalid characters which are also nonprinting are replaced by a question mark (?) on the listing. The character is then ignored.
	Delete the characters, or replace them with characters in the valid MACRO–11 character set.
L	Input line is greater than 132_{10} characters. This error condition is caused only during macro expansion when longer real arguments, replacing the dummy arguments, cause a line to exceed 132_{10} characters.
	Rewrite the macro so this does not occur.
M	Multiple definition of a label. A label was encountered which was equivalent (in the first six characters) to a previously encountered label.
	Rename one of the labels to something else.
N	A number contains a digit that is not in the current program radix. The number is evaluated as a decimal value.
	Change the erroneous digit so the number is valid in the current program radix, or redefine the current radix with the `.RADIX` directive or one of the temporary radix operators.

Error Code	Meaning
O	Op code error. Directive out of context. Permissible nesting level depth for conditional assemblies has been exceeded. Attempt to expand a macro which was unidentified after a .MCALL search. Check syntax and context. Make sure conditional nesting does not exceed 16 levels.
P	Phase error. A label's definition of value varies from one assembly pass to another, or a multiple definition of a local symbol has occurred within a local symbol block. This situation may occur if you define a local symbol block using the .ENABL LSB directive, then attempt to define a local symbol in a program section other than that which was in effect when the block was entered. An error code P also appears if a .ERROR directive is assembled. You may also be using the conditional tests .IF P1 and .IF P2 incorrectly. Check and correct program logic.
Q	Questionable syntax. Arguments are missing, too many arguments are specified, or the instruction scan was not completed. Verify that instruction syntax is correct. Also, be sure the program does not contain a carriage return with no line feed or a colon instead of a semicolon at the beginning of a comment.
R	Register error. An invalid use of or reference to a register has been made, or an attempt has been made to redefine a standard register symbol without first issuing the .DSABL REG directive.
T	Truncation error. A number generated more than 16 bits in a word. You may get this error if you specify an octal or decimal value but the radix is set to hexadecimal or if you specify an octal value but the radix is set to decimal.
U	Undefined symbol. An undefined symbol was encountered during the evaluation of an expression; such an undefined symbol is assigned a value of zero. Other possible conditions which result in this error code include unsatisfied macro names in the list of .MCALL arguments and a direct assignment (symbol=expression or symbol=:expression) statement which contains a forward reference to a symbol whose definition also contains a forward reference; also, a local symbol may have been referenced that does not exist in the current local symbol block.
Z	Instruction error. The instruction so flagged is not compatible among all members of the PDP-11 family. See Section 5.3 for details.

Appendix E
Sample Coding Standard

Local user requirements must be met in a coding standard, but following this model as closely as possible helps you and DIGITAL by simplifying communication and software maintenance. Remember that this is a sample and may not entirely apply to your system.

E.1 Line Format

Source lines are from 1 to 80 characters in the following format:

1. Label Field—If present, begins in column 1. This field should be coded in uppercase only.
2. Operation field—Begins in column 9 (tab stop 1). This field should be coded in uppercase only.
3. Operand field—Begins in column 17 (tab stop 2). This field should be coded in uppercase only.
4. Comment field—Begins in column 33 (tab stop 4). If the operand field extends beyond column 33 (tab stop 4), leave a space and start the comment. This field should be coded in uppercase and lowercase to increase readability.

E.2 Comments

To make the program easier to understand, use comments to explain the logic behind the instructions. In general, you should use a comment per line of code. However, if a particularly difficult or obscure section of code is used, precede that section with a longer explanation.

Comments that are too long for the comment field can be continued on the following line. Begin the new line with a semicolon, space over to the column the comment began in, and continue writing. All comments should be written in uppercase and lowercase to increase readability.

If a lengthy text is needed for an explanation, begin the comment with a line containing only the characters ;+ and end it with a line containing only the characters ;-. The lines between these delimiters should each begin with a semicolon and a space. For example:

```
;+
; The invert routine accepts
; a list of random numbers and
; applies the Kolmogorov Algorithm
; to alphabetize them.
;-
```

E.3 Naming Standards

E.3.1 Registers

For the general purpose registers, use the default names:

```
R0=%0           ;REG 0
R1=%1           ;REG 1
R2=%2           ;REG 2
R3=%3           ;REG 3
R4=%4           ;REG 4
R5=%5           ;REG 5
SP=%6           ;Stack pointer (REG 6)
PC=%7           ;Program counter (REG 7)
```

For hardware registers, use the hardware definition. Examples are PS (Program Status Register) and SWR (Switch Register).

For device registers, use the hardware notation. For example, the control status register for the RK disk is RKCS.

E.3.2 Processor Priority

Test or alter the processor priority by using the symbols:

PR0, PR1, PR2, . . . PR7

which should be equated to their corresponding priority bit pattern.

E.3.3 Symbols

The following chart diagrams the syntax of the five major types of symbol names[1] :

symbol	pos-1	pos-2	pos-3	pos-4	pos-5	pos-6	length
nonglobal symbol	letter	a-num/ null	a-num/ null	a-num/ null	a-num/ null	a-num/ null	> =1
global symbol	$/.	a-num/ null	a-num/ null	a-num/ null	a-num/ null	a-num/ null	> =1
global offset	letter	$/.	a-num	a-num/ null	a-num/ null	a-num/ null	> =3
global bit pattern	letter	a-num	$/.	a-num	a-num/ null	a-num/ null	> =4
local symbol	number	$					> =2

NOTES:

letter is A–Z.

a-num is an alphanumeric character.

[1] Symbols that are branch targets are also called labels, but in this appendix the term *symbol* includes labels.

symbol	pos-1	pos-2	pos-3	pos-4	pos-5	pos-6	length
null	is the absence of a character in the position.						
$/.	are reserved for DIGITAL-supplied software; do not use $ or . in your global symbols to avoid possible conflict with globals, for example, in distributed libraries.						
number	is in the range 0 to 65535_{10}.						

E.3.3.1 Symbol Examples

Nonglobal Symbols:

```
A1B
ZXCJ1
INSRT
```

Global Address Symbols:

```
$JIM
.VECTR
$SEC
```

Global Absolute Offset Symbols:

```
A$JIM
A$XT
A.ENT
```

Global Bit Pattern Symbols:

```
A1$20
B3.6
JI.M
```

Local Symbols:

```
37$
271$
6$
```

E.3.3.2 Local Symbols

When defining target symbols for branches that exist solely for positional reference, use local symbols of the form:

```
<number>$:
```

Define local symbols so the numbers proceed sequentially down the page and from page to page.

E.3.3.3 Global Symbols

Restrict your use of global symbols, within reason, to those cases where reference to the code occurs external to the code.

Never put a .GLOBL statement in a program without showing cause.

E.3.3.4 Macro Names (RSX–11)

In a macro name, the last two characters (last character possibly being null) have special significance: the next to last character is a $, the last character specifies the mode of the macro.

For example, in the three RSX–11 macro forms inline, stack, and p-section, the inline form has no suffix, the stack has an S suffix, and the p-section a C. Thus the RSX–11 Queue I/O macro can be written as any of:

```
QIO$
QIO$S
QIO$C
```

depending on the form required. These are not reserved letters.

E.3.3.5 General Symbols

Make frequently used bit patterns such as carriage return and line feed conventional symbols as they are needed, for example:

```
CR =    015
LF =    012
```

E.4 Program Modules

There are no assembler limits on program size. However, since the virtual memory capacity of a computer is finite, keep programs as compact as possible by:

- Creating them for a single function
- Writing them in accordance with the memory allocation guidelines in Appendix F

Code areas are different from data areas. Code is read-only, but data can be read-only or read-write; read-only data should be segregated from read-write data. Both areas, code and data, should have explanatory comments.

E.4.1 The Module Preface

Put each program module in a separate file. For easy reference, the file name should be similar to the name of the module. The availability of File Control Services and File Control Primitives simplify version number maintenance.

E.4.2 The Module

Below is a list of the information that is included in the example MACRO–11 module (see Section E.4.3). The information is formatted as follows. The first six items appear on the same page and do not have explicit headings.

1. A .NLIST statement, followed by any .ENABL/.DSABL or .NLIST/.LIST options that are relevant to the assembly of this module, followed by a matching .LIST statement. The .NLIST statement has a comment appended to it specifying the module edit level.
2. A .TITLE statement that specifies the name of the module. If a module contains more than one routine, .SBTTL statements are used.
3. Several .SBTTL statements giving the name, general function, and version number of the module. The .SBTTL directive inserts this information in the table of contents for quick reference.
4. A .IDENT statement that specifies the version number of the module (see Section E.8).
5. A copyright statement, and a disclaimer, followed by a form feed. The copyright, even though a comment, should be all uppercase. This ensures that the copyright will be presented correctly, even on a terminal that has only uppercase.
6. The name of the program or software package that the module is a part of.
7. The name of the author.
8. The date of module creation.
9. A 1- or 2-line abstract of the function(s) of the module.
10. A description of all external references made by the module, one per line, in alphabetical order.
11. A chronological edit trail of modifications to the module that includes the following:
    - Edit number
    - Editor's identification
    - Edit date
    - Description of the modification made

NOTE

Items 7 through 11 should appear on the same page.

12. Any references to external files by the .LIBRARY and .INCLUDE directives.
13. .MCALLs to any externally defined macros.
14. A list of the definitions of all equated symbols used in the module. These definitions should appear one per line and in alphabetical order.
15. All local macro definitions, preferably in alphabetical order.
16. All local data. The comments in this section should include:
    - Description of each element (type, size, and so forth)

- Organization (functional, alphabetical, adjacent, and so forth)
- Adjacency requirements (if any)

17. A form feed, followed by a .SBTTL statement describing the routine that follows.
18. A routine header, giving the following information:
    - Routine name
    - Description
    - Inputs
    - Calling sequence
    - Outputs
    - Side effects, register usage, and so forth

NOTE

Repeat items 17 and 18 for every routine within the module.

E.4.3 Module Example

```
        .NLIST
        .ENABL  GBL
        .LIST   MEB
        .TITLE  MACINI  - Once-only code for the MACRO-11 assembler
        .SBTTL
        .IDENT  /Y05.01/

;*****************************************************************************
;*                                                                           *
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;*                                                                           *
;*****************************************************************************
;++
```

```
;  Facility:    MACRO-11  The PDP-11 macro assembler for RT/RSX/VMS and RSTS/E
;
;    Author:    Joe Worrall
;
;   Created:    21-Aug-82
;
;  Abstract:    MACINI contains code only executed once per task invocation.
;
;       Externals       Description
;       ---------       -----------
;
;         $LIBID        File-ID of the system library account (LB:[1,1])
;         $POSID        File-ID of the P/OS library account (LB:[1,5])
;         $STABF        Workfile statistics buffer
;
;       Edit    Who     Date    Description of modification
;       ----    ---     ----    ---------------------------
;        001    Jrw     25-Aug-82       Handle P/OS .PARSE module.
;        002    Jrw     05-Sep-82       Allow recursive FINIT$'s.
;        003    Jrw     10-Nov-82       Setup statistics buffer.
;--
;       External file references

        .LIBRARY        /MACLIB/        ;Add MACLIB.MLB to macro library list
        .INCLUDE        /MACPRE/        ;Include MACPRE.MAC in assembly
;
;
;       External library ".MCALL's" for this module
;
        .MCALL  FINIT$
;
; Equated symbols
;
        ... Equated symbols ...
;
; Local macros
;
        ... Local macros ...
;
; Local data
;
        ... Local data ...
.SBTTL  $INIT - Handle once only code for MACRO-11 assembler
```

```
;+
; $INIT
; This routine is a collection of all the code, only executed
; once in any one run of the MACRO-11 task.  It's collected
; here because:
;
;       o       It's logical to keep it in one place
;       o       It keeps the code out of the root, keeping
;               the assembler SMALL.
;
; INPUTS:       n/a
;
; CALL: CALL    $INIT
;
; OUTPUTS:
;
;       Record management, statistics, and FCS buffers
;       are setup.  If the system contains EIS support,
;       the DIV and MUL routine vectors are setup to
;       point to the hardware instructions.
;
; EFFECTS:              R0 - R5  Destroyed!
;-
        ... Begin module code ...
```

E.4.4 Modularity

No other characteristic has more impact on the ultimate engineering success of a system than does modularity. Adherence to a set of call and return conventions helps achieve this modularity.

E.4.4.1 Calling Conventions (Inter-Module/Intra-Module)

Transfer of Control

Macros exist for call and return. The actual transfer is via a JSR PC instruction. For register save routines, a JSR Rn,SAVE is permitted.

The CALL macro is:

```
CALL    subr-name
```

The RETURN macro is:

```
RETURN
```

Register Conventions

On entry, a subroutine minimally saves all registers it intends to alter except result registers. On exit, it restores these registers. (The preservation of the register state is assumed across calls.)

Argument Passing

Any registers can be used, but their use should follow a coherent pattern. For example, if passing three arguments, use R0, R1, and R2 rather than R0, R2, and R5. Saving and restoring occurs in one place.

E.4.4.2 Exiting

All subroutine exits occur through a single RETURN macro.

E.4.4.3 Success/Failure Indication

The C-bit is used to return the success/failure indicator, where success equals 0, and failure equals 1. The argument registers can be used to return values or additional success/failure data.

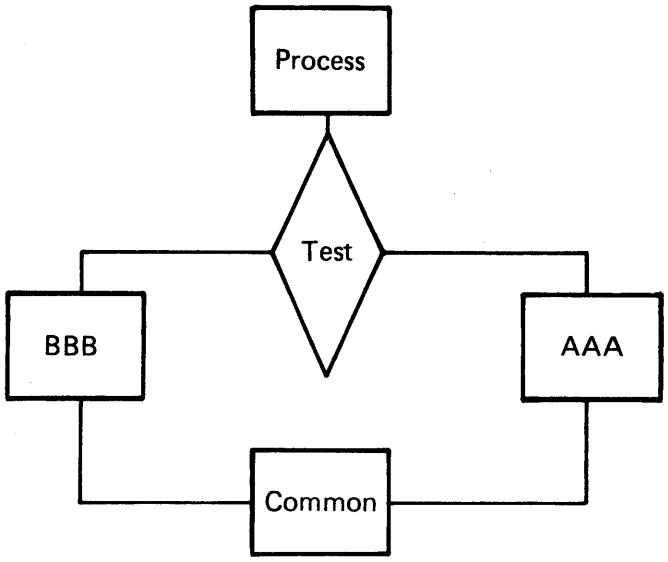
E.4.4.4 Module Checking Routines

Modules are responsible for verifying the validity of arguments passed to them. The design of a module's calling sequence should aim at minimizing the validity checks by minimizing invalid combinations. Programmers may add test code to perform additional testing during checkout. All code should aim at discovering an error as close (in terms of instruction executions) to its occurrence as possible.

E.5 Code Format

E.5.1 Program Flow

Programs are organized on the listing so that they flow down the page, even at the cost of an extra branch or jump. All unconditional branch and jump instructions should be followed by a blank line. This causes these instructions to stand out in the source code, allowing the code to be traced more easily. For example:



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appears on the listing as:

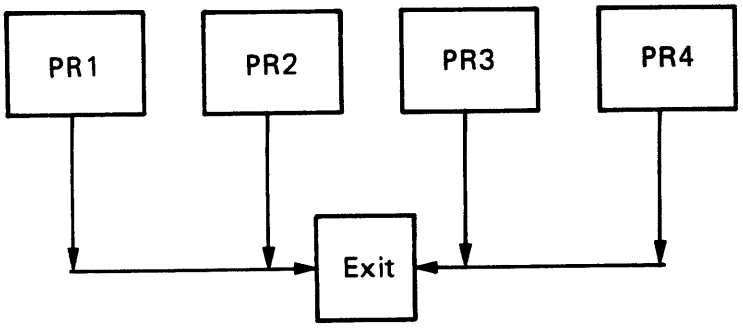
```
        TST
        BNE     BBB
AAA:    ....    ....
        ....    ....
        ....    ....
        ....    ....
        BR      CMN

BBB:    ....    ....
        ....    ....
        ....    ....
CMN:    ....    ....
        ....    ....
        ....    ....
```

rather than:

```
        TST
        BNE     BBB
AAA:    ....    ....
        ....    ....
        ....    ....
        ....    ....
CMN:    ....    ....
        ....    ....
        ....    ....
        ....    ....
BBB:    ....    ....
        ....    ....
        ....    ....
        ....    ....
        BR      CMN
```

E.5.2 Common Exits

A common exit appears as the last code sequence on the listing. Thus, the flow chart:



MLO-1257-87

appears on the listing as:

```
PR1:    ....    ....
        ....    ....
        ....    ....
        BR      EXIT

PR2:    ....    ....
        ....    ....
        ....    ....
        BR      EXIT

PR3:    ....    ....
        ....    ....
        ....    ....
        BR      EXIT

PR4:    ....    ....
        ....    ....
        ....    ....

EXIT:
```

and not as:

```
PR1:    ....    ....
        ....    ....
        ....    ....

EXIT:   ....    ....
        ....    ....
        ....    ....

PR2:    ....    ....
        ....    ....
        ....    ....
        BR      EXIT

PR3:    ....    ....
        ....    ....
        ....    ....
        BR      EXIT

PR4:    ....    ....
        ....    ....
        ....    ....
        BR      EXIT
```

E.5.3 Code with Interrupts Inhibited

Code executed with interrupts inhibited is flagged by a 3-semicolon (;;;) comment delimiter, for example:

```
..ERTZ:                         ;Enable by returning
                                ;by system subroutines,

        BIS     #PR7,PS         ;;; inhibit interrupts
        BIT     #PR7,2(SP)      ;;; c
        BEQ     10$             ;;;  o
        RTT                     ;;;   m
                                ;;;    m
10$:    ....    ....            ;;;     e
        ....    ....            ;;;      n
        ....    ....            ;;;       t
        ....    ....            ;;;        s
```

E.5.4 Code in System State

RSX-11M executive subroutines and other privileged code executed in system state is flagged by a 2-semicolon (;;) comment delimiter, for example:

```
                                ; Switch to system state, ...
                                ;
                                ; and exit.

        CALL    $SWSTK,EXIT     ; Inhibit context switching
        ...                     ;; Return in system state
        ...                     ;;
        ...                     ;;

        RETURN                  ;; Go back to user state (EXIT)
EXIT:   ...                     ; User state code
```

E.6 Instruction Usage

E.6.1 Forbidden Instructions

You should avoid certain instruction combinations because they make a program hard to read, debug, and maintain. Avoid the following programming practices:

- The use of instructions or index words as literals of the previous instruction. For example:

```
MOV   @PC,REGISTER
BIC   SRC,DST
```

  uses the bit clear instruction as a literal. This may seem to be a very neat way to save a word, but the practice can easily confuse the next person who has to work on the program. To compound the problem, the instruction will not execute properly if I/D space is enabled. In that case, @PC is a D-space reference.

- The use of the MOV instruction instead of a JMP instruction to transfer program control to another location. For example:

```
MOV    #ALPHA,PC
```

  transfers control to location ALPHA. Besides taking longer to execute, the use of MOV instead of JMP makes it nearly impossible to pick up someone else's program and tell where transfers of control take place. As a more general issue, other operations such as ADD and SUB from PC should be discouraged.

- The seemingly clever use of all single-word instructions where one double-word instruction could be used, which would execute faster and not consume any additional memory. Consider the following instruction sequence:

```
CMP    -(R1),-(R1)
CMP    -(R1),-(R1)
```

  The intent of this instruction sequence is to subtract 8 from register R1 (not to set condition codes). This can be accomplished in approximately 1/3 the time via a SUB instruction at no additional cost in memory space. The practice can also cause a memory management fault on a mapped system if the value in R1 happens to look like an unmapped address.

- Self-relative address arithmetic (.+n) is absolutely forbidden in branch instructions; its use in other contexts must be avoided if at all possible and practical.

E.6.2 Conditional Branches

When using the PDP–11 conditional branch instructions, you must make the correct choice between the signed and the unsigned branches.

Signed	Unsigned
BGE	BHIS (BCC)
BLT	BLO
BGT	BHI
BLE	BLOS (BCS)

A common pitfall is to use a signed branch (for example, BGT) when comparing two memory addresses. This works until the two addresses have opposite signs; that is, one of them goes across the 16K (100000_8) bound. This type of coding error usually results from relinking the program at different addresses and/or changing the size of the program.

E.7 Program Source Files

Source creation and maintenance are done in base levels. A base level is the point at which the program source files have been frozen. From the freeze point to the next base level, corrections are not made directly to the base level itself. Rather, a file of corrections is accumulated for each file in the base level. Whenever an updated source file is desired, the correction file is applied to the base file.

The accumulation of corrections proceeds until a logical breaking point has occurred (a milestone or significant implementation point has been reached). At this time, all accumulated corrections are applied to the previous base level to create a new base level, and correction files are started for the new base level.

E.8 PDP–11 Version Number Standard

The PDP–11 Version Number Standard applies to all modules, parameter files, complete programs, and libraries which are written as part of the PDP–11 Software Development effort. It is used to provide unique identification of all released, prereleased, and in-house software.

The version number is limited in that only six characters of identification are used. Future implementations of the Macro Assembler, Linker, and Librarian should provide for at least nine characters, and possibly twelve. It is expected that this standard will be improved as the need arises.

Version Identifier Format:

```
<version> <edit> <patch>
```

where:

<version>	consists of two decimal digits which represent the release number of a program. The version number starts at 00 and is incremented to reflect the number of major changes in the program.
<edit>	consists of two decimal digits which represent the number of alterations made to the source program. The edit number begins at 01 (is blank if there are no edits) and is incremented with each alteration.
<patch>	is a letter between B and Z which represents the number of alterations made to the binary form of the program. The patch number begins at B (is blank if there are no patches) and changes alphabetically with each patch.

These fields are interrelated. When `<version>` is changed, then `<patch>` and `<edit>` must be reset to blank. It is intended that when `<edit>` is incremented, then `<patch>` will be reset to blank, because the various bugs have been fixed.

E.8.1 Displaying the Version Identifier

The visible output of the version identifier should appear as:

```
Program
   Name <key-letter> <version> . <edit> <patch>
```

where the following Key Letters have been identified:

X	in-house experimental version
Y	field test, prerelease, or in-house release version
V	released or frozen version

'X' corresponds roughly to individual support, 'Y' to group support, and 'V' to company support.

The dot (.) which separates <version> from <edit> is not used if both <edit> and <patch> are null. When a version identifier is displayed as part of program identification, then the format is:

```
programname <space><key-letter><version> . <edit><patch>
```

Examples:

```
PIP V05.00
LINK V08.00
MACRO V05.00
```

E.8.2 Use of the Version Number in the Program

All sources must contain the version number in a .IDENT directive. In programs (or libraries) which consist of more than one module, each module must have a version number. The version number of the program or library is not necessarily related to the version numbers of the constituent modules; it is perfectly reasonable, for example, that the first version of a new FORTRAN library, V00, contain an existing SIN routine, for example V05.01.

Parameter files are also required to contain the version number in a .IDENT directive. Because the assembler records the last .IDENT seen, parameter files must precede the program.

Entities which consist of a collection of modules or programs (for example, the FORTRAN Library) have an identification module in the first position. An identification module exists solely to provide identification. For example:

```
;OTS identification
.TITLE FTNLIB
.IDENT /V02.00/
.END
```

is an identification module.

Appendix F
Allocating Virtual Memory

This appendix is intended for the MACRO-11 user who wants to avoid the problem of thrashing by optimizing the allocation of virtual memory. If you have a small system, you should pay particular attention to these conventions.

This appendix discusses the following topics:

- General hints and space-saving guidelines
- Macro definitions and expansions
- Operational techniques

This discussion assumes that you have used modular programming, as advised in Appendix E. Modular programming results in bodies of code that are small, distinct, and highly functional. Using such code, which presents many advantages, one can usually avoid the problem of insufficient dynamic memory during assembly.

F.1 General Hints and Space Saving Guidelines

Working memory is shared by a number of MACRO-11's tables, each of which is allocated space on demand (64K words of dynamically pageable storage are available to the assembler). The tables and their corresponding entry sizes are as follows:

- User-defined symbols—five words
- Local symbols—three words
- Program sections—six words
- Macro names—five words
- Macro text—nine words
- Source files—six words

In addition, several scratch pad tables are used during the assembly process, as follows:

- Expression analysis—five words
- Object code generation—five words
- Macro argument processing—three words
- .MCALL argument processing—five words

This information can serve as a guide for estimating dynamic storage requirements and for determining ways to reduce such requirements.

For example, the use of local symbols whenever possible is highly encouraged, since their internal representation requires 25 percent less dynamic storage than that required for regular user-defined symbols. The usage of local symbols can often be maximized by extending the scope of local symbol blocks through the .ENABL LSB/.DSABL LSB MACRO–11 directives (see Sections 3.5 and 6.2.1).

Since MACRO–11 does not support a purge function, once a symbol is defined, it permanently occupies its dynamic memory allocation. Numerous instances occur during conditional assemblies and repeat loops when a temporarily assigned symbol is used as a count or offset indicator. If possible, the symbols so used should be reused.

In keeping with the same principle, special treatment should be given to the definition of commonly used symbols. Instead of simply appending a prefix file which defines all possibly used symbols for each assembly, group symbols into logical classes. Each class can then become a shortened prefix file or a macro in a library (see Section F.2 below). In either case, selective definition of symbolic assignments is achieved, resulting in fewer defined (but unreferenced) symbols.

An example of this idea is seen in the definition of IAS and RSX–11M standard symbols. The RSX system macro library, for example, supplies several macros used to define distinct classes of symbols. These groupings and associated macro names are as follows:

DRERR$	Directive return status codes
FILIO$	File-related I/O function codes
IOERR$	I/O return status codes
SPCIO$	Special I/O function codes

F.2 Macro Definitions and Expansions

Dynamic storage is used most heavily for the storage of macro text. Upon macro definition or the issuance of a .MCALL directive, the entire macro body is stored, including all comments appearing in the macro definition. For this reason, comments should not be included as part of the macro text. Under RSX–11, a Librarian function switch (/SZ) is available to compress macro source text by removing all trailing blanks and tabs, blank lines, and comments. The RSX–11 system macro library (RSXMAC.SML) has already been compressed. User-supplied macro libraries (.MLB) and macro definition prefix files should also be compressed. For additional information regarding these two utility tasks, consult the applicable RSX–11M or RSX–11M–PLUS Utilities Manual (see the Associated Documents section in the Preface).

It often seems practical to include a file of commonly used macro definitions in each assembly. This practice, however, may produce the undesirable allocation of valuable dynamic storage for unnecessary macros. This waste of memory can be avoided by making the file of macro definitions a user-supplied macro library file (see Table 8–1). In that case, the names of desired macros must be listed as arguments in the .MCALL directive (see Section 7.8), or the automatic MACRO call, .ENABL MCL, must be enabled (see Section 6.2.1).

You can delete macro definitions after they have been called by using the .MDELETE request (see Section 7.9). This practice not only frees storage space, it also eliminates the overhead and the dynamic memory wasted by calling a useless macro. Alternatively, certain types of macros can be redefined to null after they have been called. The practice of deleting macros or redefining macros to null applies mainly to those that define symbolic assignments, as shown in the example below. The redefinition process can be accomplished as follows:

```
        .MACRO DEFIN
SYM1 = VAL1             ;Define symbolic assignments.
SYM2 = VAL2
          .
          .
          .
OFF1 = SYMBOL           ;Define symbolic offsets.
OFF2 = OFF1+SIZ1
OFF3 = OFF2+SIZ2
          .
          .
          .
OFFN = OFFM+SIZM
          .
          .
          .
        .MACRO DEFIN    ;Macro null redefinition.
        .ENDM

        .ENDM  DEFIN
```

Macros that are to be deleted or redefined should be defined (or read via the .MCALL directive) and called before all other macro definition and/or .MCALL processing. This procedure ensures more efficient use of dynamic memory.

F.3 Operational Techniques

When, despite your adherence to the guidelines discussed above, performance still falls below expectations, several additional measures can be taken to increase dynamic memory.

The first measure involves shifting the burden of symbol definition from MACRO–11 to the Linker or Task Builder. In most cases, the definition of system I/O and File Control Services (FCS) symbols (and user-defined symbols of the same nature) is not necessary during the assembly process, since such symbols are defaulted to global references (Appendix D, error code A). The Linker or Task Builder attempts to resolve all global references from user-specified default libraries and/or the system object library (SYSLIB). Furthermore, by applying the selective search option for object modules consisting only of global symbol definitions, the actual additional burden to the Linker is minimal.

The second way is to produce only one output file (either object or listing), as opposed to two. The additional memory required to support the second output file is allocated from available dynamic memory at the start of each assembly.

Appendix G
Writing Position-Independent Code

G.1 Introduction to Position-Independent Code

The output of a MACRO–11 assembly is a relocatable object module. The Task Builder or Linker binds one or more modules together to create an executable task image. Once created, if the program is to run, it must be loaded at the virtual address specified at link time. This is because the Task Builder or Linker has to modify some instructions to reflect the memory locations in which the program is to run. Such a body of code is considered position-dependent (dependent on the virtual addresses to which it is bound).

All PDP–11 processors offer addressing modes that make it possible to write code that does not depend on the virtual addresses to which it is bound. Such code is termed position-independent and to run can be loaded at any virtual address. Position-independent code can improve system efficiency, both in use of virtual address space and in conservation of physical memory.

In multiprogramming systems like IAS, RSX–11M, and RSX–11M–PLUS, it is important that many tasks be able to share a single physical copy of common code, for example, a library routine. To make the optimum use of a task's virtual address space, shared code should be position-independent. Position-dependent code can also be shared, but it must appear in the same virtual locations in every task using it. This restricts the placement of such code by the Task Builder or Linker and can result in the loss of virtual addressing space.

The construction of position-independent code is closely linked to the proper usage of PDP–11 addressing modes. The remainder of this Appendix assumes that you are familiar with the addressing modes described in Chapter 5.

All addressing modes involving only register references are position-independent. These modes are as follows:

`R`	register mode
`(R)`	register deferred mode
`(R)+`	autoincrement mode
`@(R)+`	autoincrement deferred mode
`-(R)`	autodecrement mode
`@-(R)`	autodecrement deferred mode

When you use these addressing modes, your code is guaranteed position-independent, provided the contents of the registers have been supplied such that they are not dependent upon a particular virtual memory location.

The relative addressing modes are position-independent when a relocatable address is referenced from a relocatable instruction. These modes are as follows:

A	relative mode
@A	relative deferred mode

Relative modes are not position-independent when an absolute address (that is a non-relocatable address) is referenced from a relocatable instruction. In this case, absolute addressing (@#A) can be used to make the reference position-independent.

Index modes can be either position-independent or position-dependent, according to their use in the program. These modes are as follows:

X(R)	index mode
@X(R)	index deferred mode

If the base, X, is an absolute value (for example, a control block offset), the reference is position-independent. For example:

```
MOV     2(SP),R0        ;Position-independent
N=4
MOV     N(SP),R0        ;Position-independent
```

However, if X is a relocatable address, the reference is position-dependent. For example:

```
CLR     ADDR(R1)        ;Position-dependent
```

Immediate mode can be either position-independent or not, according to its usage. Immediate mode references are formatted as follows:

#N	immediate mode

When an absolute expression defines the value of N, the code is position-independent. When a relocatable expression defines N, the code is position-dependent. That is, immediate mode references are position-independent only when N is an absolute value.

Absolute mode addressing is position-independent only in those cases where an absolute virtual location is being referenced. Absolute mode addressing references are formatted as follows:

@#A	absolute mode

An example of a position-independent absolute reference is a reference to the directive status word ($DSW) from a relocatable instruction. For example:

```
MOV     @#$DSW,R0       ;Retrieve directive status
```

G.2 Examples

The RSX-11M library routine PWRUP is a FORTRAN-callable subroutine that establishes or removes a user power failure Asynchronous System Trap (AST) entry point address. Embedded within the routine is the AST entry point that saves all registers, effects a call to the user-specified entry point, restores all registers on return, and executes an

AST exit directive. The following examples are excerpts from this routine. The first example, Figure G–1, has been modified to illustrate position-dependent references. The second example, Figure G–2, is the position-independent version.

Figure G–1: Example of Position-Dependent Code

```
;+
; Position-dependent code example
;-

PWRUP:: CLR     -(SP)           ;Assume success

; Perform further initialization...

        MOV     $OTSV,R4        ;Point R4 at object time system save area
                                ;the above reference to $OTSV is position-
                                ; dependent
        MOV     (SP)+,R2        ;Retrieve AST entry point address
        BNE     10$             ;Branch if one was specified
        CLR     -(SP)           ;If none, specify no power fail routine
10$:    MOV     R2,F.PF(R4)     ;Set the AST entry point
        MOV     #BA,-(SP)       ;Push the AST service address
                                ; the above reference to BA is position-
                                ; dependent
20$:

; Continue processing...

;+
; AST service routine
;-

BA:     MOV     R0,-(SP)        ;Preserve R0

; Rest of routine follows...
```

Figure G–2: Example of Position-Independent Code

```
;+
; Position independent code example
;-
PWRUP:: CLR     -(SP)           ;Assume success
; Perform necessary initialization...
        MOV     @#$OTSV,R4      ;Point R4 at object time system save area
                                ;the above reference to $OTSV is position-
                                ; independent
        MOV     (SP)+,R2        ;Retrieve AST entry point address
        BNE     10$             ;Branch if one was specified
        CLR     -(SP)           ;If none, specify no power fail routine
10$:    MOV     R2,F.PF(R4)     ;Set the AST entry point
        MOV     PC,-(SP)        ;Push our PC to relocate our AST service addr
        ADD     #BA-.,(SP)      ;Relocate our AST service address now
                                ; the above reference to BA is position-
                                ; dependent
20$:
; Continue processing...
;+
; AST service routine
;-
BA:     MOV     R0,-(SP)        ;Preserve R0
; Rest of routine follows...
```

The position-dependent version of the subroutine contains a relative reference to an absolute symbol ($OTSV) and a literal reference to a relocatable symbol (BA). Both references are bound by the Task Builder to fixed memory locations. Therefore, the routine will not execute properly as part of a resident library if its location in virtual memory is not the same as the location specified at link time.

In the position-independent version, the reference to $OTSV has been changed to an absolute reference. In addition, the necessary code has been added to compute the virtual location of BA, based upon the value of the program counter. In this case, the value is obtained by adding the value of the program counter to the fixed displacement between the current location and the specified symbol. Thus, execution of the modified routine is not affected by its location in the image's virtual address space.

The MACRO–11 Assembler provides a way of checking whether the code is position-independent. In an assembly listing, MACRO–11 inserts a single quote (') character following the contents of any word which requires the Task Builder or Linker to perform a relocation operation and, therefore, may not be position-independent code. Cases that are flagged by a single quote in the assembly listing are as follows:

- Absolute mode references, when the reference is relocatable. References are not flagged when they are absolute. For example:

```
MOV     @#ADDR,R1       ;PIC only if ADDR is absolute.
```

- Index and index deferred mode references, when the offset is relocatable. For example:

```
MOV     ADDR(R1),R5     ;Non-PIC if ADDR is relocatable.
MOV     @ADDR(R1),R5    ;Non-PIC if ADDR is relocatable.
```

- Relative and relative deferred mode references, when the specified address is relocatable with respect to another program section. For example:

```
MOV     ADDR1,R1        ;Non-PIC when ADDR1 is absolute.
MOV     @ADDR1,R1
```

- Immediate mode references to relocatable addresses.

```
MOV     #ADDR,R1        ;Non-PIC when ADDR is relocatable.
```

In one case, MACRO–11 does not flag a potential position-dependent reference. This occurs where a relative reference is made to an absolute virtual location from a relocatable instruction (see the `MOV $OTSV,R4` instruction in Figure G–1).

References requiring more than simple relocation at link time are indicated in the assembly listing. Simple global references are flagged with the letter G. Statements that contain multiple global references or require complex relocation are flagged with the letter C (see Section 3.9 and Chapter 4). It is difficult to state with certainty whether or not a C-flagged statement is position-independent. However, in general, position dependence can be decided by applying the guidelines discussed earlier in this Appendix to the resulting address value produced at link time.

Appendix H
Sample Assembly and Cross-Reference Listing

```
R5OUNP  MACRO V05.04  Wednesday 25-Mar-87 16:49
Table of contents

    2-   1      RAD50 unpack routine

R5OUNP  MACRO V05.04  Wednesday 25-Mar-87 16:49  Page 1


      1                         .TITLE  R5OUNP
      2                         .IDENT  /03/
      3
      4         ;                       Copyright (c) 1979, 1987 by
      5         ;                 Digital Equipment Corporation, Maynard, Mass.
      6         ;
      7         ; This software is furnished under a license and may be used and copied
      8         ; only  in  accord  with  the  terms  of  such  license  and  with  the
      9         ; inclusion of the above copyright notice.  This software or  any other
     10         ; copies thereof may not be provided or otherwise made available to any
     11         ; other person.  No title to and ownership of  the  software  is hereby
     12         ; transferred.
     13         ; The information in this software is subject to change  without notice
     14         ; and  should  not  be  construed  as a commitment by Digital Equipment
     15         ; Corporation.
     16         ;
     17         ; Digital assumes no  responsibility  for the use or reliability of its
     18         ; software on equipment which is not supplied by Digital.
     19         ;
     20         ; Update history:
     21         ;
     22         ;       D.H. Cutler     10-Feb-73
     23         ;       SGW             25-Mar-87

R5OUNP  MACRO V05.04  Wednesday 25-Mar-87 16:49  Page 2
RAD50 unpack routine

      1                         .SBTTL  RAD50 unpack routine
      2
      3                 ;+
      4                 ; R5OUNP
      5                 ; Unpack a 6 char RAD50 symbol to ASCII
      6                 ;
      7                 ; Enter with R2 -> Output ASCII string
      8                 ; SYMBOL, SYMBOL+2 = RAD50 symbol to unpack
      9                 ;
     10                 ; Return with R2 -> Past output string
     11                 ; R0, R1, R3 destroyed
     12                 ;-
     13
     14                         .GLOBL  SYMBOL
     15
     16 000000                  .PSECT  PUREI,I
     17
     18 000000  010446  R5OUNP::MOV     R4,-(SP)        ;Save R4
     19 000002  012704          MOV     #SYMBOL,R4      ;Point at RAD50 symbol buffer
                000000G
     20 000006  012401  1$:     MOV     (R4)+,R1        ;Get next RAD50 word
     21 000010  012703          MOV     #50*50,R3       ;Set divisor for high character
                003100
     22 000014  004767          CALL    10$             ;Unpack and store the character
                000030
     23 000020  012703          MOV     #50,R3          ;Now set divisor for middle character
                000050
     24 000024  004767          CALL    10$             ;Unpack and store the character
                000020
     25 000030  010100          MOV     R1,R0           ;Copy remaining character
     26 000032  004767          CALL    11$             ;Translate and store it
                000016
```

```
    27 000036  020427          CMP     R4,$SYMBOL+4    ;Test if last word done
               000004G
    28 000042  001361          BNE     1$              ;Branch if no
    29 000044  012604          MOV     (SP)+,R4        ;Restore R4
    30 000046  000207  3$:     RETURN                  ;Return to caller
    31
    32                ; Translate RAD50 character code to ASCII
    33                ; 0 =    space
    34                ; 1-32 = A-Z
    35                ; 33 =   $
    36                ; 34 =   .
    37                ; 35 =   unused code
    38                ; 36-47 = 0-9
    39
    40 000050  005000  10$:    CLR     R0              ;Divide RAD50 word, get
    41 000052  071003          DIV     R3,R0           ;remainder (RAD50 char) in R0
    42 000054  116022  11$:    MOVB    TABLE(R0),(R2)+ ;Get ASCII equivalent of RAD50
               000062'
    43 000060  000207          RETURN
    44
    45                         .NLIST  BEX
    46 000062     040  TABLE:  .BYTE   ' , 'A, 'B, 'C, 'D, 'E, 'F, 'G
    47 000072     110          .BYTE   'H, 'I, 'J, 'K, 'L, 'M, 'N, 'O
    48 000102     120          .BYTE   'P, 'Q, 'R, 'S, 'T, 'U, 'V, 'W
    49 000112     130          .BYTE   'X, 'Y, 'Z, '$, '., '?, '0, '1

R50UNP  MACRO V05.04  Wednesday 25-Mar-87 16:49  Page 2-1
RAD50 unpack routine

    50 000122     062          .BYTE   '2, '3, '4, '5, '6, '7, '8, '9
    51
    52         000001          .END

R50UNP  MACRO V05.04  Wednesday 25-Mar-87 16:49  Page 2-2
Symbol table

R50UNP  000000RG    002 SYMBOL= ****** G        TABLE   000062R     002

. ABS.  000000    000   (RW,I,GBL,ABS,OVR)
        000000    001   (RW,I,LCL,REL,CON)
PUREI   000132    002   (RW,I,LCL,REL,CON)
Errors detected:  0

*** Assembler statistics

Work  file  reads: 0
Work  file writes: 0
Size of work file: 64 Words  ( 1 Pages)
Size of core pool: 17920 Words  ( 70 Pages)
Operating  system: RT-11

Elapsed time: 00:00:02.45
R50UNP,R50UNP/L:TTM/C:C:R:S=R50UNP

R50UNP  MACRO V05.04  Wednesday 25-Mar-87 16:49 Page S-1
Cross reference table (CREF V05.04)

R50UNP   2-18#
SYMBOL   2-14      2-19      2-27
TABLE    2-42      2-46#

R50UNP  MACRO V05.04  Wednesday 25-Mar-87 16:49 Page R-1
Cross reference table (CREF V05.04)

R0       2-25*     2-40*     2-41*     2-42
R1       2-20*     2-25
R2       2-42*
R3       2-21*     2-23*     2-41
R4       2-18      2-19*     2-20      2-27      2-29*
SP       2-18*     2-29

R50UNP  MACRO V05.04  Wednesday 25-Mar-87 16:49 Page C-1
Cross reference table (CREF V05.04)

         0-0
. ABS.   0-0
PUREI    2-16
```

Appendix I
Obsolete MACRO–11 Directives, Syntax, and Command Line Options

I.1 Obsolete Directives and Syntax

Although supported in older versions of MACRO–11, the following directives and syntax are not supported in the current release. Table I–1 shows both the old directives and syntax and the new syntax to use. All MACRO–11 code that contains the old directives and syntax should be updated to use the new syntax.

Table I–1: Old and New Directives and Syntax

Syntax no longer supported	New syntax to use
.EOT	None
.IFZ xxx or .IFEQ xxx	.IF EQ,xxx
.IF Z,xxx	.IF EQ,xxx
.IFNZ xxx or .IFNE xxx	.IF NE,xxx
.IF NZ,xxx	.IF NE,xxx
.IFL xxx or .IFLT xxx	.IF LT,xxx
.IF L,xxx	.IF LT,xxx
.IFG xxx or .IFGT xxx	.IF GT,xxx
.IF G,xxx	.IF GT,xxx
.IFLE xxx	.IF LE,xxx
.IFDF xxx	.IF DF,xxx
.IFNDF xxx	.IF NDF,xxx

I.2 Obsolete Command Line Option

DIGITAL no longer supports the MACRO–11 command line option /P[ASS]:n. This option was originally created to speed up assemblies in some cases by scanning a given file with only one pass of the assembler. However, DIGITAL has found that the /P[ASS]:n switch has many side effects; it has caused more problems than can be documented reasonably.

Although the /P[ASS]:n option is still accepted by MACRO–11, DIGITAL no longer accepts SPRs relating to the option and has removed all documentation for it. You should update any assembly command files containing the /P[ASS]:n option by removing the references to the option.

Appendix J
Release Notes

This appendix explains the changes that have been made to MACRO–11 for each version release since Version 5.0. The new features mentioned are documented in Chapters 1 through 9 of this manual. Previous versions of this appendix assigned some of the changes to the wrong version numbers of the software. Accordingly, this appendix has been rearranged so that each change is listed under the version number when the change was actually made. If you have Version 5.5 of MACRO–11, you need not worry about when the changes happened, because all the changes will be in place. If you are still using an older version of MACRO–11, however, this appendix can help you determine whether or not a problem in that version has been fixed in a later version of the software.

NOTE

The version numbers of MACRO–11 and its host operating system are completely independent of each other. MACRO–11 V5.3 was distributed with RT–11 V5.2, for example. Either version number may change without affecting the other. Be careful not to confuse the two.

J.1 Changes—All Versions of MACRO–11

J.1.1 V5.5 Update Changes

- Hexadecimal support was added:

  `^X`, for temporary hexadecimal radix
  `.RADIX 16`, for permanent radix change
  `.LIST HEX`, to produce a hexadecimal listing

- Two new conditionals were added: `.IF P1` and `.IF P2`.

- MACRO–11 now accepts more than 254_{10} program sections, although only the first 254 appear in the symbol table. Previously, more than 254 program sections caused an assembly error.

- If a `.PAGE` directive is issued with the listing already at top-of-page, the `.PAGE` directive is ignored. In previous versions of MACRO–11, the page number was incremented, even though a new physical page was not printed.

- A `.PAGE` directive in an unexpanded macro is now ignored.

- The XOR instruction is now flagged with the Z error for certain addressing modes (execution may be different on different processors).

- Space between a macro name and the opening left angle bracket of an argument list is now optional. In previous versions, a space or tab was required. For example, if BUILD is a macro name, BUILD<A,B,C> is now valid; previously, it had to be written as BUILD <A,B,C>.
- In previous versions of MACRO–11, it was possible to change the value of a symbol that was assigned a value by using the =: operator, even though values assigned with =: are supposed to be permanent. MACRO–11 now retains a symbol's permanent attribute in all cases.
- .SBTTL lines in listings now include up to 80 characters.
- The .IRPC directive now accepts arguments of up to 124 characters; the previous limit was 96 characters.
- The error *?MACRO-F-Internal error* (on RT–11/RSTS) or *MAC—Internal error* (on IAS/RSX) was added. If you get this error, please submit an SPR to DIGITAL along with a method of duplicating the problem.

J.1.2 V5.4 Update Changes

In previous versions of MACRO–11, the assembler parsed the arguments of .IF conditional statements even if the .IF statements were within unsatisfied conditional code blocks. This could cause assembly errors when there should be none. MACRO–11 no longer parses the arguments of conditional statements within blocks of code that do not get assembled.

J.1.3 V5.3 Update Changes

- MACRO–11 did not mark symbolic expressions as complex when they contained a symbol from a relocatable psect and a symbol from an absolute psect. That resulted in incorrect Linker output if the base of the absolute psect was not zero. Those symbolic expressions are now correctly marked as complex.
- MACRO–11 did not mark symbolic expressions as complex when they contained symbols from different absolute psects. That resulted in incorrect Linker output if the base of either psect was not zero. Those symbolic expressions are now correctly marked as complex.
- When MACRO–11 directly assigned the current location counter symbol (.) to a global symbol in an absolute psect, MACRO–11 incorrectly bound the global symbol to the . ABS. psect. MACRO–11 now correctly binds the global symbol to the absolute psect in which the assignment occurred.
- If MACRO–11 encountered a label containing invalid characters, MACRO–11 would hang in an infinite loop if there existed a macro with the same name as the valid part of the label name. MACRO–11 now correctly returns an error.

J.1.4 V5.2 Update Changes

- MACRO–11 does not allow the colon (:) character as a delimiter for .ASCII or .ASCIZ strings. This is now documented in Chapter 6.
- MACRO–11 now provides support for the 8-bit DEC Multinational character set (MCS). A chart showing the MCS is located in Appendix A.

  The following directives support the MCS. For specific support information, consult the description of each directive.

Macro Directive	Section
.ASCII	6.3.4
.ASCIZ	6.3.5
.ERROR	7.5
.IF	6.9.1
.IF DIF .IF IDN .IFF	6.9.2
.IFF DIF .IFF IDN .IRP	7.6.1
.IRPC	7.6.2
.NCHR	7.4.2
.PRINT	7.5
.REM	6.1.6
.SBTTL	6.1.3
.TITLE	6.1.2

Further information on the 8-bit DEC Multinational character set is located in sections:

2.2.4	Comment field
6.3.3	ASCII conversion characters
7.3	Arguments in macro definitions and macro calls
7.3.6	Keyword arguments

J.1.5 V5.1 Update Changes

- MACRO–11 processed some index deferred arguments as floating-point numbers by default. MACRO–11 now processes all index deferred arguments as octal by default.

- MACRO–11 did not mark internal displaced relocatable statements as relocatable with a single quote (') in the assembly listing. They are now marked correctly.
- MACRO–11 set bit 3, an unused bit, in all .PSECT object records. MACRO–11 no longer sets bit 3. That change makes object files created with the new version of MACRO–11 different from object files created with previous versions of MACRO–11. As a result, they will have different PAT checksums, and a binary comparison of the files will show differences. However, the resulting task or .SAV image files will be the same.

J.1.6 V5.0 Update Changes

- The op code CALLR addr (Call-Return) has been added to the permanent symbol table (PST). This op code is equivalent to the JMP addr op code. The CALLR addr op code was added to complement the CALL addr op code, which is equivalent to the JSR PC,addr op code.
- The previous version of MACRO–11 used a range of 64$ to 127$ for automatic local symbol generation. MACRO–11 now uses a range of 30000$ to 65535$ when generating local symbols.
- Most assembler generated listing text is now in uppercase and lowercase. This change was made to increase the readability of MACRO–11 code. Lines of code that include the .SBTTL or the .TITLE directive are not converted to uppercase.
- Lines of code that include the .SBTTL directive are listed in the table of contents of an assembly listing, even if a .NLIST statement is in effect at the time the .SBTTL lines are encountered. You can specify the .NLIST directive with the TOC argument to prevent the table of contents from being printed.
- The symbol table is printed at the end of an assembly, even if the .NLIST directive is in effect. You can specify the .NLIST directive with the SYM argument to prevent the symbol table from being printed.
- All page headers include the day of the week.
- The assembler statistics information that appears at the end of the assembly listing file has been updated to include the following additional information:
  - Total number of virtual workfile reads
  - Total number of virtual workfile writes
  - Maximum amount of virtual memory used (in words and pages)
  - Size of physical memory free space (in words and pages)
  - Operating system and environment that the assembler is running under
  - Total elapsed assembly time
  - MACRO–11 command line
- The program section (.PSECT) synopsis that is printed after the symbol table in the listing file includes the program section attributes.

- The maximum number of relocatable terms in a complex expression has been changed. The maximum size of a .OBJ record that MACRO-11 can produce was increased from 42_{10} bytes to 128_{10} bytes.

  Do not compare .OBJ files that have been created by different versions of MACRO-11 when verifying whether your code generation is correct. Changes that have been made for this version of MACRO-11 (mentioned above) invalidate a direct comparison of assembler .OBJ output. Verify code generation by linking or taskbuilding the .OBJ files involved and then comparing the .SAV or the .TSK image files.

  NOTE

  .OBJ files produced by this version of MACRO-11 are different from those produced by older versions. If you use the PAT (object file patch utility), checksums must be recomputed on any object patches assembled with this new version of MACRO-11.

- The default for the LC argument has been changed from .DSABL LC to .ENABL LC.
- The following .ENABL/.DSABL options have been added:
  - .ENABL LCM/.DSABL LCM
  - .ENABL MCL/.DSABL MCL
- The following directives have been added to MACRO-11 and documented in this manual.
  - .CROSS
  - .INCLUDE
  - .LIBRARY
  - .MDELETE
  - .NOCROSS
  - .REM
  - .WEAK

J.2 Changes—MACRO-11/RSX Version Only

J.2.1 V5.5 Update Changes

There were no RSX-specific changes made to MACRO-11 V5.5.

J.2.2 V5.4 Update Changes

There were no RSX-specific changes made to MACRO-11 V5.4.

J.2.3 V5.3 Update Changes

- Previous versions of MACRO–11 would hang in an infinite loop if they encountered a record with an invalid record size. That problem has been fixed.
- MACRO–11 now fully supports RSX logical names by calling the .CSI4 SYSLIB parsing routine.

J.2.4 V5.2 Update Changes

There were no RSX–specific changes made to MACRO–11 V5.2.

J.2.5 V5.1 Update Changes

- Previous versions of MACRO–11 would exit with SUCCESS exit status even though errors were reported. That problem has been fixed.
- If MACRO–11 detected an I/O error while reading a command file, MACRO–11 would produce an odd-address trap. Now, MACRO–11 reports the error message *MAC—Command I/O error.*

J.2.6 V5.0 Update Changes

- The cross-reference options SEC and ERR have been added.

NOTE

The RSX–11 CREF program (CRF) has been updated to include support for these two new macro cross-reference options. Only the new RSX–11 CRF version (V2) distributed with RSX–11M V4.1 and RSX–11M–PLUS V2.1 should be used with this version of MACRO–11.

- The default for the command line option /[-]SP has been modified from /SP to /-SP. The new default may be modified by the system manager by using the TKB GBLPAT option described in the MACRO–11/RSX Task Build command file.

J.3 Changes—MACRO–11/RT–11 Version Only

J.3.1 V5.5 Update Changes

- In previous versions the error message *?MACRO–F–I/O Error on workfile* could occur either because of an actual I/O error or because the workfile was full. A new error message was added, *?MACRO–F–Workfile space exceeded,* and the I/O error message reserved for I/O errors only.

  You can increase the size of the RT–11 MACRO–11 workfile to a maximum of 400_8 blocks with a customization patch. Refer to the file CUSTOM.TXT on your distribution kit for the address of the location to patch. If your program requires

workfile space greater than 400_8 blocks, you will get the error message *?MACRO-F-Storage limit exceeded (64K)*. This limit cannot be increased.

- In previous versions, if you requested a CREF listing of only error codes (`/C:E`) but your program had no errors, CREF would hang. CREF now handles this case properly.

J.3.2 V5.4 Update Changes

- Invalid nonprinting characters in a MACRO–11 source file were not being detected. MACRO–11 now detects invalid nonprinting characters and flags them with an I error.
- CREF did not produce a correct cross-reference listing of a MACRO–11 source with a page length of more than 999 lines. CREF now handles pages of more than 999 lines correctly.

J.3.3 V5.3 Update Changes

- When running in memory configurations smaller than 8K words, MACRO–11 sometimes trapped with an invalid EMT error, indicating that the input `.MAC` file was not found when in fact the file did exist, or displayed spurious assembly errors. MACRO–11 now runs correctly in memory configurations smaller than 8K words.

J.3.4 V5.2 Update Changes

There were no RT–11-specific changes made to MACRO–11 V5.2.

J.3.5 V5.1 Update Changes

There were no RT–11-specific changes made to MACRO–11 V5.1.

J.3.6 V5.0 Update Changes

- The message:

  ```
  Errors detected: 0
  ```

  is no longer printed on the console terminal. MACRO–11 prints the message on the terminal only if errors have been detected in the module being assembled.
- If the first character in a MACRO–11/RT–11 command line is a semicolon (;), the line is treated as a comment and is ignored. This change was made to maintain compatibility with the RSX–11 version of MACRO–11.

- RSX–11 style command line switches may be used in addition to the 1-character options:

/M	can be represented as /M[LIB]
/E	can be represented as /E[NABL]
/D	can be represented as /D[SABL]
/P	can be represented as /P[ASS]
/L	can be represented as /L[IST]
/N	can be represented as /N[LIST]

- The default file extension for macro libraries has been changed to .MLB to conform with RSX–11. The RT–11 V5 LIBR program defaults its macro library output to the .MLB extension, also.
- Prior to this release of MACRO–11, if you specified more than one .MLB file on a command line and each file had a definition of the same macro, the first specified macro library would be used for the macro definition if called in the source program. This has been modified to work the same as the RSX–11 macro assembler. The RT–11 macro assembler now scans .MLB files from the last specified file (either in the MACRO–11 command line or by using the .LIBRARY directive) to the first specified file. The assembler then scans the system default macro library, SY:SYSMAC.SML.
- The default for the GBL argument has been changed from .DSABL GBL to .ENABL GBL.

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