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User's Manual

C/C++ Compiler Package for M32R Family V.5.00

Assembler User's Manual

Renesas Microcomputer Development Environment System

Renesas Electronics
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Rev.1.00 2005.07

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Preface

M3T-CC32R(abbreviated as CC32R) is a cross tool kit which supports software development for the Renesas M32R family of 32-bit RISC architecture microcomputers. It provides many functions suitable for development of embedded systems for the M32R family. The CC32R manual set provides information for programming by use of CC32R, targeting an M32R system.

Audience

The CC32R manual set assumes that the readers are developers programming for the M32R system using the C or assembly language. Accordingly, it also assumes that the readers are familiar with programming languages (C or assembly) and their development environment (a host machine and its operating system etc.), and have basic knowledge of the target M32R systems.

References

A manual related to development for the M32R family is :

- M32R Family User's Manual
- M32R Family Software Manual

Refer to the WWW site of the "Renesas Microcomputers" for the details of the information about development of M32R Family.

The URL is : http://www.renesas.com/

For details about the ANSI-C language, refer to :

- ANSI/ISO 9899-1990 American National Standard for Programming Languages - C (American National Standards Institute, Inc.)

Conventions

The CC32R manual set uses the following conventions :

- Symbols

Symbol	Meaning
Italics	Represents a generic description that should be replaced with a specific.
a | *b*	Represents alternative items. *a* | *b* represents either *a* or *b*.
[ ]	Encloses optional elements that can be included or omitted.
...	Indicates to repeat the preceding item zero or more times.
:	Represents omission of a or more lines.
`<RET>`	Represents to enter the return key.

- Terms(1/2)

Term	Meaning
ANSI-C	American National Standard for Programming Languages-C (ANSI/ISO 9899-1990)
Assembler (as32R)	The assembler in CC32R.
Assembly program	A program written in the assembly language.
CC32R	The cross tool kit for an M32R system.
C compiler (cc32R)	The C compiler in CC32R.
C program	A program written in the C language.
CRx	Any control register of M32R.
C standard library	The CC32R-supplied ANSI-C conforming library.
Default	A value (or values) or the process provided automatically if there is none specified by the user.
EWS	An engineering work station.
Librarian (lib32R)	The librarian in CC32R.
Library (file)	A C library file for an M32R system. It is an output file from lib32R.
Linker (lnk32R)	The linker in CC32R.

- Terms(2/2)

Term	Meaning
Link map	A list have information on sections and global symbols in an object module or a load module. It is generated by map32R.
Load module (file)	A linked object module, which is an executable file for an M32R system. It is an output file from lnk32R or lmc32R.
Load module converter (lmc32R)	The load module converter in CC32R.
Local variable	This variable is only effective in a function.
M32R M32Rx	A Renesas 32-bit RISC architecture microcomputer.
M32R system	A system using the M32R.
Map generator (map32R)	The map generator in CC32R.
Object module (file)	An object file which is translated from the C or assembly code into the object code of machine instructions for M32R. It is an output file from the C compiler or the assembler.
OS	An operating system.
Release notes	The document related to the release of the CC32R in a CC32R package (Please read it at first.).
Return value	A function value returned as an operation result from a called function to a calling function.
Rx	Any general register of M32R.
Source file	A text file written source code in the C language or the assembly language.
Space (character)	A blank which is entered by the space key or the tab key.
User library	A library file made by a user using the librarian.
Windows	Any of Microsoft Windows3.1 or Microsoft Windows95.

Organization of This Manual

This manual consists of :

Part 1

Assembler as32R

Chapter 1

Overview of as32R

1.1 About the Assembler as32R

1.1.1 as32R Functions

The as32R is the assembler contained in the cross tool kit M3T-CC32R, and has the following functions :

- Generates an object module by assembling each assembly source file.
- as32R calls :
  - a032R (macro processor)
  - a132R (assemble processor)
  - alis32R (list processor)

To obtain load modules from the object modules that the assembler generates, use the linker (lnk32R) contained in the cross tool kit M3T-CC32R.

1.1.2 as32R Features

The assembler provides the following features :

- Optimizing the operand size

  Chooses the shortest-length instruction if an instruction can have two or more lengths, depending on the operand size.

- Automatic adjusting the instruction position

  Automatically adjusts the position of an instruction that must be located at a word boundary.

- Numerical correction for dealing with a 32-bit immediate data

  Provides a means to carry out numerical correction that enables you to easily describe a 32-bit constant or address.

- Macro processing

  Handles macros. You can define macros by using macro-instructions of the assembler and call the macros.

Chapter 2

Invoking the Assembler

2.1 How to Invoke the Assembler

2.1.1 Invoking Procedure

To invoke the assembler, set environment variables (see 2.1.2), then enter the “as32R” command in line with the applicable rule to execute it (see 2.1.3).

2.1.2 Setting Environment Variables

Set the valid directories for the environment variables M32RBIN, M32RINC, M32RLIB, and M32RTMP. For the setting procedure, refer to ““M3T-CC32R Cross Tool-Kit V.x.xx Release x Release Note“. If you do not set them, the directories (see Table 2.1) are selected automatically.

Table 2.1 Environment Variables

Environment variable	Default
M32RBIN	/usr/local/M32R/bin
M32RINC	/usr/local/M32R/include
M32RLIB	/usr/local/M32R/lib
M32RTMP	/tmp

2.1.3 Command Line Syntax and Rules

The command line syntax and rules for the command, "as32R", which invokes the assembler are as follows (For details on the command options and input/ output files, see 2.1.4 through 2.2.) :

```
as32R  [-g] [-V] [-w] [-o output_filename] [-l list_filename]
       [-I dir] [-D[=def]] [-m32r] [-m32rx] [input_filename]
        <RET>
```

where :

• Without [ ]	: Indispensable
• In [ ]	: Optional
• Prefixed by -	: A command option (and its parameter(s)) (See 2.2.)
• <RET>	: Enter the return key

Figure 2.1 as32R Command Line Syntax

- Each of the items (i.e., the command name, an option, an input file name) must be separated from adjacent items by at least one space character.
- Between an option and its parameter(s), one or more spaces may be inserted. If conflicting options are specified in the same command line, the rightmost option is used.
- You can enter up to 255 characters in a command line (excluding the Return key).
- *input_filename* represents specifying one input file name.
- To link object modules, use the linker lnk32R contained in CC32R. (as32R have no functions of linking .)

2.1.4 Input File Conditions

Conditions for input files to be assembled are given in Table 2.2. You cannot assemble files that don't satisfy these conditions.

Table 2.2 Input File Conditions

Item	Condition
A file that can be input	A source file written in assembly language. Its file extension, ".ms" or otherwise, is allowed.
Instructions described	You must write an assembly-language source file to input using only the general instructions of M32R instructions, pseudo-instructions, and macro-instructions of the assembler.
Maximum length of a name	Module name : Up to 206 characters Symbol name : Up to 243 characters Section name : Up to 243 characters Preprocessor variable : Up to 32 characters Macro name : Up to 32 characters
Maximum number of names	Up to 65535 names can be processed at a time. The number may be limited by the capacity of development environment system memory.

2.1.5 Output File Naming

The output file name becomes what you specify under -o *output_filename*. If you omit this, by default, the file is named as given in Table 2.3 .

Table 2.3 Output File Name (Default)

File name	Description
file`.mo`	An object module file output as a result of assembling. A file name in which the extension of the source file name is replaced by ".mo". (If a source file has no extension, ".mo" is suffixed to the source file name.)

2.1.6 List File Naming

The list file name becomes what you specify under `-l` *list_filename* .

2.2 Command Options

2.2.1 Command Options

Table 2.4 shows the functions of the command options available for the as32R command that are valid for starting the assembler.

Table 2.4 Command Options for the Assembler(1/2)

Option	Description
`-g`	Outputs information necessary for debugging (debugging information) to the object module file.
`-I` *dir*	Adds *dir* to the directory under which a header file is to be searched. The header file search is performed in the order shown : (1) Within the directory containing the file in which the .INCLUDE instruction is written. (2) Within the directory specified by this option. (3) Within the directory for which the environment variable M32RINC is set (If not set, in the order /usr/local/M32R/include.). This option can be specified more than once (up to 10) in a command line, as in -I *dir*1 -I *dir*2. In this case, header files are searched for in the directory shown above (1), *dir*1, *dir*2, and the directory shown above (3), in that order. Spaces between "-I" and "*dir*" are optional.
`-l` *list_filename*	Creates a list file named "*list_filename*". Spaces between "-l" and "*list_filename*" are optional. If this option is not specified, a list file is not created (see Appendix D, "Assemble list file" for a list file).
`-o` *output_filename* ('`o`' is a lower case)	Generates an object module named "*output_filename*". Omitting this option generates an object module using a file name resulting from changing the extension of input file name to ".mo". If an input file name has no its extension, the output file name is named by resulting from suffixing ".mo" to the input file name.

Table 2.4 Command Options for the Assembler(2/2)

Option	Description
`-V` (upper case)	Outputs the invoking message to the standard error output. The other options are ignored. No processing actually takes place.
`-w`	Suppresses warning messages.
`-D` *name* [=*def*]	Associates the character variable *name* with the character sequence *def*. Assumes that *name*=`1` if “=*def*” is omitted. This option has the same function as macro-instruction .ASSIGNC. You may omit a space character between `-D` and *name*.
`-m32r`	Assembles M32R instructions. Parallel instructions and the instructions inherent in M32Rx cannot be processed. If no option is used in the assembler that specifies a specific CPU, the assembler by default assumes this option as it assembles instructions.
`-m32rx`	Assembles instructions that have been added to or changed in M32Rx, in addition to M32R instructions. Furthermore, parallel instructions of M32Rx can be processed. Accumulator specification in MULHI or other instructions to specify an accumulator can be omitted. (When no accumulator is specified, the assembler by default assumes A0 as it processes instructions.) Also refer to Section 2.2.2 for more information about his option.
`-m32re5`	This option makes M32R/ECU#5 extension instruction valid.Also, the floating-point constant, which is not normalized,is reduced to "0.0".
`-zdiv`	For avoiding the integral zero-division problem of M32R/ECU series, to insert NOP instructions each after the all of this DIV-instructions.

2.2.2 About M32Rx Instructions

The assembler supports parallel instructions of M32Rx. For details about parallel instructions of M32Rx, refer to "M32Rx Software Manual."

- Precautions to be observed when writing parallel instructions

O Instructions that can be written in parallel

Instructions that can be written in parallel are limited to combinations of instruction categories. (Refer to “Chapter 4 M32Rx Instructions” and "M32Rx Software Manual.")

If any other instruction statement is written, the assembler outputs the error message shown below and stops processing the instructions that follow.

(Error message)

```
a132R: “xxx”, line 1: error: invalid parallel category
```

O About operand interference

If when executing parallel instructions the same resource is simultaneously accessed for write (operand interference), assembler operation in M32Rx is not guaranteed. The same dependency relationship as this operand interference also applies to control registers such as PSW and CBR that include the condition bit (C), in which case assembler operation is not guaranteed either.

The assembler has a facility to check for operand interference. If an operand interference is committed, the assembler outputs an error message like the one shown below:

(Error message)

```
a132R: “xxx”, line 1: error: write to the same destination register
```

For details about operand interference, refer to the "M32Rx Software Manual."

Chapter 3

Assembly Language Specifications

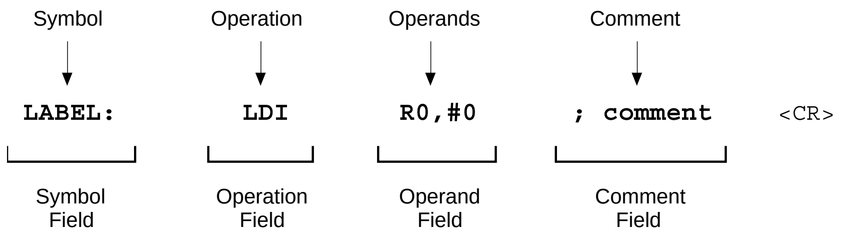
This chapter describes the basic specifications of the assembly language for M32R which is processed by the assembler. “Source” as used in this chapter refers to a source program written in assembly language.

3.1 Line Format

A source program written in assembly language is made on a line-by-line basis (you write one instruction in one line). The range of a line is defined as follows:

- From the beginning of a source file to the first new-line character.
- From the character immediately subsequent to a new-line character either to the next new-line character or to the end of a source file.

The range of a new-line character finishes one line. The number of characters in a line is unlimited. A line is made up of four fields given in Figure 3.1. A field may be omitted if it is not necessary.



• Symbol field	A field in which you write a symbol.
• Operation field	A field in which you write an operation.
• Operand field	A field in which you write instruction operands.
• Comment field	A field in which you write comments.

Figure 3.1 One Line of a Source Program

One or more space characters are required between the symbol field and the operation field and between the operation field and the operand field.

Section 3.1.1 and subsequent sections explain the individual fields. The following notation is used :

△ : One or more optional space characters
(you enter space character(s) or tab character(s))

▲ : One or more required space characters
(you enter space character(s) or tab character(s))

<CR> : A new-line character

3.1.1 Symbol Field

A symbol field is a field in which you write a symbol or a preprocessing variable for macro-instructions in a line of a source program (see 3.6 “Symbols”).

Usually you put a symbol from the first column, but you can write it from the second or subsequent column. Be careful about the following in writing a symbol :

- To write a symbol from the first column :

The syntax are :

```
symbol ; comment
symbol          ; comment<CR>
symbol<CR>
symbol;comment<CR>
↑
first column
```

Either a field extending from the first column to a colon (:) or a field extending from the first column to the column immediately before a space, new-line character, or semicolon (;) forms a symbol field. A string in the field turns to a symbol.

You can omit a colon (:) only when you put a symbol from the first column.

What you write from the first column is recognized as a symbol even if it matches a reserved word (see 3.4 “Reserved Words”).

- To write a symbol from the second or subsequent column :

  The syntax are :

  ```
  △ symbol : ; comment<CR>
  △ symbol         ; comment<CR>
  ↑
  first column
  ```

  This is to enter blank characters at the beginning of a line (from the first column to the column immediately before the symbol's first character). In this instance, be sure to place a colon (:) at the end of the symbol.

  Columns from the first column to the colon (:) form a symbol field. The part excluding the colon (:) and the space characters forms the symbol.

  If the symbol you put from the second or subsequent column matches a reserved word, an error occurs.

Examples of writing symbols in the symbol field are given in Figure 3.2. (Symbols are shown in boldface.)

```
first column
↓
SYM1   LDI       R1,#0     ; Defines a label symbol.
SYM0:  .EQU      10        ; Defines a value symbol.
  SYM2:                    ; colon (:) is required at the end
                           ; if you put a symbol from
                           ; the second or subsequent column.
```

Figure 3.2 Writing Symbols in the Symbol Field

3.1.2 Operation Field

An operation field is a field in which you put an operation in a line of the source program. An operation can be either an instruction code or a pseudo-instruction code or a macro-instruction code. You must write an operation from the second or subsequent column. Separate the operation field from the symbol field and following operand fields using one or more space characters as delimiters.

The syntax are :

```
▲operation  <CR>
▲operation△;comment <CR>
▲operation ▲operand <CR>
▲operation ▲operand△;comment <CR>
symbol:▲operation
symbol:▲operation△;comment <CR>
symbol:▲operation▲operand▲;comment <CR>
↑
first column
```

Examples of operations put in the operation field are given in Figure 3.3. (Operations are shown in boldface.)

```
     MV    R0,R1     ; Be sure to put an operation from
                     ; the second or subsequent column even if
                     ; no symbol is present.
SYM1 LDI    R1,#0    ; A blank is required between the symbol
    ↑    ↑           ; field and the operation field.
Space characters input
```

Figure 3.3 Operations Put in the Operation Field

3.1.3 Operand Field

An operand field is a field in which you specify an operand or operands in a line of a source program.

Operands for an operand field are :

- operands for general instructions
- operands for pseudo-instructions
- correction options (HIGH, SHIGH, LOW) for general instructions

The syntax are :

▲*operation* ▲*operand*<CR>
▲*operation* ▲*operand1,operand2*<CR>
▲*operation* ▲*operand*△; *comment* <CR>
Symbol : ▲*operation* ▲*operand*△; *comment* <CR>
↑
first column

To specify two or more operands, delimit them with a comma (,). Separate the operation field from the operand field with one or more spaces. No operand field is present in a line comprising an instruction that requires no operand.

Examples of operands put in the operand field are given in Figure 3.4 (Operands are shown in boldface.).

```
     Space characters input
                ↓
SYM1  LDI   R1,#0  ; Delimit two or more operands with
                   ; a comma (,). A blank is required between
                   ; the operation field and the operand field.

      NOP          ; There can be an instruction line in which
                   ; no operand field is present.

      SETH  R0,#HIGH(H'ffffffff)
                   ; A correction option (underlined) is
                   ; specified in the operand field.
```

Figure 3.4 Operands Put in the Operand Field

3.1.4 Comment Field

A comment field is a field in which you write a comment in a line of a source program. A comment is an optional description of user's information and is not to be subjected to assembling.

The syntax are :

△`;`*comment* `<CR>`
expect comment field△`;`*comment* `<CR>`
↑
first column

Be sure to start a comment with a semicolon (;). The assembler recognizes the characters from the semicolon (;) to the column immediately preceding the next new-line character as a comment field, but does not regard a semicolon (;) enclosed in a pair of double quotation marks (") as the first character of a comment field.

You can write a comment in any line (or can omit it as intended). You can use any character of the applicable character set except the new-line character.

Examples of comments put in the comment field are given in Figure 3.5 (Comments are shown in boldface.).

```
LDI   R0,#10  ;Loads 10 into R0
;LDI R0,#10   ;Loads 10 into R0
                      ;placing a semicolon in the first
                      ;column makes the whole line a comment.
;comment
```

Figure 3.5 Comments Put in the Comment Field

In a macro definition with the macro-instruction `.MACRO` ~ `.END`, a comment, which will not be expanded, can be put. See Chapter 6 “Coding Macro Instructions” for details.

3.2 Line Types

A source program consists of the following types of lines :

- General instruction line

  Specifies an M32R instruction. The assembler translates this line into object code that target on the M32R family.

- Pseudo-instruction line

  Specifies a pseudo-instruction for the assembler. This line gives the assembler directive(s) involved in assembly.

- Macro-instruction line

  define a macro by use of macro-instruction.

- Comment line

  Consists of comment(s) only. This line is not processed by the assembler.

- Blank line

  Specifies nothing (lines containing optional spaces and a new-line character only). This line is not processed by the assembler similarly to a comment line.

- Symbol line

  Specifies a symbol only. This line consists of only a symbol field or consists of a symbol field and a comment field. The specified symbol is assigned the location counter of that line.

3.3 Character Set

Table 3.1 gives characters that can be used in assembly language source programs.

Table 3.1 Character Set (1/2)

Class	Character(s)	ASCII Code	Name (Note)
Alphabetic letters	A - Z	H'41 - H'5A	Uppercase alphabetic letters
	a - z	H'61 - H'7A	Lowercase alphabetic letters
Digits	0 - 9	H'30 - H'39	Digits
Alphanumerics	Nomenclature for combination of alphabetic letters and digits		
Special characters	"	H'22	Double quotation
	#	H'23	Number sign
	$	H'24	Dollar sign (may be used as a symbol)
	&	H'26	Ampersand
	'	H'27	Single quotation
	(	H'28	Left parenthesis
	)	H'29	Right parenthesis
	*	H'2A	Asterisk
	+	H'2B	Plus
	,	H'2C	Comma
	-	H'2D	Minus
	.	H'2E	Period
	/	H'2F	Slash
	:	H'3A	Colon
	;	H'3B	Semicolon
	<	H'3C	Less than
	=	H'3D	Equal
	>	H'3E	Greater than
	@	H'40	At mark
	\	H'5C	Yen or backslash
	_	H'5F	Underscore
	|	H'7C	Logical disjunction (Vertical line)
	~	H'7E	Tilde

Table 3.1 Character Set (2/2)

Class	Character	ASCII Code	Name (Note)
Blank character	(SP)	H'20	Space
	(HT)	H'09	Horizontal tab
New-line character	(CR)	H'0D	Carriage return
	(LF)	H'0A	Line feed
	(FF)	H'0C	Form feed
Others	Characters other than the above, if available on your computer, may be used in comment only.		

3.4 Reserved Words

The assembler interprets the following identifiers as reserved words. No distinction is drawn between uppercase and lowercase letters :

- Register names
- Special symbols
- Mnemonics

3.4.1 Register Names

A register name is a reserved word that stands for a register of the M32R family, and includes the following :

- General register names

  Rx (R0 to R15), SP

  Note) R15 (stack pointer) can be specified by either R15 or SP.

- Control register names

  CRx (CR0 to CR15), PSW, CBR, SPI, SPU

  Note) These are used only for the operand of the general instructions MVFC and MVTC.

- Accumulator names (Case of M32Rx)

  A0, A1

  Note) The accumulators are also used for the multiplication instruction "MUL". Therefore take note that when this instruction is executed, the values in the accumulators, A0 and A1 are erased.

  Note) These are used only for the operand of the specification Extended Instructions of M32Rx MVTACHI, MVTACLO, MVFACHI, MVFACLO and MVFACMI.

3.4.2 Special Symbols

A special symbol is a reserved symbol specified by an operand, and includes the following :

```
SIZEOF   SHIGH   HIGH   LOW
```

3.4.3 Mnemonics

A mnemonic is a reserved word that represents either an instruction (e.g., LD, .PROGRAM).

- Mnemonics for general instructions :

  LD ST MV ADD etc.

- Mnemonics for pseudo-instructions :

  .ALIGN .PROGRAM .SECTION .END
  .EXPORT .IMPORT .GLOBAL .EQU
  .ASSIGN .DATA .DATAB .SDATA
  .SDATAB .RES

- Mnemonics for macro-instructions :

  .AIF .AELSE .AENDI .AREPEAT .AENDR
  .ASSINGA .ASSIGNC .AWHILE .AENDW .EXITM
  .INCLUDE .INSTR .LEN .SUBSTR
  .MACRO .ENDM

3.5 Names

Names are character strings that represent the following :

- Names the user can define
    - Module name (It can be defined by the .PROGRAM pseudo-instruction. A reserved word is available.)
    - Symbol name (A reserved word is not available. See 3.6 “Symbols”.)
    - Section name (It can be defined by the .SECTION pseudo-instruction. A reserved word is not available.)
    - Preprocessing variable
    - Macro name
- Names the user cannot define

    Reserved words (register names, special symbols, mnemonics)

Rules for names are given below :

- Characters you can use for the leading character

    One of alphabetic letters, dollar sign ($), and underscore (_).
    You cannot use a digit for the leading character.

- Characters you can use for the second and subsequent characters

    One of alphanumeric characters, dollar sign ($), and underscore (_)

- The number of characters you can use in a name

• Module name	: 206 characters
• Symbol name	: 243 characters
• Section name	: 243 characters
• Preprocessing name	: 32 characters
• Macro name	: 32 characters

- Distinction between uppercase and lowercase letters

    Distinction is made for names the user can define.
    No distinction is made for names the user cannot define.

You define a name according to the preceding rules. Be careful about the following in that instance :

- You cannot use a name identical to a reserved word for an entity other than a module name.
- Names the user defines, such as symbol names, section names, cannot be duplicated.

3.6 Symbols

A symbol is a result effected by replacing the value of either an address or an expression with a symbolic name. Symbols include the following :

- Value symbol
  A symbol assigned the value of an expression. It is defined by the pseudo-instruction .EQU or .ASSIGN.

  You can re-define a value symbol previously defined by a pseudo-instruction .ASSIGN by use of another pseudo-instruction .ASSIGN.
- Label symbol
  A symbol assigned the location counter of the line in which you declare a symbol. A label symbol within an absolute addressing section is assigned an absolute address, and a label symbol within a relative addressing section is assigned a relative address.

Rules for symbols are given below (For how to give a symbol name, follow the rules for describing names) :

- Where to specify
  Either in a symbol field or in an operand field.
- How to define
  To define a symbol, specify it in a symbol field. If either the pseudo-instruction .EQU or .ASSIGN is presented in the operation field in the line, the value specified by the operand is assigned to the symbol (value symbol). Otherwise, the location counter corresponding to the line is assigned to the symbol (label symbol).
- How to reference
  You can reference a defined symbol in an operand of an instruction. You can specify either an address or immediate data by use of a symbol within an expression representing an operand.

Examples of defining and referencing symbols are given in Figure 3.6.

```
          .SECTION  program
;
VAL_SYM0: .EQU      10      ; Defining a symbol
VAL_SYM1: .ASSIGN   20      ; Defining a symbol
VAL_SYM1: .ASSIGN   30      ; Re-defining a symbol that has been
                            ; defined under .ASSIGN
          SETH      R0,#VAL_SYM0
                            ; Referencing a defining symbol
          SETH      R1,#VAL_SYM1
                            ; Referencing a defining symbol
;
LABEL0:                     ; Defining a label symbol in a line
                            ; in which no instruction is present
;
LABEL1:   MV        R5,R0   ; Defining a label symbol in a line
                            ; in which instruction is present
          BL        LABEL0  ; Referencing a label symbol
;
          .END
```

Figure 3.6 Defining and Referencing Symbols

3.7 Preprocessing Variables

Preprocessing variables available as operands of macro-instructions. Otherwise, unavailable. The two kinds of preprocessing variable are "arithmetic variable" and "character variable" :

- Arithmetic variable

  A variable assigned to the value of an arithmetic expression specified as an operand of the macro-instruction .ASSIGNA. For details about arithmetic expressions, refer to Chapter 6.

- Character variable

  A variable assigned to the value of a character expression specified as an operand of the macro-instruction .ASSIGNC. For details about character expressions, refer to Chapter 6.

The following example shows declarations and references of the variables.

```
        .SECTION   program
;
V_VAL:  .ASSIGNA   10                ; defining an arithmetic variable
;
        .AREPEAT   \&V_VAL           ; referencing an arithmetic variable
        NOP
        .AENDR
;
C_VAL:  .ASSIGNC   "ABC"             ; defining a character variable
;
        .AIF       \&C_VAL EQ "ABC"  ; referencing a character variable
        MV         R0,R2
        .AELSE
        MV         R0,R3
        .AENDI
;
        .END
```

Figure 3.7 Definition and Reference of Preprocessing Variables

||||| Note |||||

To refer a preprocessing variable in an operand, prefix "\&" to the preprocessing variable name.

3.8 Expressions

An expression is to represent immediate data, a relative address, or an absolute address. An expression is a group of one or more terms combined by operators according to the algebraic rules. Terms and operators that make up an expression are as follows :

- Term — A constant, a symbol name, or a section name (An expression containing only operations on constants or on symbols assigned respective constants is specially referred to as a constant expression.)
- Operator — An arithmetic operator, a logical operator, or a shift operator

The following are coding rules :

- Which field to specify in
  You specify an expression in the operand field.
- Data type — The assembler regards an expression as a signed 32-bit integer.
- Limitation — Neither a relative value (a label symbol defined within the relative addressing section) nor an external reference symbol (a symbol defined by using the .IMPORT pseudo-instruction) can be used as a term of multiplication, division, shift operation, or logical operation.

Be careful about the result of an operation :

- Subtraction performed on two relative values within a single section results in an absolute value. However, if subtraction is performed on relative values representing respective section names, the result turns to a relative value.
- An overflow, if occurring as a result of an operation, is ignored. But if the result of operation exceeds a data size permissible in individual instructions, an error results at that moment.
- Even if the result of an operation turns meaningless due to an overflow, the result is used (within a 32-bit range). In the following example, in which the

LOW correction option is used, no error occurs at the assemble time :

```
Example :  DATA1: .equ  H'7FFFFFFF
                  LD    R0,@( LOW(DATA1+DATA1+DATA1), R1)
```

In the previous example, the result of the operation `(DATA1+DATA1+DATA1)` overflows the 32-bit range, but only the 16-bit lower-order bits of the result of operation are subjected to processing, so that no error occurs. By contrast, an error occurs in the following example :

```
Example :  DATA2: .equ  H'7FFF
                  LD    R0,@(DATA2+DATA2, R1)
```

The LOW correction option is not present in the previous example and the result of `DATA2+DATA2` exceeds the 16-bit displacement the LD instruction permits, so an error occurs.

||||| Note |||||

An expression in a macro-instruction must follow the rules in 6.3.2 “Expressions for macro-instructions”

3.8.1 Constants in an Expression

How to represent constants within an expression is given in Table 3.2.

Table 3.2 Constants

Class	Example	Rules
Binary	`B'10010001`	Prefix : Either B' or b' Digits you can use : Either 0 or 1
Octal	`Q'6072`	Prefix : Either Q' or q' Digits you can use : 0 - 7
	`01234`	A constant starting with a 0 and comprising digits 0 through 7 is also regarded as octal.
Decimal	`D'9423`	Prefix : Either D' or d' Digits you can use : 0 - 9
	`1234`	A constant starting with a digit other than 0 and comprising digits 0 through 9 is also regarded as decimal.

Hexadecimal	`H'A05`
	`0XaA84`
		Prefix : H', h', 0X, or 0x
		Digits you can use : 0 - 9, a - f, A - F

Character constant	`"CNST"`	• You describe an ASCII string by enclosing it in a pair of double quotations ("). • The maximum number of characters of a string must be four (32-bit length). • A character constant represents ASCII code. For example, the character constant “ABC” is a constant that takes on H'414243. • To write one double quotation as a character, repeat it twice (i.e., "").

||||| Note |||||

A point to note in dealing with negative numbers :
The assembler does not deal with two's complement as a negative number in evaluating an expression. So the following are dealt with as two different values :

-1
H'FFFF FFFF

3.8.2 Specifying a Value Using a Symbol Name

You can specify immediate data as a value symbol and a location counter (either a relative address or an absolute address) as a label symbol respectively. If a symbol is present in an expression, the assembler references the value defined for that symbol. For details of referencing symbols, see “3.6 Rules for Describing Symbols”.

3.8.3 Specifying a Value Using a Section Name

A section name indicates the first address of its section. A section name in the relative addressing section indicates the first address of one whole section after linkage. A section name in the absolute addressing section indicates the first address of the section described first within a single source file. Either defining

`SIZEOF`(*section_name)*

or

`sizeof` *section_name*

allows you to show the size of whole section after linkage.

3.8.4 Operators

The operators in an expression include arithmetic operators, logical operators, and shift operators are shown in Table 3.3, 3.4, and 3.5.

- Arithmetic operators

Table 3.3 Arithmetic Operators

Operator	Name	Example
+	Unary positive	`+6`
-	Unary negative	`-7`
+	Binary addition	`9+6`
-	Binary subtraction	`8-3`
*	Binary multiplication	`4*7`
/	Binary division	`5/2`
%	Binary remainder	`17%5`

- Logical operators

Table 3.4 Logical Operators

Operator	Name	Example
~	Bitwise complement	`~1`
&	Bitwise AND	`H'F3 & H'31`
|	Bitwise OR	`H'FFFF | H'1356`
~	Bitwise exclusive OR	`B'1111 ~B'0110`

Note: ~ (tilde) is used both for unary logical negation and for binary exclusive logical disjunction.

- Shift operators

Table 3.5 Shift Operators

Operator	Name	Example
<<	Bitwise left shift operator	`0x400 << 2`
>>	Bitwise right shift operator Usually a bitwise right shift operation performs a logical shift, and it performs arithmetic right shift only when the left term is explicitly negative.	`0x800 >> 1`

The precedence of operators is as given in Table 3.6.

Table 3.6 Precedence of Operators

Precedence	Operator	Name
1	()	Parentheses
2	+, -, ~	Unary positive, unary negative, unary logical negation
3	*, /, %	Binary multiplication, binary division, binary remainder
4	+, -	Binary addition, binary subtraction
5	<< , >>	Left shift, right shift
5	&	Bitwise AND
6	|	Bitwise OR
7	~	Bitwise exclusive OR

Chapter 4

Coding General Instructions

This chapter explains how to write instructions of the M32R family microprocessors.

4.1 General Instructions (M32R Instructions)

The M32R instructions can be classified into six function groups are :

- Load/store instructions
- Transfer instructions
- Arithmetic/logic operation instructions (Compare, arithmetic operation, logical operation, and shift instructions)
- Branch instructions
- EIT-related instructions
- DSP function Instructions

Appendix B shows summaries of instructions, separated by function group. For details of individual instructions, see “M32R Software Manual”.

4.2 General Instruction Line

In a general instruction line, you describe the mnemonic of an M32R instruction in the operation field, and its operand in the operand field.

The syntax of general instruction line and its examples are shown as follows :

- Syntax

▲*M32R_instruction_mnemonic* ▲[*operand*[, *operand*...]] <CR>
△*symbol* : ▲*M32R_instruction_mnemonic* ▲[*operand*[, *operand*...]] <CR>

•An item enclosed in [ ]	: May be omitted
• ▲	: A required space
• △	: An optional space
• <CR>	: A newline character

- Examples

```
LABEL0:  LD       R1,@R1           ; memory to register
         LD24     R0,#h'FF0000
         ST       R1,@R0
         JMP      R14
  ↑        ↑          ↑                    ↑
Symbol   General   Operand(s)           Comment
       instruction
        mnemonic
```

|||||| Note ||||||

You cannot place an instruction mnemonic at the first column of a line. If the beginning of a line is a mnemonic, be sure to put a space before the mnemonic.

4.3 General Instruction Operand

Syntax of operands of the M32R instructions are as follows :

- Operand (`imm` stands for an immediate integer, and `label` stands for a label)

```
Rn | CRn | @Rn | @(Rn) | @(disp,Rn) |
#imm[:8|:16] | #imm[:24] |
@+Rn | @-Rn | @Rn+ | @Rn+ |
label[:8|:24] | label[:16]
```

- `Rn` (a general-purpose register name)

```
R0 | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 |
R9 | R10 | R11 | R12 | R13 | R14 | R15 | SP
```

- `CRn` (a control register name)

```
CR0 | CR1 | CR2 | CR3 | CR4 | CR5 | CR6 |
CR7 | CR8 | CR9 | CR10 | CR11 | CR12 |
CR13 | CR14 | CR15 |
CBR | SPI |  SPU | PSW
```

- `An` (an accumulator name)

```
A0 | A1
```

There are some instructions in which you can specify a correction option (HIGH, SHIGH, or LOW) on an operand which is an immediate integer. Check the M32R Software Manual for the symbolic convention of operands of individual instructions.

4.4 Specifying the Operation Size

You have variation among instructions that perform the same operation depending on the operation size (the size of data to process). Choose an appropriate instruction suited for the operation size.

Example : Variation of instructions for transferring data from the register to memory.

- The ST instruction : Transfers 32-bit data from the register to memory
- The STB instruction : Transfers 8-bit data from the register to memory
- The STH instruction : Transfers 16-bit data from the register to memory

In dealing with an immediate integer, you need not specify an operation size. The assembler chooses a minimum size (either 8-bit or 16-bit) that can take on a specified value. An error occurs, however, if the specified value cannot be taken on.

Example :

```
LDI    Rdst, #imm
```

If the immediate value, `imm`, can be represented by an 8-bit integer, the value will be encoded as 8-bit data. Otherwise, it will be encoded as 16-bit data.

4.5 How to Use a Correction Option

In the M32R instruction set, you can deal with immediate data using a single instruction which cannot exceed 24 bits. To deal with an immediate data item that exceeds 24 bits, you use two instructions by dividing the data into 16 higher-order bits and 16 lower-order bits. To describe such operation, the assembler is provided with the correction options, HIGH, SHIGH and LOW, to be used as special symbols. Instructions in which you can use a correction option include the following :

- The instruction which can use HIGH and SHIGH :

```
SETH
```

- The instructions which can use LOW :

```
LD   LDB   LDH   LDUB   LDUH   ST   STB   STH   OR3
```

Table 4.1 (see the following page) shows rules for using the correction options .

Table 4.1 Syntax of Correction Options

Correction Option	`Syntax` and Explanation
`HIGH`	`SETH Rdst,#HIGH(imm)` This option deals with only the 16 higher-order bits of the immediate data, `imm`, as an immediate operand of the SETH instruction. Execution of the SETH instruction transfers to *Rdst* a value effected by assigning 0s to the 16 lower-order bits of `imm`.
`SHIGH`	`SETH Rdst,#SHIGH(imm)` This option turns 16 higher-order bits of the immediate data,`imm`, together with a value that corrects the sign extension of the 16 lower-order bits of the immediate data, `imm`, into the immediate operand of the SETH instruction.
`LOW`	`OR3 Rdst,Rsrc,#LOW(imm)` This option deals with only the 16 lower-order bits of the immediate data, `imm`, as the immediate operand of the OR3 instruction. Describing `SETH Rsrc,#HIGH(imm)` before this instruction allows you to set a 32-bit immediate data item to `Rdst`. *mnemonic* `Rdst,@(LOW(imm),Rsrc)` (*mnemonic* `: LD|LDB|LDH|LDUB|LDUH|ST|STB|STH)` This option deals with the 16 lower-order bits of imm as the displacement of the instruction *mnemonic*. This displacement is sign-extended. Thus describing `SETH Rsrc,#SHIGH(imm)` before this instruction transfers the content of the address `imm` to *Rdst*.

Examples of describing correction options are given below (example 1 to example 6).

Example 1 :

```
SETH    Rdst, #HIGH(imm)
```

Stores the 16 higher-order bits of the immediate data, `imm`, in the 16 higher-order bits of `Rdst`. The 16 lower-order bits of `Rdst` are changed to 0's.

Example 2 :

```
SETH    Rdst, #SHIGH(imm)
```

Stores the 16 higher-order bits of the immediate data, `imm`, in the 16 higher-order bits of `Rdst`. The 16 lower-order bits of `Rdst` are changed to 0's. In this instance, `Rdst` is corrected so that the result effected by adding the 16 lower-order bits of `#imm` to `Rdst` as a signed integer becomes `#imm`.

Example 3 :

```
LD      Rdst, @(LOW(disp), Rsrc)
```

Sign-extends the 16 lower-order bits of the displacement `disp` to 32 bits, and adds this 32-bit value to the content of `Rsrc`, reads the 32-bit data from the memory (address) the value after the addition points to, and stores it in `Rdst`. Since only the 16 lower-order bits of disp are used, the value of the displacement does not fall outside the adequate range.

Example 4 : To store a 32-bit immediate data item in the register

```
SETH        Rdst, #HIGH(imm_32)
OR3         Rdst, Rdst, #LOW(imm_32)
```

Note) #LOW(imm_32) is zero-extended under the OR3 instruction.

Example 5 : To load the content of 32-bit-addressed memory in the register

```
SETH        Rwork, #SHIGH(imm_32)
LD          Rdst, @(LOW(imm_32), Rwork)
```

Note) LOW(imm_32) is sign-extended under the LD instruction.

|||| Supplementary Note to the SHIGH Correction Option |||||

The SHIGH correction option is used to set the higher-order half word of the content of a 32-bit-mode address by use of the SETH instruction. In Example 6, suppose the value of imm_32 is address H'FC008000 :

Example 6 :

```
SETH        R1,#SHIGH(imm_32)
LD          R2,@(LOW(imm_32),R1)
```

The displacement of the LD instruction shown in the second line is sign-extended as `LOW(imm_32)=H'FFFF8000`. Thus, if you use the correction option HIGH, the address expressed by imm_32 cannot be properly obtained as shown here :

```
R1 = #HIGH(imm_32) = H'FC000000
#LOW(imm_32)+R1 = H'FFFF8000+H'FC000000
                = H'FBFF8000
```

So the definition of the correction option SHIGH is given here :

- If the most significant bit of the lower-order halfword of imm_32 is one,
  `#SHIGH(imm_32) = #HIGH(imm_32)+1`
- If the most significant bit of the lower-order halfword of imm_32 is zero,
  `#SHIGH(imm_32) = #HIGH(imm_32)`

Therefore, in Example 6, because `#SHIGH(imm_32)`=H'FC01, using the correction option SHIGH allows you to obtain the proper address.

```
R1 = #SHIGH(imm_32) = H'FC010000
LOW(imm_32)+R1 = H'FFFF8000+H'FC010000
               = H'FC008000
```

4.6 Addressing Modes

The M32R family supports the following addressing modes as a means to specify data to be processed :

- Register direct
- Register indirect
- Register relative indirect
- Register indirect + register update
  (register indirect with pre-increment, register indirect with pre-decrement, register indirect with post-increment)
- Immediate integer
- PC relative

In describing an operand of a general instruction, you use one of these addressing modes. The addressing modes you can use vary from instruction to instruction, so check the “M32R User's Manual”.

Table 4.2 shows the notation of operands in individual addressing modes together with data to be processed under this notation.

Table 4.2 Operand Notation by Addressing Mode

Addressing Mode	Operand Notation	What is Processed (Object)
Register direct	Either `Rn` or `CRn` or An	Content of the register Rn or the content of the control register CRn or the content of the accumulator
Register indirect	`@Rn`	The content of the memory addressed by "the content of the register Rn"
Register relative indirect	`@(disp,Rn)`	The content of the memory addressed by "the content of the register Rn + displacement"
Immediate integer	`#imm[:8│:16]` or `#imm[:24]`	The value of an expression
Register indirect with pre-increment	`@+Rn`	The content of the memory addressed by "the content of the "register Rn + 4"
Register indirect with pre-decrement	`@-Rn`	The content of the memory addressed by "the content of the "register Rn - 4"
Register indirect with post-increment	`@Rn+`	The content of the memory addressed by "the content of the register Rn". The content of Rn is increased by 4 after being referenced so as to be updated.
PC relative	`label[:8│:24]` or `label[:16]`	The difference between the address where the instruction is located and the address to which the expression (label) points. Usually in assembley, you describe the label located at the branch target.

Note) `Rn` stands for an arbitrary register, `CRn` for an arbitrary control register, An for an accumulator, disp for a displacement, and imm for an immediate integer.

4.7 How to Write Operands (depending on the addressing mode)

4.7.1 Register Direct

Object The value of a specified register

Syntax `Rn` or `CRn` or `An`

`Rn`	: General register (R0 to R15, SP)
`CRn`	: Control register
An	: Accumulator

- You write a general register name, a control register name or an accumulator name for a register direct operand. You can write a control register only for the operand of the instruction, MVTC or MVFC. You can write an accumulator only for the operand of the instruction, MVTACHI, MVTACLO, MVFACHI, MVFACLO or MVFACMI.
- R15, a general register name, may be written as SP. A name such as PSW may be written for a control register. For correspondence of registers, see the M32R Software Manual.
- Coding this operand references the content of the register and the accumulator.

Example `R5`

4.7.2 Register Indirect

Object The content of the memory to which the specified register points

Syntax `@Rn`

`Rn`	: General register (R0 to 15, SP)

- You write a general register name preceded by @ for a register indirect operand.
- Coding this operand references the content of the memory area to which the general register points.

Example `@R5`

4.7.3 Register Relative Indirect

Object The content of the memory area whose address is the result effected by adding the displacement to the value of the specified register

Syntax

```
@(disp,Rn)
```

`disp`	: Displacement
`Rn`	: General register (R0 to R15,SP)

- You write a displacement, a comma (,), and a general register name in this sequence preceded by `@` for a register relative indirect operand.
- You write an expression for a displacement.
- Coding this operand adds a displacement to the value (address) of a specified register, and references the content of the memory indicated by the resulting (address) of the addition.

Example

```
@(data,R7)
@(label,R8)
@(-4, R9)
@(H'FEDC,R5)
```

4.7.4 Immediate Integer (immediate)

Object The value of imm (an expression)

Syntax

```
#imm[:8|:16]     or     #imm[:24]
```

`imm` : Expression

`:8|:16` : The size of the expression (the smallest number of bits that can represent the expression)

`:24` : The size of expression

- You write an expression imm in succession to # for an immediate integer.
- If you have two alternatives of displacement in one instruction, putting either :8 or :16 in succession to an expression allows you to specify which to use. If you omit this, the assembler chooses the preferable one.
- You can use : 24 only in the LD24 instruction.
- Limitations in dealing with the trap instruction and the shift instruction are as follows :

  Limitations
  - You must not include an external reference symbol in an expression.
  - The value of an expression must be an absolute value.
  - You must not include a symbol defined by the pseudo-instruction, ASSIGN, used for forward addressing.
  - The range of an expression is limited : 0 through 15 for the TRAP instruction, and 0 through 31 for the shift instruction.
- Coding this operand references the value of the expression.

Example

```
#B'1010
#(symbol + H'1)
#-7
```

4.7.5 Register Indirect with Pre-increment

Object The content of the memory area indicated to by a general register value (address) which has been increased by the operand size (4).

Syntax

```
@+Rn
```

`Rn` : General register (R0 to 15, SP)

- You write a plus sign (+) and a general register name in this sequence preceded by @ for an operand of register indirect with pre-increment.
- Cording this operand increments the value of the general register by the operand size (4), then references the content of the memory area which the value of the general register indicates.

Example `@+R11`

4.7.6 Register Indirect with Pre-decrement

Object The content of the memory area indicated to by a general register value (address) which has been decreased by the operand size (4).

Syntax

```
@-Rn
```

`Rn` : General register (R0 to 15, SP)

- You write a minus sign (-) and a general register name in this sequence preceded by @ for an operand of register indirect with pre-decrement.
- Cording this operand decrements the value of the general register by the operand size (4), then references the content of the memory area which the value of the general register indicates.

Example `@-R13`

4.7.7 Register Indirect with Post-increment

Object The content of the address a general register indicates.

Syntax

```
@Rn+
```

`Rn` : General register (R0 to R15,SP)

- You write a general register name and a plus sign (+) in this sequence preceded by `@` for an operand of register indirect with post-increment.
- Coding this operand references the content of the memory area which the value (address) of the general register indicates. After referencing, the value of the general register is increased by the operand size (4) so as to be updated.

Example `@R1+`

4.7.8 PC Relative

Object The difference (displacement size) between the address in which the current instruction is located and the branch address

Syntax

```
label[:8|:24]
```

or

```
label[:16]
```

`label`	: Branch target
`:8|:24`	: Displacement size
`:16`	: Displacement size

- `label` is used in a branch instruction in PC relative addressing mode.
- The displacement is available in three sizes, 8 bits, 16 bits and 24 bits.
- The displacement is the value after being sign-extended to 32 bits and left-shifted by 2 bits. However, in assembly-level programming, you need not worry about this.
  By giving a label symbol as the operand of a branch instruction, the displacement is computed by the assembler.
  By specifying an expression as the operand, the displacement from the current PC to the address of the branch target indicated by the expression is calculated.
- If an instruction has two alternatives for the displacement, putting either `:8` or `:24` preceded by an expression allows you to specify which to use. If you omit this, the assembler chooses the preferable one.

Example

```
BL  DstSymbol:8
BEQ R1,R2, 1000
```

4.8 About M32Rx Instructions

The assembler supports parallel instructions of M32Rx. For details about parallel instructions of M32Rx, refer to "M32Rx Software Manual".

- To write parallel instructions in the assembler, specify the parallelspecification symbol "||" between instructions to be processed in parallel. (A label can be written at the beginning of the line. No labels can be written between "||" and instruction B.

  (Example 1)   label: instruction A || instruction B

  The parallel specification symbol "||" only specifies parallel processing to the assembler; it does not specify piplined processing of M32Rx. Which instruction is executed in pipe O or pipe S is automatically determined by the assembler. The instruction statement in Example 2 is a reverse of the instruction statement in Example 1 (reversed between left and right), but operates the same way as in Example 1.

  (Example 2)   label: instruction B || instruction A

  Instructions that can be written in parallel are limited to four combinations of instruction categories shown below. (Refer to "M32Rx Software Manual.")

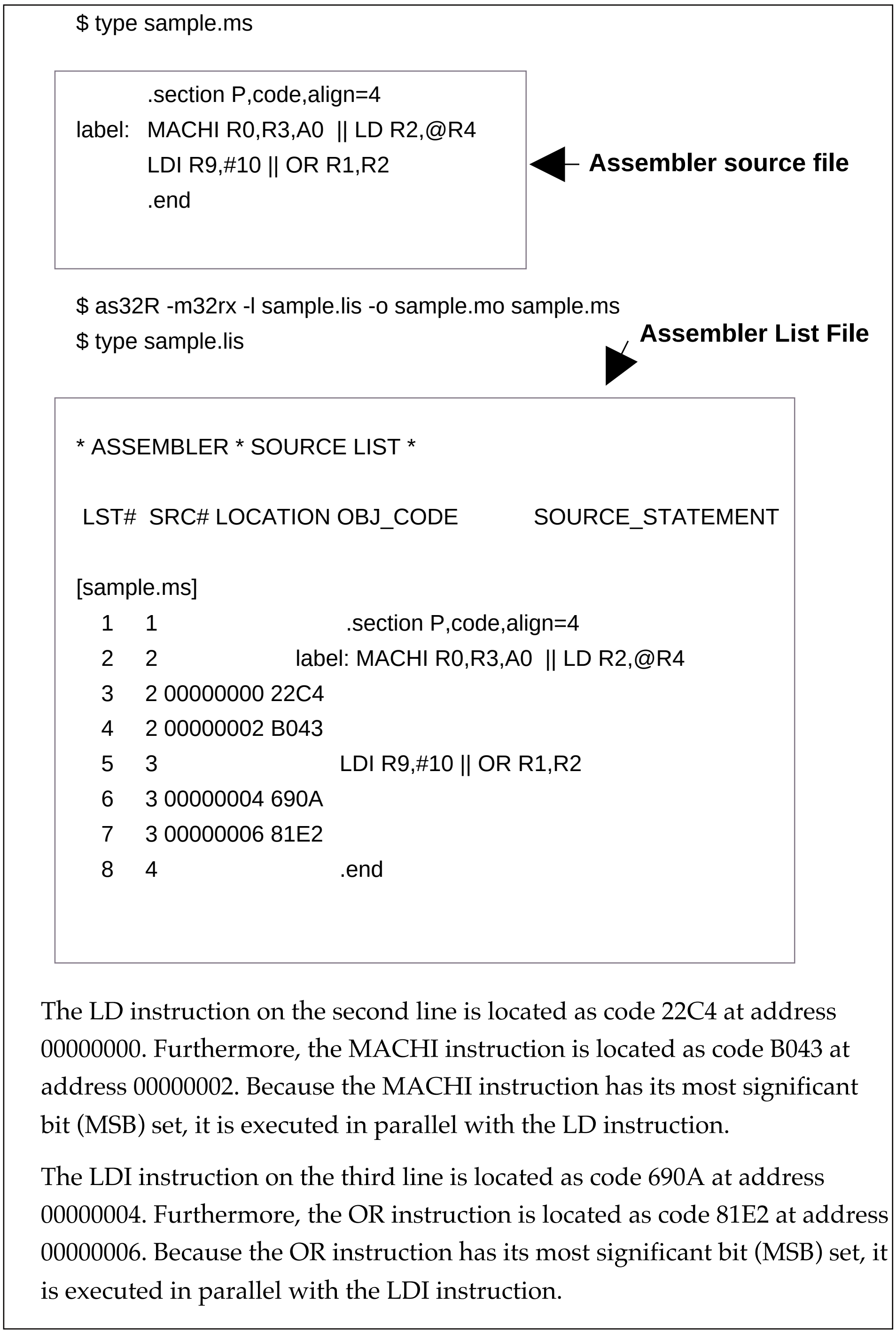
  O Left-side instruction and right-side instruction (O-, -S)
  O Left-side instruction and both-side instructions (O-, OS)
  O Both-side instructions and right-side instruction (OS, -S)
  O Both-side instructions and both-side instructions (OS, OS)

  If any other instruction statement is written, the assembler outputs the error message shown below and stops processing the instructions that follow.

  (Error message)

  ```
  a132R: “xxx”, line 1: error: invalid parallel category
  ```

  Figure 4.1 shows a description example of parallel instructions (assemble source) and its assembled result (assemble list).



```
$ type sample.ms

        .section P,code,align=4
label:  MACHI R0,R3,A0  || LD R2,@R4
        LDI R9,#10 || OR R1,R2
        .end
```

Assembler source file

```
$ as32R -m32rx -l sample.lis -o sample.mo sample.ms
$ type sample.lis
```

Assembler List File

```
* ASSEMBLER * SOURCE LIST *

 LST#  SRC# LOCATION OBJ_CODE          SOURCE_STATEMENT

[sample.ms]
   1    1                        .section P,code,align=4
   2    2                  label: MACHI R0,R3,A0  || LD R2,@R4
   3    2 00000000 22C4
   4    2 00000002 B043
   5    3                        LDI R9,#10 || OR R1,R2
   6    3 00000004 690A
   7    3 00000006 81E2
   8    4                        .end
```

The LD instruction on the second line is located as code 22C4 at address 00000000. Furthermore, the MACHI instruction is located as code B043 at address 00000002. Because the MACHI instruction has its most significant bit (MSB) set, it is executed in parallel with the LD instruction.

The LDI instruction on the third line is located as code 690A at address 00000004. Furthermore, the OR instruction is located as code 81E2 at address 00000006. Because the OR instruction has its most significant bit (MSB) set, it is executed in parallel with the LDI instruction.

Figure 4.1 Description example of parallel instructions

Chapter 5

Coding Pseudo-instructions

This chapter describes how to use the pseudo-instructions and their operands in the assembly language.

5.1 Pseudo-instructions

A pseudo-instruction is an instruction which gives directives to the assembler. The assembler is provided with the pseudo-instructions given in Table 5.1.

Table 5.1 Pseudo-instructions

Group	Pseudo-instruction	Function
Address Control	.ALIGN	Adjusts the location counter to a boundary.
Program Structure Definition	.PROGRAM	Specifies a module name.
	.SECTION	Declares a section.
	.END	Marks the end of a source program.
Symbol External Definition/External Reference		
	.EXPORT	Declares an external definition symbol.
	.IMPORT	Declares an external reference symbol.
	.GLOBAL	Declares an external definition/external reference symbol.
Set Symbol	.EQU	Declares a value symbol.
	.ASSIGN	Declares a value symbol (possible to reassign).
Set Data	.DATA	Sets integer data.
	.DATAB	Sets integer data (data block).
	.SDATA	Sets character string data.
	.SDATAB	Sets character string data (data block).
Reserve Memory	.RES	Reserves a data area.

For details of the individual pseudo-instructions, see Appendix B, “Pseudo-instruction Reference”.

5.2 Pseudo-instruction Line

A pseudo-instruction line is composed of a pseudo-instruction mnemonic in the operation field the operand(s) in the operand field.

Syntax and examples of the macro instruction line :

- Syntax

△*pseudo-instruction mnemonic* ▲[*operand*[, *operand*...]] <CR>
△*symbol* : ▲*pseudo-instruction mnemonic* ▲[*operand*[, *operand*...]] <CR>

•An item enclosed in [ ]	: May be omitted
• ▲	: A required space
• △	: An optional space
• <CR>	: A newline character

- Examples

```
        .SECTION   P,CODE,ALIGN=4      ;Section P
        .END

            ↑                 ↑                  ↑
  Pseudo-instruction      Operands            Comment
      mnemonic
```

||||| Note |||||

You cannot use a symbol in dealing with an instruction that cannot specify a symbol.

5.3 Pseudo-instruction Operand

Operands of the pseudo-instructions are shown below. For convention of operands of individual instructions, refer to Appendix B.

- **Syntax**

[*expression*[, *expression* | , *character_string*]]
[*expression*[, *expression*]...]
symbol_name[, *symbol_name*]
symbol_name[, *symbol_name*]...
module_name
section_name[, *attribute_a*][, *attribute_b*]
character_string[, *character_string*]

- **Rules**

To write an expression, follow the rules described in 3.8 "Expressions". To specify a module name, a section name, and a symbol name, refer to the rules in 3.5 "Names". To specify a character string, see Figure 5.3 and the following.

Syntax	"*ASCII_character_string*" | <*character_code*>	
Examples	`"MOJI"`	`; H'4D, H'4F, H'4A, H'49`
	`"MOJ"<49>`	
	`<4D><4F>"JI"`	
	`"char""acter"`	

Figure 5.1 Syntax of Character String

A character string can be represented by ASCII character string, character codes (the numeric values of the characters in the ASCII character set), or their combination.

An ASCII character string is a sequence of characters enclosed in double quotations (as in "abc").

A character code (ASCII value) is an expression enclosed in '<' and '>' .

An expression that specifies a character code cannot include a forward addressing symbol. Moreover, the expression must be a constant expression, and can take on values from -128 up to 255.

Up to 255 characters can be specified in a string, except up to 242 characters for the .SDATAB pseudo-instruction .

5.4 Size Specifier

For some instructions, you can specify the size of the data processed by the instruction using a size specifier. Sizes specifiers that can be used for pseudo-instructions are given in Table 5.2.

Table 5.2 Sizes Specified Using Pseudo-instructions

Size Specifier	Explanation
`.B`	Byte (8 bits)
`.H`	Halfword (16 bits)
`.W`	Word (32 bits) Default (a word is assumed if you do not specify operation size).

A size specifier, `.`*size*, is preceded by mnemonic in the operation field as follows :

Syntax *mnemonic*`[.B|.H|.W]`

Example

```
WORK:     .RES.B    20
```

No distinction is made between uppercase letters and lowercase letters in a size specifier. Put no space character between the mnemonic and the size specifier.

Chapter 6

Coding Macro-instructions

6.1 Macro-instructions

The assembler supports the following macro-instruction (Table 6.1) and string handling functions to handle user-defined macros.

Table 6.1 Macro-instructions

Macro-instruction	Description
.MACRO-block (.MACRO~.ENDM)	Defines one or more lines consist of instruction(s) and/or pseudo-instruction(s) as one macro body[Note1)] (This is called "macro definition"). A defined macro body can be expanded on the source program by a macro call[Note2)].
.ASSIGNA	Defines the value of an arithmetic expression as an arithmetic variable.
.ASSIGNC	Defines the value of a character expression as a character variable.
.INCLUDE	Reads the file specified by its operand.
.AIF-block (.AIF~.AELSE~.AENDI)	Selects macro expansion on condition.
.AWHILE-block (.AWHILE~.AENDW)	Iterates macro expansion on condition.
.AREPEAT-block (.AREPEAT~.AENDR)	Repeats macro expansion *n* times.
.EXITM	Ends macro expansion.

Note1) Macro body
: The part following a .MACRO macro-instruction and preceding the corresponding .ENDM.
This is a macro definition can be called with the macro name defined by .MACRO. See 6.4.

Note2) Macro call
: Using a user-defined macro name. a032R expands the macro name.
(i.e., the macro name is replaced with the corresponding macro body.) See 6.4.

Table 6.2 String Handling Functions

String Handling Function	Description
.LEN	Counts the number of characters in a string.
.INSTR	Locates a string in another string.
.SUBSTR	Gets a string.

Refer to Appendix C, “Macro-instruction Reference” for more information on the macro-instructions and the string handling functions.

6.2 Macro-instruction Line

A macro-instruction line is composed of a symbol or a macro-defined symbol (i.e., a preprocessing variable) in the symbol field, a macro-instruction mnemonic in the operation field, and the operand in the operand field.

Syntax and examples of the macro instruction line :

- Syntax

△*macro-instruction_mnemonic*▲[*operand*] △`<CR>`
△*symbol* : ▲*macro-instruction_mnemonic*▲[*operand*] △`<CR>`

To call a macro,

△*macro_name*▲[*argument*] △`<CR>`
△*symbol* : ▲*macro_name*▲[*argument*] △`<CR>`

•An item enclosed in [ ]	: May be omitted
• ▲	: A required space
• △	: An optional space
• <CR>	: A newline character

- Examples

```
                 .INCLUDE    "DATAB.H"           ;sample
AVAR_1:          .ASSIGNA     10

     ↑                ↑           ↑                     ↑
   Symbol     Macro-instruction  Operand              Comment
(Preprocessing    mnemonic
  variable)


MCR:              R7,r7
 ↑                  ↑
 Macro name       Arguments
```

For information on how you write macro-instruction lines, see 6.3.

6.3 Preprocessing Variables and Expressions

You can write any of the following in an macro instruction line :

- Preprocessing variables : Formal parameter
  Arithmetic variable
  Character variable

- Expressions : Arithmetic expression
  Character expression
  Logical expression
  (Make sure the expressions are dealt with differently from those used in the M32R instructions.)

For details of respective items, see 6.3.1 “Preprocessing Variables” and 6.3.2 “Expressions for Macro-instructions”.

6.3.1 Preprocessing Variables

A preprocessing variable is a parameter inside a macro body to which you can pass an actual argument when the macro is expanded. A preprocessing variables are classified into three types as given below depending on the way of definition :

- Formal parameter : Defined in the operand field of the .MACRO instruction.
- Arithmetic variable : Defined by the .ASSIGNA instruction.
- Character variable : Defined by the .ASSIGNC instruction.

The makeup of these variables is explained below.

6.3.1.1 Formal Parameters

Syntax

```
\formal_parameter_ name
```

Description

A formal parameter is defined in the .MACRO statement.

Preceding a formal parameter name with a backslash (\) allows you to reference a formal parameter under macro definition.

The value of formal parameter is set by a macro call, but you can set an initial value to a formal parameter in the .MACRO statement too.

You can reference a formal parameter within the macro body in which the formal parameter is defined.

A formal parameter name must be described according to the name rule.

Example

```
.MACRO    MCR   ARG_1           ; .MACRO statement
          MV    R5,\ARG_1       ; macro body
          ADD   R6,\ARG_1       ;
.ENDM                           ; .ENDM statement
  :
MCR   R7                        ; macro call
```

<Macro expansion results>

```
          MV    R5,R7
          ADD   R6,R7
```

6.3.1.2 Arithmetic Variables

Syntax

\&arithmetic_variable_name

Description

You define an arithmetic variable by use of the .ASSIGNA instruction and set its value.

Preceding an arithmetic variable name with a backslash (\) and & allows you to reference the value of arithmetic variable.

You can reference an arithmetic variable within every macro body and in arithmetic expressions, character expressions, and logical expressions outside the macro body.

Example

```
.MACRO    MCR                         ; .MACRO statement
          LDI     R5,#\&AVAR_1        ; inside a macro body
          ENDM                        ; .ENDM statement
           ⋮
AVAR_1:   .ASSIGNA    10
          MCR                         ; macro call
           ⋮
AVAR_2:   .ASSIGNA    \&AVAR_1        ; outside a macro body
```

<Macro expansion results>

```
          LDI     R5,#10
```

6.3.1.3 Character Variables

Syntax

```
\&character_variable_name
```

Description

You define a character variable by use of the .ASSIGNC instruction and set its value.

Preceding a character variable name with a backslash (\) and & allows you to reference the value of character variable.

You can reference a character variable within every macro body and in arithmetic expressions, character expressions, and logical expressions outside the macro body.

Example

```
.MACRO     MCR                              ; .MACRO statement
                \&CVAR_1     R5,#1     ; inside a macro body
                \&CVAR_2     R5,#2     ;
           .ENDM                            ; .ENDM statement
           :
CVAR_1: .ASSIGNC    "SLLI"
CVAR_2: .ASSIGNC    "\&CVAR_1"              ; outside a macro body
           MCR                              ; macro call
```

<Macro expansion results>

```
           SLLI    R5,#1
           SLLI    R5,#2
```

6.3.2 Expressions for Macro-instructions

The three kinds of expressions which are available in a macro-instruction line are shown below :

• Arithmetic expression	: A group of one or more terms joined by use of operators and parentheses according to the algebraic rules.
• Character expression	: A group of one or more terms joined.
• Logical expression	: A group of one or more terms joined by use of relational operators, logical operators, and parentheses.

The makeup of these expressions is explained below.

6.3.2.1 Arithmetic Expressions

■ Coding rules for arithmetic expressions

An arithmetic expression is a sequence of one or more terms (operands) joined by use of operators and parentheses according to algebraic rules.

An arithmetic expression is a signed 32-bit entity.

An overflow resulting from an arithmetic operation is ignored.

Division yields its quotient only, any remainder is discarded.

A 0, if assigned to the divisor, causes an error.

What you can use as terms in arithmetic expressions are available in three types given below :

- Constants
- Preprocessing variables
- String handling functions (.LEN, .INSTR)

■ Coding rules for constants

The four types of constants which are available as terms in arithmetic expressions (Write with parenthesized prefixes such as B' or b'.) :

• Binary	(`B'` or `b'`)
• Octal	(`Q'` or `q'`)
• Decimal	(`D'` or `d'`)
• Hexadecimal	(`H'` or `h'`)

Omitting a prefix (B', Q', D', or H' etc.) assumes decimal.

Examples are given below.

```
B'01000101
Q'741
D'3209
H'B5F6
87905
```

■ Coding rules for preprocessing variables

You can use the following preprocessing variables as terms in arithmetic expressions : formal parameters, arithmetic variables, and character variables.

The value of a formal parameter must be constant.

A character variable must represent a character string that denotes a constant (Example : `B'0101`); otherwise an error occurs.

■ Coding rules for string handling functions (.LEN, .INSTR)

String handling functions you can use as terms in arithmetic expressions are available in two types given below.

- .LEN function : The function value is assigned the number of characters in a string.
- .INSTR function : The function value is assigned the position of any character in a string.

Examples are given below.

```
.LEN("ABC")+3
.INSTR("DEF","E")*4
```

■ Operators and Precedence

Table 6.3 shows operators you can use in arithmetic expressions.

Table 6.3 Arithmetic Operators

Operator	Description
+	Unary plus
-	Unary negation
+	Binary addition
-	Binary subtraction
*	Binary multiplication
/	Binary division

Table 6.4 shows precedence of operators.

Table 6.4 Precedence of Operators

Precedence	Operators	Description
1	( )	Parentheses
2	+ -	Unary plus, Unary negation
3	* /	Binary multiplication, binary division
4	+ -	Binary addition, binary subtraction

■ The form of an arithmetic expression

Figure 6.1 shows the makeup of arithmetic expressions.

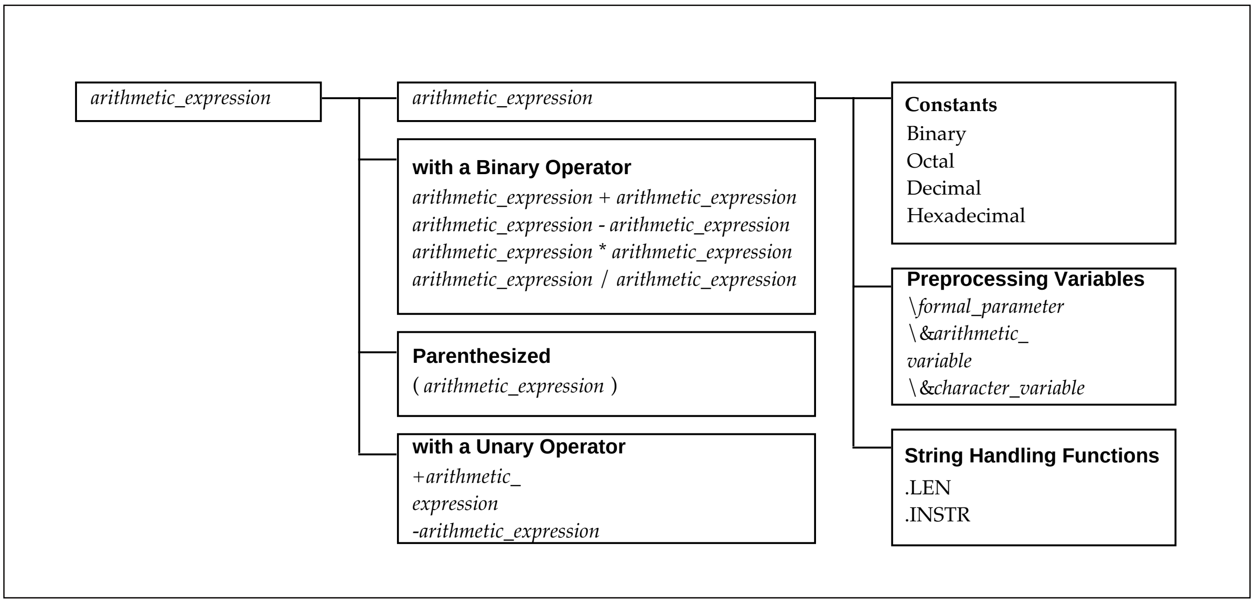

arithmetic_expression
arithmetic_expression
with a Binary Operator
arithmetic_expression + arithmetic_expression
arithmetic_expression - arithmetic_expression
*arithmetic_expression * arithmetic_expression*
arithmetic_expression / arithmetic_expression
Parenthesized
(*arithmetic_expression*)
with a Unary Operator
+*arithmetic_expression*
-*arithmetic_expression*
Constants
Binary
Octal
Decimal
Hexadecimal
Preprocessing Variables
formal_parameter
\&*arithmetic_variable*
\&*character_variable*
String Handling Functions
.LEN
.INSTR

Figure 6.1 The Form of an Arithmetic Expression

■ Examples of arithmetic expressions

Examples are given below.

```
\ARG_1 + 1                ——— formal parameter
\&AVAR_1 - \&AVAR_2       ——— arithmetic variable
(-\&CVAR * 2)             ——— character variable
```

6.3.2.2 Character Expressions

■ Coding rules for Character expressions

A character expression is a sequence of one or more terms joined.

To join terms, write them consecutively but put one or more space between adjacent ones.

What you can use as terms in character expressions are available in three types given below :

- Character string
- Preprocessing variables
- String handling functions (.SUBSTR)

■ Coding rules for character strings

Character strings can be used as terms of character expressions.

A character strings must be enclosed in a pair of double quotation marks (as in "abc") .

You cannot use character codes as character strings.

To include a double quotation mark in a character string, repeat it twice as "".

The number of characters in a character string has to be within in a range from 0 to 255.

Examples are given below.

```
"MOJI"
"MO""JI"                  ---- represents MO"JI
"M" "O" "J" "I"           ---- represents MO"JI
```

■ Coding rules for preprocessing variables

You can use the following preprocessing variables as terms in character expressions : formal parameters, arithmetic variables, and character variables.

You have to enclose a preprocessing variable in a pair of double quotation marks (`"  "`).

If you reference either a formal parameter or a character variable, its value is replaced with the corresponding character string.

If you reference an arithmetic variable, the string showing a decimal integer replaces its value (such as `"1234"`).

■ Coding rules for string handling functions (.SUBSTR)

The .SUBSTR functhion, which is a string handling function is available as a terms in a character expression.

Calling a .SUBSTR function, it is possible to refer the value of a certain string from the specified string.

For example, you may write as follows.

```
.SUBSTR("AABCCD",1,3) "DEF"
```

■ The form of a character expression

Figure 6.2 shows the makeup of character expressions.

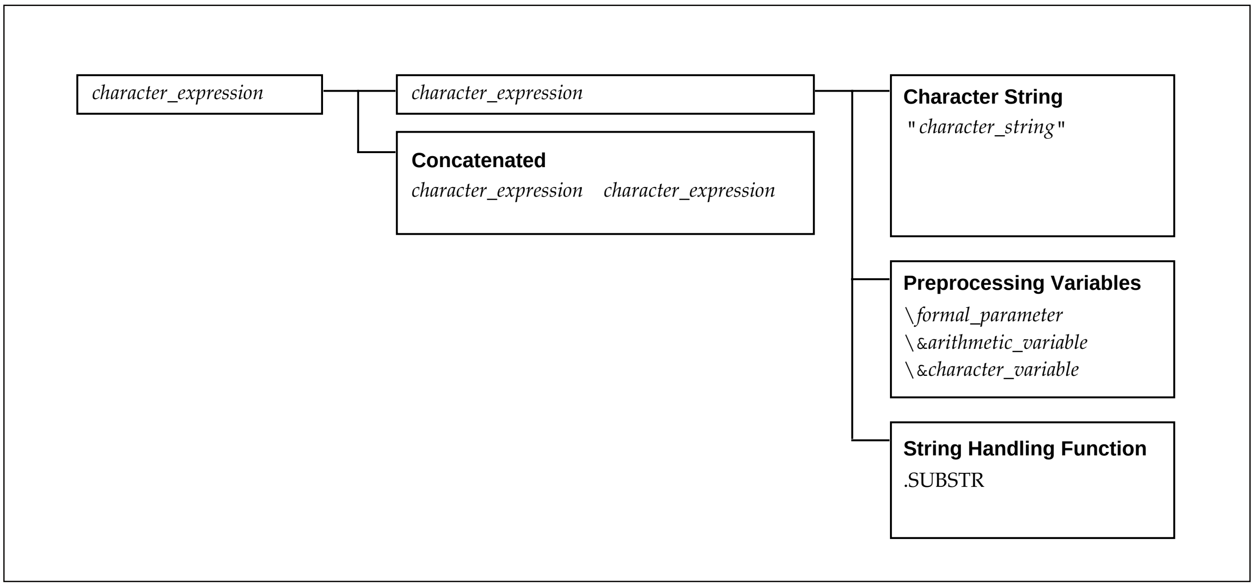


Figure 6.2 The Form of a Character Expression

■ Examples of character expressions

Examples are given below.

```
"\ARG_1" "ABCD"
"\&AVAR_1" "\ARG_1"
"\&CVAR_1" "\&CVAR_2" "EFG"
```

6.3.2.3 Logical Expressions

■ Coding rules for logical expressions

A logical expression is a sequence of one or more terms joined by use of relational operators, logical operators, and parentheses.

A logical expression yields either true of false.

■ Terms in logical expressions

What you can use as terms in logical expressions are available in three types given below :

- Arithmetic relational expressions
- Character relational expressions
- Arithmetic expressions

■ Coding rules for arithmetic relational expressions

You can use arithmetic relational expressions as terms in logical expressions.

Putting a relational operator between one arithmetic expression and another forms an arithmetic relational expression, and it yields either true or false.

Examples are given below.

```
\&AVAR_1  GT  5
\&AVAR_2  NE  \&AVAR_3
```

■ Coding rules for character relational expressions

You can use character relational expressions as terms in logical expressions.

Putting a relational operator between one character expression and another forms a character relational expression, and it yields either true of false.

Examples are given below.

```
"\&CVAR_1"  EQ  "MOJI"
"MOJI" "\&CVAR_2"  NE  "MOJISHIKI"
```

■ Coding rules for arithmetic expressions

You can use arithmetic expressions as terms in logical expressions.

If you directly give any numerical value other than 0 or if a value referenced is any numerical value other than 0, then it is regarded as true.

If you directly give a 0 or if a value referenced is 0, then it is regarded as false.

Examples are shown below.

```
\&AVAR_1
5             ————true
0             ————false
```

■ Operators and precedence

Table 6.5, 6.6, and 6.7 show operators you can use in arithmetic expressions.

Table 6.5 Arithmetic Operators used in Logical Expressions

Operator	Description
+	Unary plus
-	Unary negation
+	Binary addition
-	Binary subtraction
*	Binary multiplication
/	Binary division

Table 6.6 Relational Operators used in Logical Expressions

Operator	Description
`EQ`	Equal to (=)
`NE`	Not equal to (≠)
`LT`	Less than (<)
`LE`	Less than or equal to (≦)
`GT`	Greater than (>)
`GE`	Greater than or equal to (≧)

Table 6.7 Logical Operators used in Logical Expressions

Operator	Description
`NOT`	Unary logical NOT
`AND`	Binary logical AND
`OR`	Binary logical OR

Table 6.8 shows operator precedence.

Table 6.8 Operator Precedence for Logical Expressions

Precedence	Operators	Description
1	`( )`	Parentheses
2	`+ -`	Unary plus, unary negation
3	`* /`	Binary multiplication, binary division
4	`+ -`	Binary addition, binary subtraction
5	`EQ NE LT LE GT GE`	Comparison operators
6	`NOT`	Unary logical NOT
7	`AND`	Binary logical AND
8	`OR`	Binary logical OR

■ The form of a logical expression

Figure 6.3 shows the makeup of logical expressions.

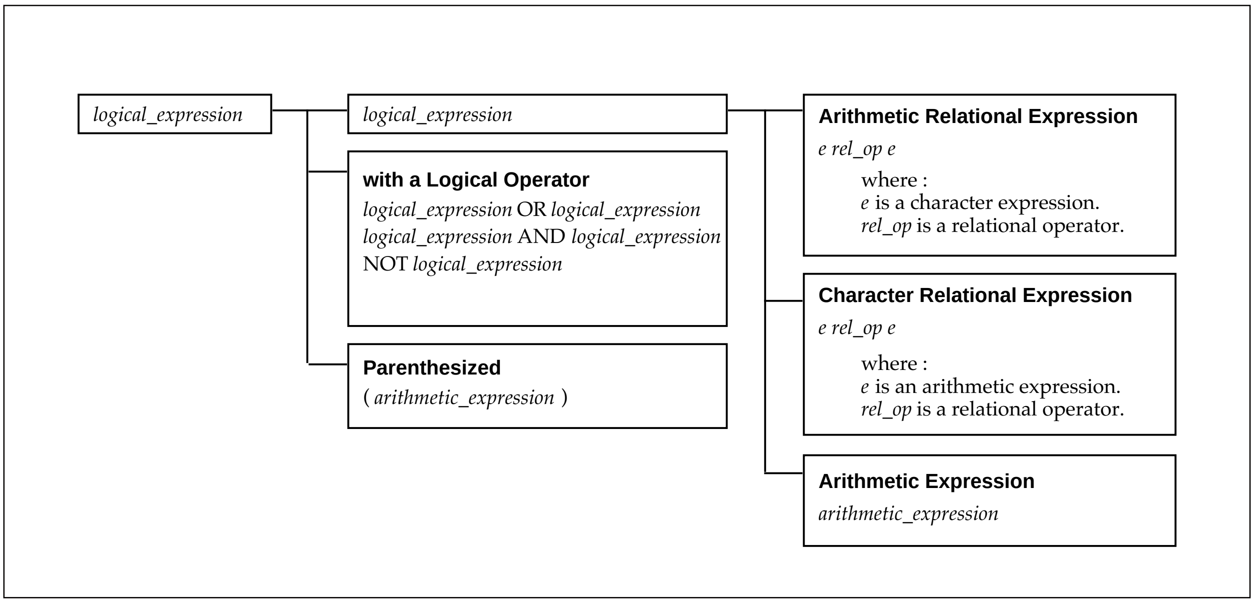

logical_expression
logical_expression
with a Logical Operator
logical_expression OR *logical_expression*
logical_expression AND *logical_expression*
NOT *logical_expression*
Parenthesized
(*arithmetic_expression*)
Arithmetic Relational Expression
e rel_op e
where :
e is a character expression.
rel_op is a relational operator.
Character Relational Expression
e rel_op e
where :
e is an arithmetic expression.
rel_op is a relational operator.
Arithmetic Expression
arithmetic_expression

Figure 6.3 The Form of a Logical Expression

6.4 Macro Definition and Expansion

6.4.1 About Macro Processes

A macro process is to defines a name (a macro name) for a series of M32R instructions or pseudo-instructions in a source program and to replace the macro name with what is defined using a macro instruction within the same source program. Macro processes include macro definition, macro call, and macro expansion.

- Macro definition — A sequence of steps to memorize M32R instructions, pseudo-instructions, etc. extending over one or more lines as a single block. This block is termed a macro body.
- Macro call — A sequence of steps to specify that a macro body memorized at the time of defining a macro is to be expanded into a source program. Writing a macro name given at the time of defining a macro in the operation field achieves a macro call.
- Macro expansion — A sequence of steps to expand a macro body in a source program by means of a macro call.

The form of macro definition and macro-call is given in Figure 6.4. And Figure 6.5 shows examples of macro expansion.

```
.MACRO  macro_name [formal_parameter[,formal_parameter]...   ;macro definition
.........................................................   ┐
........................................................................   ├─ inside  macro body
................................................   ┘
.ENDM
    :
macro_name  [argument]                                        ;macro call
```

Figure 6.4 Syntax of Macro Definition and Macro Call

```
.MACRO  MCR   ARG_1,ARG_2                          ; definition
        MV    R5,\ARG_1           ; macro body   ;
        ADD   R6,\ARG_2           ;              ;
.ENDM                             ;
    :
        MCR    R7,R7              ; macro call
```

<Macro expansion results>

```
        MV    R5,R7
        ADD   R6,R7
```

Figure 6.5 Macro Expansion

When a macro is expanded, you can give an argument from the operand of the macro-call statement.

Here follow how to define macros, how to write macro bodies and the expansion results, and how to call macros (6.4.2 through 6.4.4).

6.4.2 How to Define Macros

Macro definition is to memorize as a single block (a macro body) instructions or pseudo-instructions extending over one or more lines. How to define a macro and how it works are explained below.

Syntax

`.MACRO` *macro_name* [*formal_parameter* [, *formal_parameter*] ...]
`.ENDM`

formal_parameter : *formal_parameter_name* [=*initial_value*]

Description

The .MACRO macro-instruction declares the start of macro definition. You can set a macro name, the formal parameters, and the formal parameter's initial value to the operands of the .MACRO instruction. The user-defined macro name can be used as an object of macro call.

Macro definition is made up of the .MACRO instruction, a macro body, and the .ENDM statement. One or more spaces or tab is required between the macro name and the formal parameter. You cannot include different macro definition in macro definition. A formal parameter defined under the .MACRO instruction is valid within the relevant macro definition alone. You cannot use same-named formal parameters in one .MACRO instruction line. Either macro names or formal parameter names must conform to the name rule.

To set an initial value, you write the value after putting an equal sign (=) in succession to a formal parameter.

When you omit an argument in a macro call, if no initial value was defined under the .MACRO instruction, an empty string turns to the formal parameter, otherwise the initial value turns to the formal parameter.

To define what contains a space (   ), a comma (,), an equal sign (=), or a less-than sign (<) as an initial value, the initial value must be enclosed either in angular brackets as in <*initial_value*> or in double quotation marks as in "*initial_value*". In this instance, the double quotation marks are assumed as parts of the initial value, but the angular brackets are not.

The .ENDM instruction marks the end of macro definition. The .ENDM instruction must surely be present at the end of macro definition.

Here follow two examples of macro expansion.

Macro Expansion Example 1

```
.MACRO     MCR   ARG_1,ARG_2            ; .MACRO statement
           MV    \ARG_1,\ARG_2          ; macro body
           ADD   \ARG_1,R7              ;
.ENDM                                   ; .ENDM statement
           ⋮
MCR   R5,R6                             ; macro call
```

<Macro expansion results>

```
MV         R5,R6
ADD        R5,R7
```

Macro Expansion Example 1

```
.MACRO  MCR  ARG_1=STR_DATA,ARG_2    ; .MACRO statemant
.SECTION   \ARG_1                    ; macro body
.SDATA     "\ARG_2"                  ;
.ENDM                                ; .ENDM statemant
           ⋮
MCR   ,123                           ; macro call
```

<Macro expansion results>

```
.SECTION   STR_DATA
.SDATA     "123"
```

6.4.3 How to write a macro body and its expansion

A macro body refers to statements lying between the .MACRO statement and the corresponding .ENDM statement. A “statement” here means a group of one or more M32R instructions or pseudo-instructions (except other macro definition).

A macro body is subjected to the following at expansion-time of the macro :

- Substituting preprocessing variables
- Excluding substitutes
- Handling ordinal numbers
- Deciding comments

Here follow explanations of them.

6.4.3.1 Substituting Preprocessing Variables

Preprocessing variables in a macro body are, during macro expansion, substituted with their corresponding values. To discriminate a preprocessing variable from the character string following it, delimit them with a single quotation mark (').

A single quotation mark is not regarded as a formal parameter. (The ' is not part of a name). To use a single quotation mark ' as a character after a preprocessing variable, repeat it twice as ''. The ' used as a delimiter will not appear after expansion.

```
.MACRO   MCR        ARG_1,ARG_2           ; .MACRO statement
         MV         \ARG_1'1,\ARG_1'2     ; macro body
         .SDATA     "\ARG_2''PROG"        ;
.ENDM                                     ; .ENDM statement
        ⋮
MCR     R,ASM                             ; macro call

<Macro expansion results>

         MV      R1,R2
         .SDATA     "ASM'PROG"
```

Figure 6.6 Example of Substituting Preprocessing Variables

6.4.3.2 Excluding Substitutes

Syntax

\ *(string)*

Description

A parenthesized character string preceded by a backslash (\) is not subjected to substitution. A backslash and a pair of parentheses ((and)) used for excluding substitutes will not appear after expansion.

This character string to be excluded from substitution cannot exceed more than one line. The absence of right parenthesis) in a line up to its end is dealt with as an error, and the extent up to the end of line is excluded from substitution.

Example

```
.MACRO  MCR     ARG_1                      ; .MACRO statement
          .SDATA    "\ARG_1"               ;  macro body
          .SDATA    "\(\ARG_1)"            ;
.ENDM                                      ;  .ENDM statement
     :
 MCR   TEST                                ;  macro call
```

<Macro expansion results>

```
.SDATA    "TEST"
.SDATA    "\ARG_1"
```

6.4.3.3 Handling Ordinal Numbers

Syntax

```
\@
```

Description

An ordinal number (\@) is increased every time a macro call is made. This number here is a five-digit decimal number whose value is from 00001 to 99999. The number 00001 appears where the first expansion takes place.

Example

```
          .MACRO    MCR              ; .MACRO statement
A\@:      MV        R5,R6            ;  macro body
B\@:      ADD       R1,R5            ;
          .ENDM                      ;  .ENDM statement
            :
          MCR                        ;  macro call

<Macro expansion results>
A00001:  MV    R5,R6
B00001:  ADD   R1,R5
```

6.4.3.4 Deciding Comments

Syntax

```
\;
```

Description

A comment placed after a backslash and a semicolon (\;) will not be expanded. If \; is present halfway in a line, then the subsequent segment will not be expanded.

Example

```
.MACRO     MCR                         ; .MACRO statement
           ADD   R5,R6;TEST_1          ;  macro body
           SLLI  R5,#1\;TEST_2         ;
.ENDM                                  ;  .ENDM statement
            ⋮
MCR                                    ;  macro call
```

<Macro expansion results>

```
ADD     R5,R6;TEST_1
SLLI    R5,#1
```

6.4.4 Macro Call

A macro call directs the assembler to expand a macro body memorized through macro definition into the source program (to do macro expansion). Here follow explanations of macro call.

Syntax

[*symbol*]	*macro_name*	[*arg* [, *arg*] ...]

arg: *argument* —— When position-specified
formal_parameter_name=*argument* —— When keyword-specified

Description Write a macro name you want executed as the operation to expand its macro body. The arguments can be specify as its operands by the following ways : "position-specification", "keyword-specification", and "complex-specification" (described at a later point in this section).

To assign two or more arguments, delimit one argument from another by putting a comma (,) between them. If you put commas consecutively, arguments corresponding to the respective positions are regarded as omitted.

Values of arguments specified at the time of a macro call is given higher precedence than the initial values defined at the time of macro definition.

When you omit an argument, the initial value set at the time of macro definition is used as the argument, and an empty character string is used if no initial value was set.

To turn a string that contains a space ( ), a comma (,), an equal sign (=), or a less-than sign (<) into an argument, enclose the string either in angular brackets as in <*arg*> or in double quotation marks as in `"`*arg*`"`. For example, the argument `A<B` is represented as `<A<B>` . In this instance, the angular brackets will not be included in the initial value, but double quotation marks will be included.

■ Position-specification of arguments

Assign arguments in sequence of formal parameters as defined in macro definition. If the number of arguments is less than that of the formal parameters, the missing arguments are regarded as omitted. If the number is greater than that of the formal parameters, an error occurs and the excessive arguments are ignored.

Here follows an example.

```
.MACRO  MCR   A,B=R2,C,D=R10,E,F   ; .MACRO statemant
              MV   \A,\B           ; \C
              ADD  \D,\E           ; \F
.ENDM                              ; .ENDM statement
              ⋮
MCR    R1,,<*TEST<1>>*,R5,R6      ; macro call

<Macro expansion results>

        MV   R1,R2;*TEST<1>*
        ADD  R5,R6;
```

■ Keyword-specification of arguments

You may assign arguments regardless of the sequence of arguments as defined at the time of macro definition. To do it, specify an argument immediately preceded by a formal parameter name (defined in the macro definition) with an assignment operator (*formal_parameter_name=argument*).

If you assign duplicate formal parameters in the same line, the last specified formal parameter takes effect. If some of the formal parameters are not assigned as arguments in a macro call, they are regarded as omitted. Assigning what is not defined at the time of macro definition in making a macro call is dealt with as an error, and the assignment is ignored.

Here follows an example.

```
 .MACRO MCR   A=R1,B=R6,C,D              ; .MACRO statemant
              MV   \A,\B                 ; \C
              SLLI \D

 .ENDM                                   ; .ENDM statement

        ⋮

 MCR    C=<*TEST<2>>*,A=R2,D=<R7,#2>,A=R5    ; macro call

<Macro expansion results>

        MV   R5,R6;*TEST<2>*
        SLLI R7,#2
```

■ Complex-specification of arguments

You can use position-specifications and keyword-specifications in combination.

If some position-specified argument and some keyword-specified argument are one and the same formal parameter, the last specified argument is used.

Here follows an example.

```
.MACRO  MCR    A,B=R6,C,D=<R7,#1>       ; .MACRO statement
        ADD  \A,\B                      ; \C
        SLLI \D
.ENDM                                   ; .ENDM statement
          ⋮
 MCR   R5,D=<R7,#2>,,C=TEST,<*TEST_3*>  ; macro call
```

<Macro expansion results>

```
        ADD  R5,R6;*TEST_3*
        SLLI R7,#2
```

6.5 Nested Structure for Processing Macros

You can nest macro definitions, macro calls, and macro instructions etc., that is, you can write macro definitions or macro instructions inside other macro bodies or other control bodies using macro instructions.

Table 6.9 shows nesting in processing macros. The marks 'Yes', 'No', and '?' indicate whether or not the code shown in the column "What?" can be written in "Where?" as follows :

Yes : You can write.
No : You can not write.
? : You can or cannot use depending on circumstances.

Table 6.9 Nesting of Macros

Where? What?	Outside a Macro Definition	Inside a Macro Body	Inside a included File (by .INCLUDE)	Inside .AIF-block	Inside .AWHILE-block	Inside .AREPEAT-block	In Expressions Note1)
Macro Definition	Yes	No	Yes	Yes	No	No	No
Macro call	Yes	Yes	Yes	Yes	Yes	Yes	No
.ASSIGNA statement	Yes	Yes	Yes	Yes	Yes	Yes	No
.ASSIGNC statement	Yes	Yes	Yes	Yes	Yes	Yes	No
.INCLUDE statemant	Yes	Yes	Yes	Yes	Yes	Yes	No
.AIF-block	Yes	Yes	Yes	Yes	Yes	Yes	No
.AWHILE-block	Yes	Yes	Yes	Yes	Yes	Yes	No
.AREPEAT-block	Yes	Yes	Yes	Yes	Yes	Yes	No
.EXITM statement	No	Yes	No	?	Yes	Yes	No
.LEN, .INSTR, .SUBSTR	No	No	No	?	?	?	Yes
Preprocessing variables	No	Yes	No	No	No	No	Yes

Note1) Expressions mean arithmetic expressions, character expressions, and logical expressions in the following statement : .ASSIGNA, .ASSIGNC, .AIF, .AREPEAT, and .AWHILE.

The EXITM instruction can be put inside an .AIF-block only when the .AIF construct is written inside a macro body or an .AWHILE-block or an .AREPEAT-block. (You cannot write it elsewhere.)

A preprocessing variable can be used inside an .AIF-block or an .AWHILE-block or an .AREPEAT-block, provided that they are inside the relevant macro body (you cannot specify it outside macro definition). Arithmetic expressions, character expressions, and logical expressions are available regardless of the inside and the outside of macro definition.

6.6 Sample Programming

Using macro-instructions allows you to substitute instructions lying over one or more lines with a single instruction or to repeatedly expand instructions lying over one or more lines. In the example given below, .MACRO and .AREPEAT are taken up to explain how to use the macro instructions. Figure 6.7 shows an example of coding macro instruction lines.

```
         .SECTION   PROGRAM
;
SYMBOL:  .ASSIGNA   10
;
         .MACRO     ABC  ARG1, ARG2
                    LD24 \ARG1,#10
                    ADD3 \ARG2,\ARG1,#\&SYMBOL
         .ENDM
;
;
         ABC             R6, R7
         .AREPEAT        \&SYMBOL
            NOP
         .AENDR
;
         .END
```

Figure 6.7 Example of coding macro-instruction lines

The segment to be subjected to macro substitution is termed a macro body. A macro body is declared by use of .MACRO and .ENDM (the segment lying between .MACRO and .ENDM is the macro body). In the .MACRO instruction line, specify a macro name and its formal parameters after the mnemonic. In line 5 of Figure 6.7, `ABC` stands for the macro name, and `ARG1` and `ARG2` stand for the formal parameters. To refer a formal parameter within the macro body, precede the formal parameter with a backslash (\).

The macro name is used in a macro call (line 11 of Figure 6.7). The macro body is expanded in the macro-calling line. Character strings specified as actual arguments of the macro call are passed as arguments of the macro body, just as they are.

In using macro-instructions, arithmetic variables declared by the pseudo-instruction .ASSIGNA are available. An arithmetic variable is an entity effected by assigning an arithmetic expression to an arbitrary name. To refer an arithmetic variable, precede the variable name with a backslash and an ampersand (\&). You can use arithmetic variables within macro bodies and operands of macro-instructions (limited only to the cases in which you can write arithmetic expressions). For details of arithmetic expressions, see 6.3.2.1 “Arithmetic Expressions”.

||||| Note |||||

You cannot use symbols declared by the pseudo-instructions .EQU and .ASSIGN for macro-instructions, so be careful.

6.7 Limitations

Limitations in programming using macros are shown below :

- Nesting the .INCLUDE instructions

  The .INCLUDE instructions up to eight levels can be nested.

- The number of macro definitions

  Up to 1024 macros can be defined.

- The size of macro bodies

  Up to 128 kilobytes for macro bodies in total can be used.

- Nesting macro calls

  Macro calls up to 32 levels can be nested.

- Nesting .AREPEAT blocks or .AWHILE blocks.

  Either .AREPEAT blocks or .AWHILE blocks up to 32 levels can be nested.

- Statement size within an .AREPEAT-block or an .AWHILE-block

  16 kilobytes per statement either in an .AREPEAT-block or in an .AWHILE-block can be used.

Chapter 7

Messages from the Assembler

7.1 Getting Execution Result of the Assembler

The execution result of the assembler can be judged by the messages and the exit status.

7.1.1 Message Format

Upon encountering an error condition, the assembler outputs the error message describing the error status to the standard error output, in the following format :

- Syntax

tool_name : *input_information* : *message_type* : *message*

Note) “*input_information* :” is output only when necessary.

- Pattern

`a132R` : *file name* : *message_type* : *message*
`a132R` : *file name,line number* : *message_type* : *message*
`a132R` : *<command line>* : *message_type* : *message*
`a132R` : *message_type* : *message*

Note: Underlined items are *input_information* (no the underline is output).

- Example

```
a132R : "abc.ms",line5 : error : invalid character &
```

File name Message type Message
Tool name Line number

7.1.2 Message Types

Messages are classfied into three types depending on their severity, as shown in Table 7.1

Table 7.1 Message Type

Message Type	When an Error Occurs
Warning	Outputs a warning message and continues processing.
Error	Outputs an error message and stops processing.
Fatal error	Outputs an error message and stops processing.

For details of messages, see 7.2 “Message Lists”.

7.1.3 Exit Status

After execution, the assembler returns the exit status (value showing the execution result) as shown in Table 7.2.

Table 7.2 Exit Status

Exit Status	Result
0	Complete successfully or warning occurs.
1	Error occurs.

7.2 Message Lists

7.2.1 Warning Messages

Table 7.3 Warning Messages (1/2)

Message	Description
`constant overflow, regard as` *value*	A constant term specified has overflowed. This is regarded as *value*.
`entry point address is not in a code section`	The address specified as an entry point is not in a code section.
`entry point is not word aligned address`	The address specified as an entry point is not word-aligned.
`ignore allocation attribute of a dummy section`	You cannot specify a location attribute (`ALIGN=`*alignement* or `LOCATE=` *beginning-address*) for a dummy section, so it is ignored.
`ignore sign bit at` *n*`-bit immediate data`	There is a possibility that a 0-extended *n*-bit immediate data item doesn't agree with a specified value. [Example] `OR3 R0,R0,#-1` ;generation of code "`OR3 R0,R0,#0x0000ffff`"
`instruction out of a code section`	An instruction is described in a section whose section attribute is not CODE. If the section attribute is not CODE, a label in that section is not necessarily word-aligned, so there may be possibility in which the program does not execute correctly.
`instruction's behavior is undefined`	With the specified combination of operands, an execution result of the instruction is not guaranteed. [Example] `LD R0,@R0+`
"*label*"`: ignore label declaration`	A label is specified, but you cannot define a label in this line, so it is ignored. You cannot define a label in a line containing one of the pseudo-instructions given below: `.ALIGN, .PROGRAM, .SECTION, .END, .EXPORT, .IMPORT, .GLOBAL`

Table 7.3 Warning Messages (2/2)

Message	Description
"*label*" : not referenced import symbol	The label is not referenced in the assembly source program, but it is declared as an externally referenced symbol. In this instance, a132R does not output the reference information to the object file.
no section directive, generate section P	Section declaration by use of the pseudo-instruction .SECTION has not appeared, so the P section is automatically generated. This P section is regarded as the specification, .SECTION P,code,align=4 .
sign extension at *n*-bit displacement	There is a possibility that an *n*-bit displacement does not agree with the specified value. [Example] LD R0,@(65535,R1) ; generation of code LD R0,@(-1,R1)
sign extension at *n*-bit immediate data	There is a possibility that a sign-extended *n*-bit immediate data item doesn't agree with the specified value. [Example] ADDI R0,#255 ; generation of code ADDI R0,#-1
too long symbol, truncated	A symbol name is too long and truncated.
caution! there are some data in code section	Invalid data that is not an instruction (e.g., directive command .data) is written in the code section. Although a warning message is output, data will be located correctly.

7.2.2 Error Messages

Table 7.4 Error Messages (1/10)

Message	Description
`addressing mode error in operand` *n*	Operand *n* has been invalidly specified.
`.AENDI directive is missing`	The .AENDI statement corresponded to an .AIF statement is not found.
`.AENDR directive is missing`	The .AENDR statement corresponded to an .AREPEAT statement is not found.
`.AENDW directive is missing`	The .AENDW statement corresponded to an .AWHILE statement is not found.
`.AREPEAT buffer overflow`	Text to be expanded in .AREPEAT-block is too much. (The maximum available space to save the text is 16 Kbytes .)
`argument buffer overflow`	The space to buffer arguments of macros is not enough.
`argument specification error`	An argument in a macro call is malformed.
`argument specification is too long`	The argument specification is too long in a macro call.
`.AWHILE buffer overflow`	Text to be expanded in .AWHILE-block is too much. (The maximum available space to save the text is 16 Kbytes .)
`branch to invalid address`	The address specified as a branch target is invalid. The branch target must be word-aligned.

Table 7.4 Error Messages (2/10)

Message **Description**

can’t evaluate expression value

The assembler cannot evaluate the expression. In using the following pseudo-instructions, the expression must allow evaluation by the assembler at the time the relevant line is processed:

Expression	Specifiable?	
	Constant	Relative Address
A value to be assigned to a label by either .EQU or .ASSIGN.	Yes	Yes
An entry point address to be specified by .END *expression*	Yes	Yes
The number of repetitions to be specified by expression1 under .DATAB[.{B|H|W}] *expression1*, *expression2*	Yes	No
A reserved area to be specified under .RES[.{B|H|W}] *expression*	Yes	No

constant overflow

The value is more than the constant can be assigned.

division by zero in operand *n*

An operation has resulted in division by 0.

duplicate section attribute

The specification of attributes of a section under the pseudo-instruction .SECTION is a duplicate. You must specify one of CODE, DATA, COMMON, STACK, or DUMMY as the section attribute; and you must specify either “ALIGN= *alignment*” or “LOCATE= *beginning-address*” as a location attribute.

.ENDM directive is missing

A macro body is not closed with the .ENDM statement.

entry point should be in a code section

The address of an entry point has been invalidly specified. The specified address is not located anywhere in the sections assembled.

expression syntax error in operand *n*

A syntax error in an expression has been found in the operand *n*.

illegal label location

You can not put a symbol on the symbol field in the instruction line.

Table 7.4 Error Messages (3/10)

Message	Description
`illegal location for .AELSE`	The .AIF statement corresponded to an .ELSE statement is not found.
`illegal location for .AENDI`	The .AIF statement corresponded to an .AENDI statement is not found.
`illegal location for .AENDR`	The .AREPEAT statement corresponded to an .AENDR statement is not found.
`illegal location for .AENDW`	The .AWHILE statement corresponded to an .AENDW statement is not found.
`illegal location for .ENDM`	The .MACRO statement corresponded to an .END statement is not found.
`illegal location for .EXITM`	You wrote an .EXITM macro-instruction outside a macro.
`illegal name`	A character string of a preprocessing variable or a macro name etc. is illegal for the naming rules.
`illegal number`	A numerical value is inappropriate.
`illegal operand`	An operand of a macro-instruction is malformed.
`illegal placed source file`	The source file name is specified in inappropriate position in the command line.
`illegal redefinition`	An arithmetic variable are defined as a character variable, and vise versa.
`illegal suffix`	There is unnecessary code in the macro-instruction line.
`include nest over 8`	The nesting levels of file inclusion overflowed the maximum level 8.

Table 7.4 Error Messages (4/10)

Message	Description
`invalid address` *addr*	The specified start address *addr* is invalid.
`invalid alignment value` *value*	The specified boundary adjustment *value* is invalid.
`invalid character` *ch*	Character *ch* is not syntactically permitted.
`invalid repeat times -`*num*	The number of repetitions of -*num* is invalid. The number of repetitions must be 0 or greater.
`invalid reserve area size -`*num*	The size of the area to be reserved of -*num* is invalid. The size of the area to be reserved must be 0 or greater.
“*label*”`: can’t assign`	You cannot assign a value to *label* by use of the pseudo-instruction .ASSIGN. There is a possibility that this may be a section name, may already have been defined as a label, or may already have been declared as an externally referenced label or externally defined label.
“*label*”`: symbol declared inconsistently`	*label* has been declared inconsistently with a previous declaration. An external symbol has been declared with the .IMPORT pseudo-instruction.
“*label*”`: symbol redeclared`	The same label has been declared again. No label can be re-defined except for labels that are defined by .ASSIGN.
“*label*”`: undefined symbol`	*label* is an undefined symbol.
`line too long`	Too many characters have been written in a line.
`loop nest is too deep`	The nesting level of iterations (by .AWHILE or .AREPEAT) overflowed the maximum level 32.

Table 7.4 Error Messages (5/10)

Message	Description
macro buffer overflow	The space to buffer macro bodies is not enough.
macro call nest is too deep	The nesting level of macro call is too large than macro calls can be nested (32 levels)
macro name is missing	No macro name is specified in a macro definition.
macro table overflow	You defined more macros than the maximum definable number (1024) of them.
"*macro-instruction*" : too many operands	Too many operands are specified for the macro-instruction *macro-instruction*.
missing ,	A ',' is required.
missing =	An '=' is required.
missing >	A '>' is required.
missing) in operand *n*	A ')' is required in the *n*th operand.
multiple definition of macro	There are two macros named the same name.
multiple definition of parameter	Two formal parameters in a macro definition are one and the same name.
n-bit displacement overflow in operand *m*	The *n*-bit displacement in operand *m* has overflowed.
n-bit immediate data overflow in operand *m*	The *n*-bit immediate data in operand *m* has overflowed.

Table 7.4 Error Messages (6/10)

Message	Description
name is too long	A preprocessing variable name is too long.
negative loop counter	The operand of .AREPEAT can not be specified a negative value.
nesting of macro definition	There is macro definition inside a macro body.
non terminate string	The termination of a string has not been specified. A string must be enclosed in a pair of double quotation marks.
operator is not a permitted relative address operation	*operator* is not allowed to use as an operation for a relative address.
"*option*" : illegal placed option	The option *option* is specified in inappropriate position in the command line.
"*option*" : invalid option	Specifying the option *option* is inappropriate.
"*option*" : missing option argument	There is no parameter after the option *option*.
.PROGRAM module-name redefined	You can specify a module name only once under the pseudo-instruction .PROGRAM.
.PROGRAM module-name required	A module name is required under the pseudo-instruction .PROGRAM.
required a section name in operand *n*	A section name must be specified for sizeof in operand *n*.
required label declaration	A label to be assigned to a value must be declared on the line containing the pseudo-instruction .EQU or .ASSIGN.

Table 7.4 Error Messages (7/10)

Message	Description
required operand *n*	Operand *n* must be specified.
“*section_name*”: inconsistent section attribute	The specification of the section attribute of *section_name* is inconsistent with a previous declaration. Omitting the specification of all attributes causes a previous declaration to be in effect.□
section name required	A section name must be specified under the pseudo-instruction .SECTION.
shift amount should be a constant	The amount of the shift must be specified by a constant expression.
sizeof(*section_name*): not a constant	sizeof (*section_name*) is not a constant. This cannot be used as a constant expression.
string : constant syntax error	*string* has resulted in a syntax error. Interpretation started by regarding it as a constant term in an expression, but a syntax error has been detected.
:*string* : invalid displacement size in operand *n*	The displacement size “:*string*“ specified in the operand *n* is invalid.
:*string*: invalid immediate size in operand *n*	The immediate data size “:*string*“ specified in the operand *n* is invalid.
.*string* : invalid size in operand *n*	The operand size “.*string*” specified in the operand *n* is invalid.
string is too long	The character string *string* is too long.
“*symbol*”: can’t import/export	You cannot make *symbol* be either an externally referenced symbol or an externally defined *symbol*. There is a possibility that *symbol* may have been made to be a section name or a label defined under .ASSIGN.

Table 7.4 Error Messages (8/10)

Message **Description**

"*symbol*" : inconsistent import/export declare

Specification of an external reference or external definition for *symbol* is inconsistent with a previous definition.

"*symbol*" : not a section name in operand *n*

The symbol used in the expression sizeof (*symbol*) in the operand *n* is not a section name.

"*symbol*" : not has constant value

symbol is not a symbol to which a constant is assigned. This cannot be used as a constant expression.

syntax error at or near *token* in operand *n*

A syntax error has been found near *token* in operand *n*.

syntax error in constant expression

A syntax error has been found in a constant expression. There is a possibility that a label assigned to an address has been used.

syntax error in directive operand

An operand of a pseudo-instruction has been invalidly specified.

syntax error in expression

An expression is in syntax error.

syntax error in macro body

Specification for excluding substitutes is inappropriate.

syntax error in macro operand

A formal parameter or an initial values in a macro definition line are malformed.

too complex expression in operand *n*

This expression is too complex to process.

too large reserve area

A value specified as the size of the area to be reserved is too large. It has exceeded the 32-bit logical address space.

Table 7.4 Error Messages (9/10)

Message **Description**

too long command line

There are too many characters in a command line.

too long string

The string is too long. The number of characters for a character constant in an expression must be equal to 4 or less; or equal to 242 or less under the pseudo-instruction .SDATAB.

too many arguments

There are too many arguments in a macro call.

too many source files

You specified too many source files.

trap number should be a constant

A trap number must be specified by a constant expression.

unexpected end-of-file

A syntax error has been found. An unexpected end of file has appeared.□

unexpected end-of-line

A syntax error has been found. An unexpected end of line has appeared.

unexpected *token*, required symbol

token has appeared where a symbol must be specified. The operand of .EXPORT, .IMPORT, or .GLOBAL is a suite of symbols of which each is connected by a comma.

unknown directive *.token*

.token is an unknown pseudo-instruction.

unknown instruction *token*

.token is an unknown instruction.

unknown size *.token*

.token is an unknown operand size.

value : overflow for byte

The value of an expression has become *value* which cannot fit in a byte.

Table 7.4 Error Messages (10/10)

Message	Description
value `: overflow for halfword`	The value of an expression has become *value* which cannot fit in a halfword.
value `: overflow for word`	The value of an expression has become *value* which cannot fit in a word.
"*variable*" `: preprocess value is not defined`	There is an undefined preprocessor variable *variable* inside a macro body or in an expression.
`zero division in the expression`	An expression contains a division by zero.
`instruction placed on odd location`	The instruction written here will be located at an odd address (its location counter shows an odd number).
floating point number overflow	There occurred floating-point number overflow. The maximum value that can be expressed was set.
floating point number underflow	There occurred floating-point number underflow. The value was set to zero (0).
too many digits in floating point number; extra digits ignored	The floating-point number in the exponent part overflowed. The maximum value that can be expressed was set.

7.2.3 Fatal Error Messages

Table 7.5 Fatal Error Messages

Message	Description
can’t create default section	A default section cannot be generated. Assembling has been stopped.□
“*file_name*” : can’t close file	The file *file_name* could not be closed.
“*file_name*” : can’t open file	The file *file_name* could not be opened.
“*file_name*” : cannot delete file	The temporary file *file_name* could not be deleted.
out of heap space	Memory space is not enough.
out of memory	Take measures such as increase available memory, divide files into secondary ones etc.
too many errors ! Good bye !	Many errors have been detected. Assembling has been stopped.
“*tool*” : can’t execute file	The assembler cannot invoke *tool*.

Appendix A

M32R Instruction Set Summary

This appendix outlines general instructions (elements of the M32R instruction set), function group by function group. They are roughly classified into the following six groups :

- Load/store instructions
- Transfer instructions
- Arithmetic/logic operation instructions (Compare, arithmetic operation, logical operation, and shift instructions)
- Branch instructions
- EIT-related instructions
- DSP function Instructions

Note) "Exception", "interrupt", and "trap" are collectively referred to as "EIT".

This appendix uses the conventions in Table A.1 to indicates operands.

Table A.1 Appendix A Conventions (1/2)

Operand	Meaning
R*n*	A general register (*n*=0-15).
CR*n*	A control register.
A*n*	An accumulator (*n*=0, 1).
@R*n*	Content of memory indicated by the content of a general register (address).
@R*n*+	Indicates that the content of a general register Rn is incremented by 4 (the register is updated) after Rn is referenced (register indirect).
@+R*n*	Indicates that the content of a general register Rn is incremented by 4 (the register is updated) before Rn is referenced (register indirect).
@-R*n*	Indicates that the content of a general register Rn is decremented by 4 (the register is updated) before Rn is referenced (register indirect).

Table A.1 Appendix A Conventions (2/2)

Operand(s)	Meaning
`Rsrc`, `Rsrc`*n*	A referenced general register. (It has an address or a value of an object.)
`CRsrc`	A referenced control register.
`Rdst`, `CRdest`	A destination register.
`disp_`*n*	An *n*-bit displacement.
`imm_`*n*	An *n*-bit signed immediate integer.
`label_`*n*	A label put at the branch target (*n* represents a displacement).

For details of individual instructions, see “M32R Software Manual”.

A.1 M32R Instruction Set

■ Load/Store Instructions

Table A.2 Load/Store Instructions

Group	Mnemonic	Operand(s)	Function
Load / Store	LD	Rdest, @Rsrc	Load
	LD	Rdest, @(disp16, Rsrc)	
	LD	Rdest, @(LOW(disp), Rsrc)	
	LD	Rdest, @Rsrc+	
	LDB	Rdest, @Rsrc	Load byte
	LDB	Rdest, @(disp16, Rsrc)	
	LDB	Rdest, @(LOW(disp), Rsrc)	
	LDH	Rdest, @Rsrc	Load halfword
	LDH	Rdest, @(disp16, Rsrc)	
	LDH	Rdest, @(LOW(disp), Rsrc)	
	LDUB	Rdest, @Rsrc	Load byte unsigned
	LDUB	Rdest, @(disp16, Rsrc)	
	LDUB	Rdest, @(LOW(disp), Rsrc)	
	LDUH	Rdest, @Rsrc	Load halfword unsigned
	LDUH	Rdest, @(disp16, Rsrc)	
	LDUH	Rdest, @(LOW(disp), Rsrc)	
	LOCK	Rdest, @Rsrc	Load locked
	ST	Rsrc1, @Rsrc2	Store
	ST	Rsrc1, @(disp16, Rsrc2)	
	ST	Rsrc1, @(LOW(disp), Rsrc2)	
	ST	Rsrc1, @+Rsrc2	
	ST	Rsrc1, @-Rsrc2	
	STB	Rsrc1, @Rsrc2	Store byte
	STB	Rsrc1, @(disp16, Rsrc2)	
	STB	Rsrc1, @(LOW(disp), Rsrc2)	
	STH	Rsrc1, @Rsrc2	Store halfword
	STH	Rsrc1, @(disp16, Rsrc2)	
	STH	Rsrc1, @(LOW(disp), Rsrc2)	
	UNLOCK	Rsrc1, @Rsrc2	Store unlocked

■ Transfer Instructions

Table A.3 Transfer Instructions

Group	Mnemonic	Operand(s)	Function
Transfer	LD24	Rdest, #imm24	Load 24-bit immediate
	LDI	Rdest, #imm8	Load immediate
	LDI	Rdest, #imm16	
	MV	Rdest, Rsrc	Move register
	MVFC	Rdest, CRsrc	Move from the control register
	MVTC	Rdest, CRsrc	Move to the control register
	SETH	Rdest, #imm16	Set high-order 16-bit
	SETH	Rdest, #HIGH(imm)	
	SETH	Rdest, #SHIGH(imm)	

■ Arithmetic/logic Operation Instructions

Table A.4 Arithmetic/Logic Operation Instructions (1/2)

Group	Mnemonic	Operand(s)	Function
Compare	CMP	Rsrc1, Rsrc2	Compare
	CMPI	Rsrc, #imm16	Compare immediate
	CMPU	Rsrc1, Rsrc2	Compare unsigned
	CMPUI	Rsrc, #imm16	Compare unsigned immediate
Arithmetic operation	ADD	Rdest, Rsrc	Add
	ADD3	Rdest, Rsrc, #imm16	Add 3-operand
	ADDI	Rdest, #imm8	Add immediate
	ADDV	Rdest, Rsrc	Add (with overflow checking)
	ADDV3	Rdest, Rsrc, #imm16	Add 3-operand (with overflow checking)
	ADDX	Rdest, Rsrc	Add with carry
	NEG	Rdest, Rsrc	Negate
	SUB	Rdest, Rsrc	Subtract
	SUBV	Rdest, Rsrc	Subtract (with overflow checking)
	SUBX	Rdest, Rsrc	Subtract with borrow
	DIV	Rdest, Rsrc	Divide
	DIVU	Rdest, Rsrc	Divide unsigned
	MUL	Rdest, Rsrc	Multiply
	REM	Rdest, Rsrc	Remainder
	REMU	Rdest, Rsrc	Remainder unsigned

Table A.4 Arithmetic/Logic Operation Instructions (2/2)

Group	Mnemonic	Operand(s)	Function
Logic operation	`AND`	`Rdest, Rsrc`	AND
	`AND3`	`Rdest, Rsrc, #imm16`	AND 3-operand
	`NOT`	`Rdest, Rsrc`	Logical NOT
	`OR`	`Rdest, Rsrc`	OR

	`OR3`
	`OR3`
		`Rdest, Rsrc, #imm16`
		`Rdest, Rsrc, #LOW(imm)`
			OR 3-operand

	`XOR`	`Rdest, Rsrc`	Exclusive OR
	`XOR3`	`Rdest, Rsrc, #imm16`	Exclusive OR 3-operand
Shift	`SLL`	`Rdest, Rsrc`	Shift left logical
	`SLL3`	`Rdest, Rsrc, #imm16`	Shift left logical 3-operand
	`SLLI`	`Rdest, #imm5`	Shift left logical immediate
	`SRA`	`Rdest, Rsrc`	Shift right arithmetic
	`SRA3`	`Rdest, Rsrc, #imm16`	Shift right arithmetic 3-operand
	`SRAI`	`Rdest, #imm5`	Shift right arithmetic immediate
	`SRL`	`Rdest, Rsrc`	Shift right logical
	`SRL3`	`Rdest, Rsrc, #imm16`	Shift right logical 3-operand
	`SRLI`	`Rdest, #imm5`	Shift right logical immediate

■ Branch Instructions

Table A.5 Branch Instructions

Group	Mnemonic	Operand(s)	Function
Branch	BC	label_8	Branch on C-bit
	BC	label_24	
	BEQ	Rdest, Rsrc,label_16	Branch on equal
	BEQZ	Rsrc, label_16	Branch on equal zero
	BGEZ	Rsrc, label_16	Branch on greater than or equal to zero
	BGTZ	Rsrc, label_16	Branch on greater than zero
	BL	label_8	Branch and link
	BL	label_24	
	BLEZ	Rsrc, label_16	Branch on less than or equal to zero
	BLTZ	Rsrc, label_16	Branch on less than zero
	BNC	label_8	Branch on not C-bit
	BNC	label_24	
	BNE	Rdest, Rsrc, label_16	Branch on not equal
	BNEZ	Rsrc, label_16	Branch on not equal to zero
	BRA	label_8	Branch
	BRA	label_24	
	JL	Rsrc	Jump and link
	JMP	Rsrc	Jump
	NOP	none	No operation

■ EIT-related Instructions

Table A.6 EIT-related Instructions

Group	Mnemonic	Operand(s)	Function
EIT-related	RTE	none	Return from EIT
	TRAP	#imm_4	Trap

Note) “Exception”, “interrupt”, and “trap” are collectively referred to as “EIT”.

■ DSP Function Instructions

Table A.7 DSP Function Instructions

Group	Mnemonic	Operand(s)	Function
DSP Function	MACHI	Rsrc1, Rsrc2	Multiply-accumulate high-order halfwords
	MACLO	Rsrc1, Rsrc2	Multiply-accumulate low-order halfwords
	MACWHI	Rsrc1, Rsrc2	Multiply-accumulate word and high-order halfword
	MACWLO	Rsrc1, Rsrc2	Multiply-accumulate word and low-order halfword
	MULHI	Rsrc1, Rsrc2	Multiply high-order halfwords
	MULLO	Rsrc1, Rsrc2	Multiply low-order halfwords
	MULWHI	Rsrc1, Rsrc2	Multiply word and high-order halfword
	MULWLO	Rsrc1, Rsrc2	Multiply word and low-order halfword
	MVFACHI	Rdest	Move from accumulator high-order word
	MVFACLO	Rdest	Move from accumulator low-order word
	MVFACMI	Rdest	Move from accumulator middle-order word
	MVTACHI	Rsrc	Move to accumulator high-order word
	MVTACLO	Rsrc	Move to accumulator low-order word
	RAC	none	Round accumulator
	RACH	none	Round accumulator halfword

A.2 Extended Instructions of M32Rx/D Series

A.2.1 New Extended Instructions of M32Rx

The table below lists the new instructions that have been added in the M32Rx/D series from the M32R family instruction set.

■ New Extended Instructions of M32Rx

Table A.8 New Extended Instructions of M32Rx

Group	Mnemonic	Operand(s)	Function
Compare	CMPEQ	Rsrc1, Rsrc2	Compare (between registers)
	CMPZ	Rsrc	Compare (register and immediate value 0 (zero))
Arithmetic operation	DIVH	Rdest, Rsrc	Divide (16-bit signed integer)
Branch	BCL	pcdisp8 or pcdisp24	Branch when condition bit (C) = 1 and store return address in R14
	BNCL	pcdisp8 or pcdisp24	Branch when condition bit (C) = 0 and store return address in R14
DSP Function	MACLH1	Rsrc1, Rsrc2	Multiply and accumulate (register x register + accumulator A1 -> accumulator A1)
	MACWU1	Rsrc1, Rsrc2	Multiply and accumulate (register x register + accumulator A1 -> accumulator A1)
	MSBLO	Rsrc1, Rsrc2	Multiply and accumulate (register x register - accumulator A1 -> accumulator A1)
	MULWU1	Rsrc1, Rsrc2	Multiply (register x register -> accumulator A1)
	SADD		Add (accumulator A0 + accumulator A1 -> accumulator A0)
	SATB	Rdest, Rsrc	Round off byte size for register data
	SATH	Rdest, Rsrc	Round off halfword size for register data

Note: Because mnemonics for accumulators ACC0 and ACC1 are specified by A0 and A1, they are expressed by A0 and A1 in the above table.

A.2.2 Specification Extended Instructions of M32Rx

The table below lists the instructions whose specifications have been extended in the M32Rx/D series from the M32R family instruction set.

■ Specification Extended Instructions of M32Rx

Table A.9 Specification Extended Instructions of M32Rx

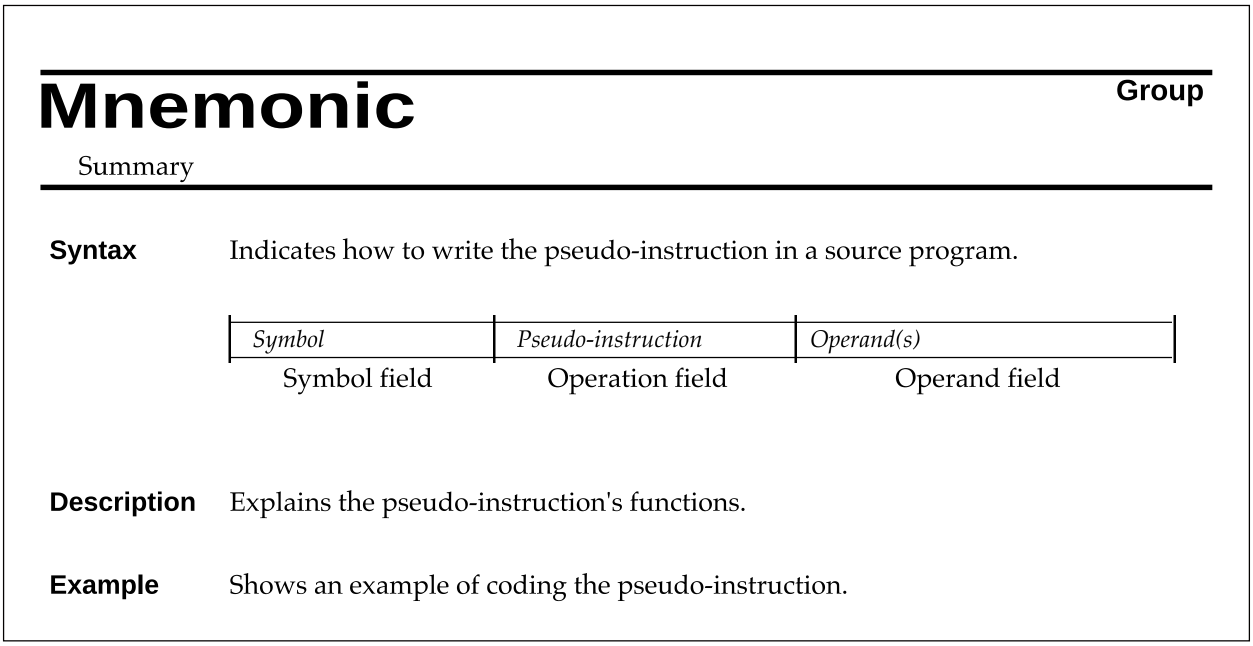
Group	Mnemonic	Operand(s)	Function
DSP Function	MACHI	Rsrc1, Rsrc2, Adest	Pursuant to extension to two accumulators, accumulators A0 and A1 can be specified in operand description.
	MACLO	Rsrc1, Rsrc2, Adest	
	MULHI	Rsrc1, Rsrc2, Adest	
	MULLO	Rsrc1, Rsrc2, Adest	
	MVFACHI	Rdest, Asrc	
	MVFACLO	Rdest, Asrc	
	MVFACMI	Rdest, Asrc	
	MVTACHI	Rsrc, Adest	
	MVTACLO	Rsrc, Adest	
	RAC	Adest, Asrc, #imml	Pursuant to extension to two accumulators, accumulators A0 and A1 can be specified in operand description. Also, the bitwise left-shifted value where accumulator is specified by immediate data (imm1) is reflected in round-off operation.
	RACH	Adest, Asrc, #imml	

Note: Because mnemonics for accumulators ACC0 and ACC1 are specified by A0 and A1, they are expressed by A0 and A1 in the above table.

Appendix B

Pseudo-instruction Reference

This appendix explains the pseudo-instructions of the assembler in an alphabetical order. The symbolic convention is as given in Figure B.1.



Mnemonic

Group

Summary

Syntax Indicates how to write the pseudo-instruction in a source program.

Symbol	*Pseudo-instruction*	*Operand(s)*
Symbol field	Operation field	Operand field

Description Explains the pseudo-instruction's functions.

Example Shows an example of coding the pseudo-instruction.

Figure B.1 Pseudo-instruction Reference Format

If a *symbol* is not written in the symbol field, you cannot specify a symbol in the symbol field. You need to separate one field from another by putting one or more spaces (space characters) between them.

The notation given in Table B.1 is used throughout this appendix.

Table B.1 Appendix B Conventions

Symbol	Meaning
[ ]	Encloses an optional element
.size	Represents a size specification such as "`.B`"

.ALIGN

Address Control

Adjusts the location counter to a boundary.

Syntax

	`.ALIGN`	*expression*

expression : Adjustment for location counter
expression=2^n (n=0,1,2,...,31)

Description

The pseudo-instruction .ALIGN advances the location counter to the boundary specified by the expression *expression*, if the current location counter does not lie at the boundary specified by the pseudo-instruction .SECTION. .ALIGN does nothing if the current location counter lies at the boundary specified.

The rules for specifying the expression in this pseudo-instruction are as follows :

- A location counter adjustment value for the expression must satisfy the following conditions :

  An absolute value within a range from 1 through 2^{31}, and *n*th power of 2

  A value equal to or less than a location counter adjustment value declared by the pseudo-instruction .SECTION

- The expression is a constant expression.
- A symbol to be used as a term in the expression must have been defined before this pseudo-instruction.
- If the value of the location counter adjustment declared by the .ALIGN pseudo-instruction is equal to or less than the value of the location counter adjustment declared by ALIGN=*expression* in the .SECTION pseudo-instruction , an error occurs.

Example

```
.ALIGN     4
```

.ASSIGN

Set Symbol

Declares a value symbol (possible to reassign).

Syntax

symbol	`.ASSIGN`	*expression*

expression : Symbol value

Description

The pseudo-instruction .ASSIGN assigns the value of *expression* to the symbol *symbol* specified in the symbol field.

A value symbol defined by this pseudo-instruction is termed a “changeable value symbol”. It is dealt with as follows :

- Its value can be changed by use of the pseudo-instruction .ASSIGN.
- It cannot be used as an externally defined symbol.
- No debugging information about it is output.

The rules for specifying the expression in this pseudo-instruction are as follows :

- One of these values can be assigned to the expression :
  An absolute value
  A positive relative value (only one relative value)
- A symbol to be used as a term in the expression must have been defined before this pseudo-instruction appears.

Example

```
COUNT:  .ASSIGN   h'1084
```

.DATA

Set Data

Sets integer data.

Syntax

[*symbol*]	`.DATA` [`.`*size*]	*expression* [`,` *expression*] ...

size	: Size specification	`.B`(byte = 8 bits) `.H`(halfword = 16 bits) `.W` (word = 32 bits [default])
expression	: An integer to be set	

Description

The pseudo-instruction .DATA reserves the areas having the size specified by *size*, and sets values (integers) assigned to the expressions *expression*s. You specify the size of the area using `.B`(byte = 8 bits), `.H`(halfword = 16 bits), or `.W` (word = 32 bits). If no specification is given, `.W` is specified.

The rules for specifying the expression in this pseudo-instruction are as follows :

- Either an absolute value or a relative value can be assigned to the expression. And a signed integer or an unsigned integer can be assigned.
- The expression must be assigned a value that can be expressed within the range specified by *size*.

Example

```
TABLE:  .DATA.H    h'12, h'35A8
```

.DATAB

Set Data

Sets integer data (data block).

Syntax

[*symbol*]	.DATAB [. *size*]	*expression_a* , *expression_b*

.size : Size specification .B(byte = 8 bits)
.H(halfword = 16 bits)
.W (word = 32 bits [default])

expression_a : The number of blocks to reserve

expression_b : An integer to be set

Description

The pseudo-instruction .DATAB reserves data areas having the size specified by *size* with as many as *expression_a* indicates, and sets integers represented by *expression_b* in the respective areas. The size of the area is specified by using the size specifiers .B(byte = 8 bits), .H(halfword = 16 bits), or .W (word = 32 bits). If no specification is given, .W is specified.

The rules for specifying the expressions in this pseudo-instruction are as follows :

- *expression_a* must be a constant expression which is assigned to an absolute integer equal to 0 or greater. A symbol to be used as a term in *expression_a* must have been defined before this pseudo-instruction.
- *expression_b* can be assigned to a signed integer or an unsigned integer. The value of *expression_b* must be within a range specified by *.size.*

Example

```
TABLE:  .DATAB.W   10, h'48153CD
```

.END

Program Structure Definition

Marks the end of a source program.

Syntax

	`.END`	[*expression*]

expression : Specification for the start address of program (entry point)

Description

The pseudo-instruction .END marks the end of the source program. Source programs, if put after this pseudo-instruction, are ignored, but cause no error.

By writing an expression in the operand field, an entry point can be specified. An entry point indicates the program's start address.

The rules for specifying the expression in this pseudo-instruction are as follows :

- The value of the expression must be an address in the source program.
- One of these values can be assigned to the expression :
  An absolute value
  A positive relative value (only one relative value)
- Omitting the expression sets no entry point.

The entry point must be an address within the CODE section.

||||| Note |||||

If two or more modules have entry point information, an error occurs at link-time.

Example

```
.END  LABEL
```

.EQU

Set Symbol

Declares a value symbol.

Syntax

symbol	`.EQU`	*expression*

expression : Symbol value

Description

The pseudo-instruction .EQU assigns the value of the expression *expression* to the symbol *symbol* specified in the symbol field. You cannot define the same symbol more than once.

The rules for specifying the expression in this pseudo-instruction are as follows :

- One of these values can be assigned to the expression :
  A constant
  A positive relative value (only one relative value)
- The symbol to be used as a term in the expression must have been defined before this pseudo-instruction appears..

Example

```
SYMBOL: .EQU h'D51
```

.EXPORT

Symbol External Definition/External Reference

Declares an external definition symbol.

Syntax

	`.EXPORT`	*symbol* [, *symbol*] ...

Description

The pseudo-instruction .EXPORT declares a symbol defined in a module to be referenced by another module.

The symbol(s) must satisfy the conditions as follows :

- It has either an absolute value or an address in a source program.
- It is defined in a relevant module.
- It is other than those for which a value is defined by use of the pseudo-instruction .ASSIGN.

This pseudo-instruction can be use in any line in a source program.

Example

```
    .EXPORT    LABEL0, SYMBOL0
```

.GLOBAL

Symbol External Definition/External Reference

Declares an external definition / external reference symbol.

Syntax

	.GLOBAL	*symbol* [, *symbol*] ...

Description

The pseudo-instruction .GLOBAL has two functions :

- Declaration of externally defined symbols

  Declares a symbol defined in a module to be referenced by another module.

- Declaration of externally referenced symbols

  Declares that a symbol defined in another module is an externally referenced symbol when referencing it.

The rules for specifying the symbol(s) in this pseudo-instruction are as follows :

- The symbol(s) must be either an absolute value or an address in a source program.
- A symbol defined by the pseudo-instruction .ASSIGN cannot be declared to be an external defined symbol.
- A specified symbol is regarded as an externally defined symbol if defined in the relevant module or as an externally referenced symbol if not defined.

This pseudo-instruction can be use in any line in the source program.
This pseudo-instruction can be use instead of the pseudo-instructions .IMPORT and .EXPORT (.GLOBAL has functions similar to those of .IMPORT and .EXPORT.).

Example

```
.GLOBAL    EXTLAB, IMPSYM
```

.IMPORT

Symbol External Definition/External Reference

Declares an external reference symbol.

Syntax

	.IMPORT	*symbol* [,*symbol*]

Description

The pseudo-instruction .IMPORT declares that a symbol defined elsewhere is an externally referenced symbol when referencing it.

The rules for specifying the symbol(s) in this pseudo-instruction are as follows :

- A symbol to be declared must have been defined in another module by use of the pseudo-instruction .EXPORT or .GLOBAL.
- A symbol already defined in the same module cannot be declared by this pseudo-instruction.

This pseudo-instruction can be use in any line in the source program.

Example

```
.IMPORT    EXTLAB, EXTSYM
```

.PROGRAM

Program Structure Definition

Specifies a module name.

Syntax

	`.PROGRAM`	*module_name*

Description

The pseudo-instruction .PROGRAM specifies a module name. The module name *module_name* specified by this pseudo-instruction is kept unchanged and is passed to the load module. A debugger uses the module name to load a load module to be debugged.

If this pseudo-instruction is omitted (a module name is not declared by this pseudo-instruction), the name formed by deleting the extension (`.mo`) from the assembler-generated object module name becomes the module name. If the object module name is not in conformity with the naming rules, the portion up to the first occurrence of period (.) becomes the module name.
(Example : For `A.B.C.D`the module name becomes `A`)

The rules for specifying the module name in this pseudo-instruction are as follows :

- A module name must follow the naming rules. For the naming rules, see 3.5 "Naming Rules".
- A name used as a module name can be also used as a name other than a module name.

This pseudo-instruction can be used only once in a source program.
This pseudo-instruction can be placed in any line in the source program.

Example

```
.PROGRAM   MAIN
```

.RES

Reserve Memory

Reserves a data area.

Syntax

[*symbol*]	`.RES[.`*size*`]`	*expression*

.size : Size specification `.B`(byte = 8 bits)
`.H`(halfword = 16 bits)
`.W` (word = 32 bits [default])

expression : The number of blocks to reserve

Description

The pseudo-instruction .RES reserves areas having their size specified by *.size* as many areas as the number expression indicates. You specify the size of area by using `.B`(byte = 8 bit), `.H`(halfword = 16 bits), or `.W` (word = 32 bits). If no specification is given, `.W` is specified.

Rules for specifying expression in using this pseudo-instruction are given below.

- The value of expression must satisfy the conditions as follows :
  An absolute value
  An integer equal to 0 or greater
- A symbol to be used as a term in the expression must have been defined before this pseudo-instruction appears.

Example

```
WORK:   .RES.B     20
```

.SDATA

Set Data

Sets character string data.

Syntax

[*symbol*]	`.SDATA`	*string* [, *string*]

Description

The pseudo-instruction .SDATA reserves a data area and sets the strings in that area.

The rules for specifying the strings in this pseudo-instruction are as follows :

- A string consists of sequences of characters enclosed in double quotation marks (as in `"abc`)"and/or ASCII codes enclosed in angle brackets (as in `<49>`).
- To include a double quotation mark in a string, put it twice in succession, as in `""`.

Example

```
TABLE:  .SDATA     "HELLO", "WORLD"
```

.SDATAB

Set Data

Sets character string data (data block).

Syntax

[*symbol*]	`.SDATAB`	*expression* , *string*

expression : The number of blocks to reserve

Description

The pseudo-instruction .SDATAB reserves data areas for strings with as many areas as the number expression indicates, and sets strings in the respective areas.

The rules for specifying the expression in this pseudo-instruction are as follows :

- The value of expression must satisfy the conditions as follows :
  An absolute value
  An integer equal to 0 or greater
- A symbol to be used as a term in the expression must have been defined before this pseudo-instruction appears.

The rules for specifying the strings in this pseudo-instruction are as follows :

- A string consists of sequences of characters enclosed in double quotation marks (as in `"abc`)"and/or ASCII codes enclosed in angle brackets (as in `<49>`).
- To include a double quotation mark in a string, put it twice in succession, as in `""`.

Example

```
TABLE:  .SDATAB    20, "HELLO"
```

.SECTION

Program Structure Definition

Declares a section.

Syntax

	`.SECTION`	*section_name* [, *attribute_a*] [, *attribute_b*]

attribute_a : `CODE` | `COMMON` | `DATA` | `DUMMY` | `STACK`
Section attribute (default : `CODE`)

attribute_b : `ALIGN=` *expression* | `LOCATE=`*expression*
Location attribute (default : `ALIGN=4`)

Description

The pseudo-instruction .SECTION issues a section declaration by specifying the following :

- Specifying a section name
- Declaring whether or not a section may be executed and indicating the linking method to the linker (specifying a section attribute)
- Specifying the locating method of a section (specifying a location attribute)

For details of linkage and location of sections, see “CC32R User's Manual <Assembler> lnk32R”.

<The default section>

The default section specifications are :

```
.SECTION P,CODE,ALIGN=4
```

The section name defaults to P, the section attribute defaults to CODE, and the location attribute defaults to ALIGN=4).

The assembler generates a default section if one of the following instructions exist between the beginning and the first .SECTION pseudo-instruction in a source program :

- An instruction to generate object code such as a general instruction or an area-reserving pseudo-instruction, etc.

<Continuation of section>

If the pseudo-instructions .SECTION, which specifies the same section name, exists more than once within a source program, the sections having the same name are regarded as a single contiguous section. In this instance, the first .SECTION pseudo-instruction represents the beginning of the section and others represent the continuation of sections. The location counter, when sections continue, indicates :

the location counter of the end of the immediately preceding same-named section + 1

<Section size>

The maximum location value among the same-named sections results in the section size. Inconsistencies, for example specifying different attributes, must not exist among .SECTION pseudo-instructions specifying the same section name in a program.

The rules for specifying the section name in this pseudo-instruction are as follows :

- The section name must follow the naming rules.

<Specification rules for the operands>

The rules for specifying the attributes in this pseudo-instruction are as follows :

- The section attribute *attribute_a* and the location attribute *attribute_b* can be put in an optional sequence.
- The section attribute *attribute_a* and the location attribute *attribute_b* can be specified single attribute respectively.

The following are details of attribute specifications :

- About section attribute (*attribute_a*)

The section attribute declares whether or not a section may be executed and gives directives as to the linking method of sections to the linker. If the section attribute is omitted, CODE is assumed by default.
The following shows section attributes which you can specify with their specifications.

Section Attribute (Meaning)	Specifications
CODE (code section)	The section is executable (The executable section is limited to only CODE). The linking method for this section is simple link.
DATA (data section)	The section is non-executable. The linking method for this section is simple link.
STACK (stack section)	The section is non-executable. The linking method for this section is simple link.
COMMON (common section)	The section is non-executable. The linking method for this section is common link.
DUMMY (dummy section)	The section is non-executable. You cannot specify the location attribute *attribute_b* here. A dummy section is assembled, but no object code is output. The symbols defined within a dummy section are given a location counter in relation to the section's beginning, which is counted as 0, to be dealt with as symbols having an absolute value.

Sections are linked in one of two linking methods, simple link or common link. The following are the linking methods :

Linking Method	Linking and Handling by the Linker
Simple link	Links all the same-named sections to regard them as a single contiguous section. The alignment (the boundary adjustment) in locating sections complies with the respective location attributes specified under the pseudo-instruction .SECTION.
Common link	Shares same-named sections present in other modules and memories as well. Same-named sections to be linked must have the same attributes. The maximum size among the sections to be linked becomes the section size after linkage.

||||| Supplement about the dummy section |||||

A dummy section is a special section to be used in dealing with structure data. It is used to declare symbols representing the structure data members. Examples of declaration are :

```
     .SECTION  ABC, DUMMY
DT0:.RES.W      1
DT1:.RES.H      1
DT2:.RES.H      1
```

An offset (an absolute value) from the section's beginning is assigned to the label symbols defined in a dummy section as shown before. Thus the program above is equivalent to an instance in which the following definition is given by use of the pseudo-instruction .EQU :

```
DT0:.EQU       0
DT1:.EQU       4
DT2:.EQU       6
```

Using a dummy section allows you to easily reference, set, add, or delete a member of a structure . For example, to reference a member of the structure shown previous and assign an integer to it, you write as follows (the first label of structure data is assumed to be STRU) :

```
LD24 R0,#STRU
LDI  R1,#10
ST   R1,@( DT0, R0 )
LDI  R1,#20
STH  R1,@( DT1, R0 )
SDL  R1,#30
STH  R1,@( DT2, R0 )
```

- About location attribute (*attribute_b*)

The location attribute declares whether the section is either in relocatable format or in absolute format, and gives directives as to the locating method of the section to the linker. If you omit the location attribute, the default attribute, ALIGN=4 (bytes), applies to a relocatable format section.
The location attributes which you can specify and their specifications are :

Location Attribute	Description
`ALIGN=` *expression*	Gives the following directives to the linker : • The section involved is a relocatable format section. • A location method on memory (how to adjust a boundary) The expression *expression* indicates the position for adjusting a boundary. The rules for specifying the expression are : • This value must satisfy the following conditions : An absolute value A value effected by raising 2 to *n*th power within a range from 1 through 2^{31}. But "CODE section" value must satisfy the following conditions : An absolute value A value effected by raising 2 to *n*th power within a range from 4 through 2^{31}. • A symbol to be used as a term in the expression must have been defined before this pseudo-instruction appears.
`LOCATE=` *expression*	Gives the following directives to the linker : • The section involved is an absolute format section. Locates, after assembling, the section at the address expression specified. An absolute format section again cannot be relocated by the linker. Another section having the same section name must not be present in other source programs when linked. The expression *expression* indicates an absolute address. The rules for specifying the expression are : • The expression must be assigned an absolute value. • A symbol to be used as a term in expression must have been defined before this pseudo-instruction appears.

Example

```
.SECTION   ABC, CODE, ALIGN=4
.SECTION   ABC, COMMON,ALIGN=4
.SECTION   P,CODE,ALIGN=4
.SECTION   D,DATA,ALIGN=4
```

Appendix C

Macro-instruction Reference

This appendix explains the macro-instructions and the string handling function for macro processing of the assembler in an alphabetical order. The symbolic convention is as given in Figure C.1.

Mnemonic (or Function name) **Group**

Summary

Syntax Indicates how to write the macro-instruction in a source program.

Symbol	*Macro-instruction*	*Operand(s)*
Symbol field	Operation field	Operand field

When writing a string handling function, follow its syntax regardless of fields as shown above.

Description Gives the description of the macro-instruction's (or the string handling function's) function. In this column, "*statements* " means any one or more instructions.

Example Shows an example of coding the macro-instruction (or the string handling function).

Figure C.1 Macro-instruction Reference Format

If nothing is given in the symbol field, you cannot specify a symbol in the symbol field. You need to separate one field from another by putting one or more spaces (white-space characters) between them.

The notation given in Table C.1 is used throughout this appendix.

Table C.1 Appendix C Conventions

Symbol	Meaning
[ ]	Encloses an optional element.

.AIF .AELSE .AENDI

Macro-instruction

Selects macro expansion on condition.

Syntax

	.AIF	*logical_expression*

	[.AELSE]	

	.AENDI	

Description

The syntax .AIF – .AELSE – .AENDI chooses which to expand according to the evaluation of a logical expression. Write this .AIF-block as shown below to define a macro.

```
.AIF logical_expression

        [statements1]

[.AELSE]

        [statements2]

.AENDI          ;an .AENDI instruction terminates the .AIF-block (not to be omitted).
```

First *logical_expression* is evaluated. If the result is true, *statements1* is expanded , if false, *statements2* is expanded, then the assember exits from this block. You may omit *statements1* and *statements2*, and if omitted, nothing is expanded. When the .AELSE instruction is omitted, if the logical expression yields false, the assember expands nothing and exits from this block.

If *logical_expression* is faulty, an error occurs and the logical expression is evaluated as false. Follow 6.3.2.3 “Logical Expressions” to use logical expressions.

Example

```
   .MACRO  MCRIF   ARG_1
   .AIF .LEN("\ARG_1") EQ \&AVAR_1
        ADDI  R\&AVAR_1,#1
   .AELSE
        ADDI  R\&AVAR_1,#2
   .AENDI
   .ENDM
      ⋮
AVAR_1: .ASSIGNA   5
   MCRIF ABCDE
```

<After expansion>

```
   ADDI  R5,#1
```

.AREPEAT .AENDR

Macro-instruction

Repeats macro expansion *n* times.

Syntax

	`.AREPEAT`	*arithmetic_expression*

	`.AENDR`	

Description

The syntax .AREPEAT – .AENDR repeats expansion according to the evaluation of an arithmetic expression. Write this .AREPEAT-block as shown below to define a macro.

```
.AREPEAT   arithmetic_expression

      [ statements ]

.AENDR      ; an .AENDR instruction terminates the .AREPEAT-block (not to be omitted).
```

The assember calculates the value of *arithmetic_expression*, and expands *statements* repeatedly as many times as the value indicates, and exits from this block. You may omit *statements*, and if omitted, the assember expands nothing. If *arithmetic_expression* is 0, as32R does nothing and exits from this block.

If *arithmetic_expression* is assigned a negative number or is faulty, an error occurs and nothing is expanded. Follow 6.3.2.1 “Arithmetic Expressions” to use arithmetic expressions.

Example

```
        .MACRO     MCRRE
        .AREPEAT   \&AVAR_1
             ADDI  R5,#\&AVAR_2
AVAR_2: .ASSIGNA   \&AVAR_2 + 1
        .AENDR
        .ENDM
             :
AVAR_1: .ASSIGNA   3
AVAR_2: .ASSIGNA   5
        MCRRE
```

<After expansion>

```
        ADDI  R5,#5
        ADDI  R5,#6
        ADDI  R5,#7
```

.ASSIGNA

Macro-instruction

Defines an arithmetic variable.

Syntax

arithmetic_variable_name	`.ASSIGNA`	*arithmetic_expression*

Description

An arithmetic variable is an item to which the value of an arithmetic expression is assigned. You can reference an arithmetic variable only inside a macro body or within an arithmetic expression given in the operand field of a macro instruction. You can redefine an arithmetic variable by use of the .ASSIGNA instruction. You cannot redefine by use of the .ASSIGNC instruction an arithmetic variable that has been defined under this .ASSIGNA instruction.

Set a signed decimal integer to the arithmetic expression *arithmetic_expression*. A faulty arithmetic expression results in an error, and *arithmetic_variable_name* is assigned a 0. Follow 6.3.2.1 “Arithmetic Expressions” to write arithmetic expressions.

Example

```
        .MACRO    MCRAA
             ADDI R5,#\&AVAR_1
             ADDI R6,#\&AVAR_2
        .ENDM
        ⋮
AVAR_1: .ASSIGNA  10
AVAR_2: .ASSIGNA  \&AVAR_1 + 5
        MCRAA
```

<After expansion>

```
   ADDI R5,#10
   ADDI R6,#15
```

.ASSIGNC

Macro-instruction

Defines a character variable name.

Syntax

character_variable_name	.ASSIGNC	*character_expression*

Description

This instruction defines a character expression specified by a character expression as the value of character variable. You can use a character variable only within a macro instruction. You can redefine a character variable by use of the .ASSIGNC instruction. You cannot redefine by use of the .ASSIGNA instruction a character variable that has been defined under this .ASSIGNC instruction.

The assembler sets a 0-character to 255-character character variable to a specified character variable as a value.

A faulty character expression results in a error, and an empty character string is assigned to the character variable *character_variable_name* as its value. Follow 6.3.2.2 “Character Expressions” to use character expressions.

Example

```
        .MACRO     MCRAC
             \&CVAR_1   R5,R6
        .AIF "\&CVAR_1" NE "\&CVAR_2"
             \&CVAR_2   R5,R7
        .AENDI
        .ENDM
             ⋮
CVAR_1: .ASSIGNC   "ADD"
CVAR_2: .ASSIGNC   "MV"
        MCRAC
```

<After expansion>

```
   ADD  R5,R6
   MV   R5,R7
```

.AWHILE .AENDW

Macro-instruction

Iterates macro expansion on condition.

Syntax

	.AWHILE	*logical_expression*

	.AENDW	

Description

The syntax .AWHILE – .AENDW repeats expansion according to the evaluation of a logical expression. Write this .AWHILE -block as shown below to define a macro.

.AWHILE *logical_expression*

[*statements*]

.AENDW ; an .AENDW instruction ends the .AWHILE-block (not to be omitted).

First *logical_expression* is evaluated. If the result is true, *statements* is expanded , if false, *logical_expression* is evaluated again. That is, the assember repeatedly expands *statements* until *logical_expression* yields false, and exits from this block when *logical_expression* yields false. If the first evaluation result is false, the assembler expands nothing and gets out of this block. You may omit *statements*, and if omitted, nothing is expanded.

A faulty logical expression results in an error Follow 6.3.2.3 “Logical Expressions” to use logical expressions.

Example

```
                .MACRO     MCRWH ARG
                .AWHILE    \&AVAR GE \ARG
                     ADDI  R\ARG,#\&AVAR
        AVAR:        .ASSIGNA   \&AVAR / 2
                .AENDW
                .ENDM
                     .
                     .
                     .
        AVAR:        .ASSIGNA   20
                MCRWH 5
```

<After expansion>

```
   ADDI  R5,#20
   ADDI  R5,#10
   ADDI  R5,#5
```

.EXITM

Macro-instruction

Ends macro expansion.

Syntax

	.EXITM	

Description

This instruction allows you to terminate the macro expansion. This instruction, if put in an .AWHILE- block or in an .AREPEAT-block, causes control to break out of that block. If blocks are nested, control exits from the innermost loop that embodies this instruction.

You can put this instruction within an .AIF- block, provided that the .AIF-block is put inside a macro body or within an .AWHILE-block or an .AREPEAT-block (see also 6.5 “Nested Structure for Processing Macros”).

Example

```
        .MACRO    MCREX
        .AWHILE   1
             LDI  R\&AVAR,#1
             .AIF \&AVAR EQ 5
        .EXITM
        .AENDI
AVAR:        .ASSIGNA   \&AVAR-1
        .AENDW
        .ENDM

             ⋮

AVAR:        .ASSIGNA   8
        MCREX
```

<After expansion>

```
   LDI  R8,#1
   LDI  R7,#1
   LDI  R6,#1
   LDI  R5,#1
```

.INCLUDE

Macro-instruction

Reads a file into the source file.

Syntax

	`.INCLUDE`	"*filename*"

Description

This instruction reads (includes) the file *filename*. Specifying *filename*, you can use either the relative path name or the absolute path (full path) name.

You can nest this instruction. That is, you can write .INCLUDE instructions within a file included by the .INCLUDE instruction. This instruction can be nested up to 8 levels.

If the relative path name is specified, the file is searched for in the following order :

(1) In the directory containing the file in which the .INCLUDE instruction is written.
(2) In the directory specified with the -I option.
(3) In the directory specified by the environment variable M32RINC. If M32RINC is not defined, `/usr/local/M32R/include` will be searched.

If the file *filename* is not present, an error occurs.

Example

```
.INCLUDE   "DATAB.H"  ; including DATAB.H
```

.INSTR

String Handling Function

Locates a string in another string.

Syntax

```
.INSTR(character_expression_a,character_expression_b[,arithmetic_expression])
```

character_expression_a : A character string searched for the string *character_expression_b*

character_expression_b : A character string to be searched for

arithmetic_expression : The starting point to search

Description

The .INSTR function searches the string *character_expression_a* for the string *character_expression_b*, and calculates its position. The position is measured relatively from the first position of the string *character_expression_a* which is dealt with as position 0.

If *character_expression_b* is not found in *character_expression_a*, or if you make a mistake in specifying the starting point *arithmetic_expression*, then the function value is assigned as -1.

You assign the start position in the string *character_expression_a* to the arithmetic expression *arithmetic_expression*. If you omit *arithmetic_expression*, searching starts from the position 0. The value of *arithmetic_expression* must be an integer equal to 0 or greater.

You cannot use the .INSTR function elsewhere than in arithmetic expressions or in logical expressions. For arithmetic expressions, character expression, and logical expressions, see 6.3.2 “Expressions for Macro-instructions”.

Example

```
.MACRO    MCR  ARG_1,ARG_2
.AIF      .INSTR("\ARG_1","\ARG_2",1) EQ 3
     ADD  R5,R6
.AELSE
     MV   R5,R6
.AENDI
.ENDM
   ⋮
     MCR  FUNCTION,CT
```

<After expansion>

```
ADD  R5,R6
```

.LEN

String Handling Function

Counts the number of characters in a string.

Syntax

```
.LEN(character_expression)
```

Description

The .LEN function calculates the number of characters of the string *character_expression*. The number of characters of *character_expression* must be within the range from 0 to 255.

You cannot use the .LEN function elsewhere than in arithmetic expressions or in logical expressions. For arithmetic expressions, character expression, and logical expressions, see 6.3.2 “Expressions for Macro-instructions”.

Example

```
    .MACRO    MCR
        LDI   R5,#\&AVAR
    .ENDM
      :
CVAR: .ASSIGNC     "FUNCTION"
AVAR: .ASSIGNA     .LEN("\&CVAR")
    MCR
```

<After expansion>

```
    LDI  R5,#8
```

.SUBSTR

String Handling Function

Gets a string.

Syntax

.SUBSTR(*character_expression*,*arithmetic_expression_a*,*arithmetic_expression_b*)

character_expression	:	A character string from which characters are extracted
arithmetic_expression_a	:	The starting point to extract in *character_expression*
arithmetic_expression_b	:	The number of characters to be extracted

Description

The .SUBSTR function extracts the segment of the string which consists of *arithmetic_expression_b* characters from the character string *character_expression*. You indicate the start position to extract this by use of *arithmetic_expression_a*. The position is relatively indicated by dealing with the beginning of the string as 0.

The values of the arithmetic expressions must be integers equal to 0 or greater. If *arithmetic_expression_b* is 0, an empty character string is taken out. If you fail to extract the string having *arithmetic_expression_b* characters, an empty character string is taken out.

You cannot use the .SUBSTR function elsewhere than in character expressions or in logical expressions. For arithmetic expressions, character expression, and logical expressions, see 6.3.2 “Expressions for Macro-instructions”.

Example

```
.MACRO     MCR   ARG_1,ARG_2
.AIF       .SUBSTR("\ARG_1",0,3) NE "\ARG_2"
           MV    R5,R6
.AELSE

           \ARG_2 R5,R6
.AENDI

.ENDM

   ⋮

           MCR   ADDX,ADD
```

<After expansion>

```
ADD   R5,R6
```

.MACRO .ENDM

Macro-Instruction

Defines one or more lines as one macro body.

Syntax

	`.MACRO`	*macro_name* [*arg* [, *arg*] ...]

	`.ENDM`	

arg : *formal_parameter_name*[=*initial_value*]

Description

To define a macro, write .MACRO-block which consists of the .MACRO instruction, a macro body, and the .ENDM instruction.

First declare the start of macro definition by the .MACRO instruction. In this line, you can define the macro name, the formal parameter(s), the initial value(s) of the parameter(s).

The macro name defined under the .MACRO instruction is processed as a macro call in the subsequent source program. When you omit an actual argument in a macro call, the initial value defined under the .MACRO instruction turns to the argument. In this case, if no the initial value is defined, an empty string turns to.

Follow the name rules (see 3.5 “Names”) and the rules given below in coding macro names, formal parameter names, and initial values.

- One or more spaces or tabs is required between the macro name and the first formal parameter.
- You cannot include a different macro definition in a macro definition.
- A formal parameter argument defined under the .MACRO instruction is available inside the relevant macro definition alone. You cannot use same-named formal parameters in one .MACRO instruction line.
- To set an initial value to a formal argument, you put the assignment operator (=) in succession to the formal argument. You can assign an arbitrary string to the initial value. To define what contains a space ( ), a comma (,), an equal sign (=), or a less-than sign (<) as an initial value, you must enclose the initial value either in angular brackets (< >) or in double quotation marks (`"  "`). In this instance, the angular brackets are not included in the initial value, but the double quotation marks are included.

Finally, declare the end of the macro definition with The .ENDM instruction.

The .ENDM instruction must surely be present at the end of macro definition.

Example

Example 1 :

```
.MACRO     MCR   ARG_1,ARG_2      ; .MACRO statement
     MV    \ARG_1,\ARG_2          ; macro body
     ADD   \ARG_1,R7              ;
.ENDM                             ; .ENDM statement

    ⋮

     MCR   R5,R6                  ; macro call
```

<After expansion>

```
MV    R5,R6
ADD   R5,R7
```

Example 2 :

```
.MACRO     MCR   ARG_1=STR_SEC,ARG_2  ; .MACRO statement
     .SECTION   \ARG_1                ; macro body
     .SDATA     "123\ARG_2"           ;
.ENDM                                 ; .ENDM statement

    ⋮

 MCR                                  ; macro call
```

<After expansion>

```
.SECTION   STR_SEC
.SDATA     "123"
```

Appendix D

Assembler List File

This appendix illustrates examples of an input assembly source file and the assembler list file (list file) and explains the organization and the components.

By specifying the command option “-l *list_filename*”, the assembler generates an assembler list file which shows the assembly source generated from the input file, the object code (machine code) , location information (addresses) and error messages etc.

The following pages shows the following lists as examples of input source files:

- List D.1   Assembly source file j.ms (containing the .INCLUDE line)
- List D.2   Header file j.h (included into j.ms)

The list file `j.lis` (List D.3) is generated as the result of processing the input source files by the assemble processor a132R invoked by the assembler driver as32R.

List D.1 Example of Input File j.ms

```
        .SECTION        P,CODE,ALIGN=4
        .EXPORT $main
        .macro jj arg1, arg2
                ldi \arg1, \arg2
                add \arg1, r0
        .endm
$main:
        .aif 1
        ST      r2,@-R15
        .aelse
        ST      r1,@-R15
        .aendi
        MV      r2,R15
        .include "j.h"
        bl      $main0
$main0: ADDI    R5,#-4
        ST      R14,@-R15
        jj      r3, #5
        LDI     R1,#20
        ST      R1,@(-4,r2)
        bl      _main0
        LD      R1,@(-4,r2)
        ST      R1,@-R15
        .GLOBAL _bb
        .SECTION        S,DATA,LOCATE=0x200000
        .datab.w 5,8
data0:
        .data.h 0xF000
        .datab.w 1, 0xF000
        .SECTION        T,DATA,ALIGN=4
rel_data:
        .datab.w 20, 0x66668888
        .sdata "This Line is SDATA"<0>
        .sdata  "F000"
        .END
```

List D.1 Example of Input File j.h (Header File)

```
_main1:
        .aif 1
        ST      r3,@-R15
        .aelse
        ST      r1,@-R15
        .aendi
        MV      r3,R15
        ADDI    R5,#-4
        ST      R14,@-R15
        LDI     R1,#20
        ST      R1,@(-4,r3)
        LD24    R1,#-4
        ST      R1,@-R15
        .GLOBAL _refs
```

List D.3 Example of List File (`j.lis`)

```
* ASSEMBLER * SOURCE LIST *

 LST#  SRC# LOCATION OBJ_CODE               SOURCE_STATEMENT

[j.ms] ✶1
    1     1                             .SECTION        P,CODE,ALIGN=4
    2     2                             .EXPORT $main
    3     3                             .macro jj arg1, arg2
    4     4                                     ldi \arg1, \arg2
    5     5                                     add \arg1, r0
    6     6                             .endm
    7     7                      $main:
    8     8                             .aif 1
    9     9 00000000 227F               ST      r2,@-R15
   10    10                             .aelse
   11    11                    X        ST      r1,@-R15
   12    12                             .aendi
   13    13 00000002 128F               MV      r2,R15
   14    14                             .include "j.h"
[j.h]
   15     1                   1  $main1:
   16     2                   1         .aif 1
   17     3 00000004 237F     1         ST      r3,@-R15
   18     4                   1         .aelse
   19     5                   1X        ST      r1,@-R15
   20     6                   1         .aendi
   21     7 00000006 138F     1         MV      r3,R15
   22     8 00000008 45FC     1         ADDI    R5,#-4
   23     9 0000000A 2E7F     1         ST      R14,@-R15
   24    10 0000000C 6114     1         LDI     R1,#20
                     F000 ✶2
   25    11 00000010 A143FFFC 1         ST      R1,@(-4,r3)
   26    12 00000014 E1FFFFFC 1         LD24    R1,#-4
# a132R: "j.h", line 12: warning: ignore sign bit at 24-bit immediate data ✶4
   27    13 00000018 217F     1         ST      R1,@-R15
   28    14                   1         .GLOBAL _refs
[j.ms]
   29    15 0000001A 7E01               bl      $main0
   30    16 0000001C 45FC        $main0:        ADDI    R5,#-4
   31    17 0000001E 2E7F               ST      R14,@-R15
   32    18                             jj      r3, #5
   33    18 00000020 6305      &                ldi r3, #5
   34    18 00000022 03A0      &                add r3, r0
   35    19 00000024 6114               LDI     R1,#20
                     F000
   36    20 00000028 A142FFFC           ST      R1,@(-4,r2)
   37    21 0000002C 7EFC               bl      $main0
                     F000
```

```
  38    22 00000030 A1C2FFFC           LD      R1,@(-4,r2)
  39    23 00000034 217F               ST      R1,@-R15
                    F000
  40    24                             .GLOBAL _bb
  41    25                             .SECTION        S,DATA,LOCATE=0x200000
  42    26 00200000 [5]  ✶3            .datab.w 5,8
                    00000008
  43    27                      data0:
  44    28 00200014 F000               .data.h 0xF000
  45    29 00200016 0000F000           .datab.w 1, 0xF000
  46    30                             .SECTION        T,DATA,ALIGN=4
  47    31                      rel_data:
  48    32 00000000 [20]               .datab.w 20, 0x66668888
                    66668888
  49    33 00000050 54686973           .sdata "This Line is SDATA"<0>
                    204C696E ✶5
                    65206973
                    20534441
                    544100
  50    34 00000063 46303030           .sdata  "F000"
  51    35                             .END
```

Here follows the organization of assembler source list output to the list file (explanations of the parts bearing **✶1** through **✶5** are also given).

The assembler source list is made up of items shown in Table D.1. There may be instances in which information of some items is not output. The headings (`LST#`, and the like) are output at the beginning of the list.

Table D.1 Lines in the Assembler Source List

Item	Description
LST#	A line number in the list (in decimal). There are lines having no line number, so this doesn't agree with the total number of lines in this list.
SRC#	A source line number (in decimal). This indicates a line number of the input source file.
LOCATION	An address to locate code (in 8-digit hexadecimal). If less than eight digits, higher order digits are indicated by 0's. This indicates an offset in the case of a relative section.
OBJ_CODE	This chiefly indicates generated code.
SOURCE_STATEMENT	The content of the corresponding line of source file.

There can be instances in which the type of line (Refer to Table D.2) is shown between OBJ_CODE and SOURCE_LIST.

Table D.2 Line Types

Mark	The line is ...
X	A line which has been skipped inside the .AIF-block (consists of macro-instructions) .
&	A expanded line due to a macro call, an .AREPEAT-bock or an .AWHILE-block.
number	Nesting levels of the macro-instruction .INCLUDE (in decimal).
none	Otherwise.

Some other indications are given below. Explanations are given by taking up the parts (labeled ✶**1** through ✶**5**) in the assembler source list shown in the example of list file (List D.3).

- **File name (✶1)**

```
-----------------------------------------------------------------
[j.ms]
-----------------------------------------------------------------
```

This indicates the input source file name. A file name is indicated in the form of [*filename*]. This is indicated in a point at which a file containing what are given up to that point changes to another file containing the subsequent lines, for example, the beginning of a list file, source files nested by the .INCLUDE macro-instruction, or the like.

- **NOP code (✶2)**

```
-----------------------------------------------------------------
   F000
-----------------------------------------------------------------
```

There are instances in which the assembler generates the NOP code so as to adjust the alignment. In these instances, the NOP code `F000` is output in the `OBJ_CODE` section. No address is indicated in the `LOCATION` section. “`NOP`” is not indicated in the `SOURCE_STATEMENT` section either.

- **The number of iteration (✶3)**

```
-----------------------------------------------------------------
   29    15 0000001A [5]      1     .datab.w 5,8
                     00000008
-----------------------------------------------------------------
```

In the case of a pseudo-instruction that generates data repeatedly, such as the .DATAB pseudo-instruction, the number of iterations is indicated in the `OBJ_CODE` section. The number of repetitions is in decimal and enclosed in `[ ]`. The value of data are successively given in the next and subsequent lines. No address is indicated in the `LOCATION` section. If the number of repetitions is 1, it is not indicated, and data are left indicated without being changed. Only the top address of the data is indicated in the `LOCATION` section.

- **Errors/warnings (✶4)**

```
-----------------------------------------------------------------
   # a132R: "j.ms", line 12: warning: ignore sign bit at 24-bit
immediate data
-----------------------------------------------------------------
```

Either a warning message or an error message is indicated in lines subsequent to the line in which it occurs. If the assembly process turns impossible depending on the type of error, neither the `LOCATION` sections nor the `CODE` sections are output at all. The name of command tool that the assembly driver as32R activates (either "`a032R:`" or "`a132R:`") is indicated at the beginning, which means the following :

- `a032R:` An error that occurred in the macro processor a032R
- `a132R:` An error that occurred in the assembly processor a132R

The line is preceded by '`#`'.

- **Machine code (✶5)**.

```
-----------------------------------------------------------------
   50    33 00000050 54686973  .sdata "This Line is SDATA"<0>
                     204C696E
                     65206973
                     20534441
                     544100
-----------------------------------------------------------------
```

Data code effected by a single pseudo-instruction is output, one word (4 bytes) per line in hexadecimal. If the code exceeds one word, it is successively output to the next and subsequent lines. In this instance, no address is indicated in the `LOCATION` section.

Appendix E

M32R/ECU#5 Extension Instruction

A program including the instruction extended with M32R/ECU#5, such as FPU instruction, can be assembled. To make this function effective, use the following option.

E.1 Option designation

Where M32R/ECU#5 extension instruction is assembled, the following option must be specified.

-m32re5	This option makes M32R/ECU#5 extension instruction valid.

Also, the floating-point constant, which is not normalized, is reduced to "0.0".

E.2 M32R/ECU#5 extension instruction

This function is compatible with the instructions shown in Table 8 below. For details, refer to M32R/ECU#5 Software Manual.

Table E.1 M32R/ECU#5 Extension Instruction List.

Classification	Opecode	Operand	Function Outline
Store instruction	STH	Rsrc1,@Rsrc2+	The half-word value is stored in memory from the register. (with post increment)
Bit-manipulation instruction	BSET BCLR	#bitpos,@(disp16,Rsrc) #bitpos,@(disp16,Rsrc)	Set ì1î to the designated bit. Set ì0î to the designated bit.
	BTST	#bitpos,Rsrc	Take out the designated bit of the register to C flag.
	SETPSW	#imm8	Set ì1î to any bit of PSW SM, IE and C.
	CLRPSW	#imm8 S	et ì0î to any bit of PSW SM, IE and C.
Floating-point instruction	FADD	Rdest,Rsrc1,Rsrc2	Floating point add.(Rdest = Rsrc1 + Rsrc2)
	FSUB	Rdest,Rsrc1,Rsrc2	Floating point subtract.(Rdest = Rsrc1 - Rsrc2)
	FMUL	Rdest,Rsrc1,Rsrc2	Floating point multiply. (Rdest = Rsrc1 * Rsrc2)
	FDIV	Rdest,Rsrc1,Rsrc2	Floating point divide. (Rdest = Rsrc1/Rsrc2)
	FMADD	Rdest,Rsrc1,Rsrc2	Floating-point multiply and add operation (Rdest = Rdest + Rsrc1*Rsrc2)
	FMSUB	Rdest,Rsrc1,Rsrc2	Floating-point multiply and substract operation (Rdest = Rdest - Rsrc1*Rsrc2)
	ITOF	Rdest,Rsrc	Transformation from integer to single precision floating point numeral
	UTOF	Rdest,Rsrc	Transformation from unsigned integer to single precision floating point numeral
	FTOI	Rdest,Rsrc	Transformation from single precision floating point numeral to 32-bit integer
	FTOS	Rdest,Rsrc	Transformation from single precision floating point numeral to 16-bit integer
	FCMP	Rdest,Rsrc1,Rsrc2	Floating point comparison (Rdest = Rsrc1 & Rsrc2 compare results)
	FCMPE	Rdest,Rsrc1,Rsrc2	Floating point comparison (Rdest = Rsrc1 & Rsrc2 compared results)

Meaning of Notation

R*n*	[R*dest*, R*src*(*1/2*)] General register (*n* = 0 to 15)
@R*n* +	Indicates that the R *n* contents are incremented by 4 (register updated) after general register R *n* reference (register indirect)
@(*disp_nn*,R*n*)	Indicates register indirect with added *disp_nn*
bitpos	Bit position of specified data (*bitpos* = 0 to 7)
disp_nn	Displacement value
imm_nn	Ssigned integer immediate

Appendix F

Floating Point Compatible Function

A program including the instruction extended with M32R/ECU#5, such as FPU instruction, can be

F.1 Floating-point constant

F.1.1 Description format

There are 2 types of formats:

[a] Normal notation

```
[(+|-)] <(f'|F')> <Floating decimal fraction value> [Precision designation] [(+|-)
```

- Sign

  The "+" & "-" at the head are the signs. If omitted, it follows that the plus (+) has been specified.

- Precision designation

  If this precision designation is omitted, single precision is selected.
  Yet, if the normal notation is used on the pseudo instruction (see "F.2 Extended pseudo instruction".) that has size-designation, the size of this pseudo instruction will be adopted.

s or S	:	Single precision
d or D	:	Double precision

- Exponent

  The exponent indicates the power of 10 with sign.

  Example)

f'1.0s + 10	: (Single precision) 1.0 raised to 10th power
-f'3.14159s + 10	: (Single precision) -3.14159 raised to 10th power
+F'3.14159D - 10	: (Double precision) 3.14159 raised to -10th power

[b] C language compatible notation

```
[(+|-)] <Floating decimal fraction value> [(e|E) (+|-) Exponent] [f|F]
```

- Sign

  The "+" & "-" at the head are the signs. If omitted, it follows that the positive (plus) has been specified.

- Precision designation

If this precision designation is omitted, double precision is selected.
Yet, if the C language compatible notation is used on the pseudo instruction (see "F.2 Extended pseudo instruction".) that has small size-designation, the size of this notation is small.

f or F	Single precision
(No designations) ...	Double precision (Case of that on the small-sized pseudo designation is eliminated.)

Example)

1.0e + 10f	: (Single precision)1.0 raised to 10th power
-3.14159F + 10f	: (Double precision)-3.14159 raised to 10th power
+3.14159 - 10F	: (Double precision)3.14159 raised to -10th power

- Exponent

This exponent indicates the power of 10 with sign posterior to "e" or "E".

F.1.2 Available place

If the floating-point constant is described in the following place, it is replaced with the floating-point constant replaced with the format of single precision (4 bytes) or double precision (8 bytes) conforming to IEEE-754.

- Pseudo instruction

Both double precision and single precision can be described with .FDATA & .FDATAB pseudo instruction parameters.

- General instruction

Only single precision can be described in correction option (HIGH, LOW, SHIGH).

F.1.3 Compatibility

Single precision and double precision of floating-point constant are compatible with internal expression of float type and double type used in C-compiler respectively.

F.1.4 Non-normalized numeral handling

When the -m32re5 option (Refer to "7.2") is designated for the assembler, the non-normalized numeral is reduced to "0.0".

F.2 Extended pseudo instruction

3 pseudo instructions corresponding to the floating point can be utilized.

F.2.1 Format

.FDATA [.size] ConstantA [, ConstantA]	Lays out the floating-point constant.
.FDATAB [.size] ExpressionB, ConstantA	Lays out the continuous floating point constant.
.FRES [.size] ExpressionB	Maintains the floating-point constant area.

* Meaning of Symbols

. size	: Size designation
.s or .S	: Single precision
.d or .D	: Double precision
ConstantA	: Floating-point constant
ExpressionB	: Quantity

F.2.2 Function of pseudo instruction

- .FDATA pseudo instruction

  This instruction secures the data area with precision designated with ".size", and stores internal expression of constant a (floating point number) inside its area.

  Example)

  ```
  .FDATA  F'1.0S+2, F'2.0S+2   ; 1.0e + 2f and 2.0e + 2f are laid out.
  ```

- .FDATAB pseudo instruction

  This instruction secures the data area with precision designated by ".size" by the quantity in Expression b, and stores internal expression of constant a value (floating point number) inside its area continuously by the quantity in expression b.

  Example)

  ```
  .FDATAB  8,  F1.0S+2   ; 1.0e + 2f are laid out continuously by 8.
  ```

- .FRES pseudo instruction

  This instruction secures the data area with precision designated by ".size" by the quantity in Expression b.

Example)

```
.FRES.S  4   ; 4 areas for single precision floating-point numeral
               are secured.
```

F.2.3 Common items

- he size is designated by .s or .S (single precision) and .d or .D (double precision).
- Requirements for constant a (floating-point constant)

  Constant a must be within the range of size designation.
  Only one constant can be described. (The constant expression <F'1.0 + F'2.0, etc.> cannot be described.)
- Requirements for expression b (Quantity)
  The constant expression and positive value, that is, 0 or more integer are required. When a symbol is included, the definition prior to this pseudo instruction is required.

F.3 Utilization of floating point in general instruction line

For the instruction in which the correction option (HIGH, LOW, SHIGH) is effective, the single precision floating-point constant can be described. (No double precision is applicable to the correction option.

[Where normal notation is used]

```
SETH R0, #HIGH (f'1.0s + 2)

OR3   R0, R0, #LOW (f'1.0s + 2)
```

[Where C-language interchangeable notation is used]

```
SETH R0, #HIGH (1.0e + 2f)

OR3   R0, R0, #LOW (1.0e + 2f)
```

*Since the internal expression of 1.0 Å~ 10 raised to 2nd power is 42C80000 (hexadecimal), the above is equivalent to the following description.

```
SETH R0, #HIGH (0 Å~ 42C80000)

OR3   R0, R0, #LOW (0 Å~ 42C80000)
```

Appendix G

Restrictions on Usage

There are restrictions of the CC32R.
For other precautions of only this version, see the 'Precautions on using' of the next chapter.

■ How to get files that is not included the debug-informatio

C compiler cc32R, assembler as32R and linker lnk32R have come to be generating the debugging information always. Namely, the object module and load module files that these tools generate always include the debugging information.

Such a outputting debug-information is not possible to impede in those options.

The strip32R can process even the object module that compiler and assembler generated in addition to the load module that the linker. The strip32R can process even the object module that compiler and assembler generated in addition to the load module that generated the linker. In other words, if each output files are processed with strip32R after cc32R, as32R or lnk32R, these tools act as conventional CC32R (V.4.10 or before).

Example of using strip32R: (% expresses a prompt)

Usually usage:

The strip32R is able to apply to each output file of the cc32R, as32R and lnk32R. Strip32R is able to process both files of object-module (before the link) and load module (after the link).

```
% cc32R -c -o sample1.mo sample1.c
% strip32R sample1.mo
% as32R sample2.ms
% strip32R sample2.mo
% lnk32R -o sample.abs sample1.mo sample2.mo
% strip32R sample.abs
```

To process two or more files at a time:

For example, after all the compiling and the assembling completed, the strip32R can process all the files of them.

```
% cc32R -c sample1.c sample2.c sample3.c
% cc32R -c sample4.c
% as32R -c sample5.ms
% strip32R sample1.mo sample2.mo sample3.mo sample4.mo sample5.mo
```

Even the wild card can be designated.

```
% strip32R *.mo
```

■ Cautions on using the base register function with standard library for C

[The supplement of attention on using the base register function]

Combinations of the object file as follows are not recommended. (For more details, refer to the "A.1.6 Base Register Function Limitations" of the M3T-CC32R User's Manual <C Compiler>.)

(1) The combination of object files that was created in using base register function and in not using this function.

(2) The combination of object files that was created by using different access control files.

[Attention to use the base register function and C standard library in same time]

Attached C standard library was created when the base register function is ineffective. Therefore, attached C standard library and the object file that used the base register function correspond to above (1).
In such case, the base register does not have the base address when the standard library function is executing. The base register will returns the base address after these standard functions, although the base register will not have the base address when as follows:

(1) Interrupt processing routine
Because the interrupt process happens during execution of standard library functions, you must think value of the base register is undefined.

(2) User function that is called from the particular standard library functions (qsort, bsearch etc.)

[Solutions]

When the base register function and the C standard library are used in same time, please use one of the solution methods following (1) and (2).

(1) Create a special standard library by using same access control file from the user program. And replace present standard library with it.

(2) Re-compile interrupt processing routine and user function that is called from the partcular standard library functions (qsort, bsearch etc.) by not using the base register function.

■ Avoiding the integral zero-division problem of M32R/ECU series

In M32R/ECU Series Microcomputer, if zero division calculation (its divisor is equal zero) is executed for integral division instructions (they are DIV, DIVU, REM and REMU. abbreviated as DIV-instructions), the result will be inaccurate calculations for some instructions that are executed immediately after 0 division.

For more details, refer to the Technical News No.M32R-06-0301 “M32R/ECU series Usage Notes for 0 Division Instruction”.

The correspondence in CC32R and explain about avoiding the zero-division problem by -zdiv option below.

[Correspondence methods]

The case of C language program or assembly language program

(1) Please re-program so the zero-division does not occur in logical, following the tehnical news suggests. CC32R generates the DIV-instructions to the integral calculations both divisions (/ and also /=) and remainders (% and also %=) of C language, please program so that the divisor do not become 0. Also, in assembly language, please program so that the second parameter of DIV-instructions (it means divisor) do not become 0.

(2) If you can not accomplish (1) completely, re-compile or re-assemble with -zdiv option insted of (1).

The case of using standard libraries

Even if the DIV-instructions computes the zero-dividion in the standard library functons, the problem does not occur. It is because the standard library is already treated about avoiding this problem.
Furthermore, The functions of the zero-division measurement libraries (m32RcRZ.lib, m32RcRZM.lib, m32RcRZL.lib) that was prepared in CC32R V.4.10 Release 1, have been incorporated to general standard libraries (m32RcR.lib, m32RcRM.lib, m32RcRL.lib). Because of this, If you have been using CC32R V.4.10 Release 1 and use the zero-division measurement libraries, please use general standard libraries instead of them.

The case of using non-standard libraries

In use the customer-made libraries or the re-build libraries from the standard library sources set of attachment to CC32R, please re-build or re-compile with -zdiv option.

[Explanation of the -zdiv option]

When it uses in compiling with cc32R

Compiling with -zdiv option, it generates assembly source with inserting NOP instructions each after the all of created DIV-instructions. Also, it inserts NOP instructions as same in asm functions too.
However, if you use -zdiv option with -S or -CS in same time, compiler generates assembly source with removing comment and coverting alphabetic letters to upper.
In the case of inputting assembly sources to cc32R, it performs same from assembling by as32R.

When it uses in assembling with as32R

If assemble code includes DIV-instructions with -zdiv option, it inserts NOP instructions each after the all of this DIV-instructions. However, it except case of that NOP instruction already exists after the DIV-instruction.
It means there is not following object between the DIV-instruction and the NOP-instruction. In other words, the compiler inserts NOP instruction after the DIV-instruction, if there is following object between the DIV-instruction and the NOP-instruction.

(1) Labels

(2) Generic M32R instructions except NOP instruction

(3) as32R pseudo-instructions influencing the code areas (as follows)
.ALIGN .DATA .DATAB .END .FDATA .FDATAB .FRES .RES
.SDATA .SDATAB .SECTION

On indirect calling a function that has variable arguments

The program will not run correctly if a function having a variable argument is called indirectly by using a pointer variable to a function without prototype declaration.

[Code Example]

```
#include <stdio.h>
int (*funcptr)() = printf;
int main (void) {
    (*funcptr) ("calling printf with %d\n", 1);
}
```

[Solution]

Include a prototype declaration for the pointer variable to the function. (Rewrite the above code as follows.)

```
#include <stdio.h>
int (*funcptr) (const char *,...) = printf;
int main(void) {
    (*funcptr) ("calling printf with %d\n", 1);

}
```

Data definition within the code section

The assembler outputs a warning (warning: caution! there are some data in code section) so as to alert you to data items (or space areas) present in the code section.
It is recommended to put data items in the data section.
You can suppress this warning by use of the option "-warn_suppress_code_data".

Use of preprocessor variables inside a macro body

If, as in the following example, a preprocessor variable appears starting in the first column of the line immediately after a macro call in the macro body, the preprocessor variable may not be correctly expanded when the macro call is effected.

[Code Example]

```
    .macro INST_MACRO
    MOV        #0,R0
    .endm
    .macro LABEL_MACRO label
    INST_MACRO
\label:                    ; putting a preprocessor variable from the first column
    .endm
    .section P,code,align=2
    LABEL_MACRO L1         ; this expansion will be failed
    LABEL_MACRO L2         ; this expansion will be failed

    .end
```

[Solution]

Inside a macro body, write a preprocessor variable from the second column or the subsequent.

■ About compiling the functions of 500 or more lines

When you compile a program that has the big functions of 500 or more lines by CC32R, a error "Out of memory" will occur.
In this case, divide this function so that its lines decrease.

■ Precautions about changing C Calling Convention

CC32R V.3.00 Release 1 (or newer) always generates code for function parameters by registers. Accordingly, objects of CC32R V.3.00 Release 1 (or newer) and V.2.10 Release 1 can't be linked without measuring. Correspond in the following methods.

(1) C language program that passes the function argument by using stack

It means objects and libraries that was compiled by the CC32R V.2.10 Release 1 without -RBPP option.

[How to adapt]

Compile them with CC32R V.3.00 Release 1 (or newer).

(2) Program of the assembly language that is handing over the function argument by stack

It is the program of the assembly language passing the argument of the function by using stack, and that calls function of C language or is called from it. (They include start up program and low level library functions.)

[How to adapt]

- * Change the assembly language program in accordance with the setting rule of the function argument of V.3.00 Release 1. (Refer to the chapter of "the C calling rule" of the M3T-CC32R user's manual <C Compiler>.)
- * When function passes the argument by registers, this function name is not under score (_) to the top but dollar mark ($) is added in object file. You need to change the function name in the assembly language that you have this to the name that complied with.

When you links these programs (above (1) and (2)) without this adaptation and program made for CC32R V.3.00 Release 1 (or newer), the error "external symbol not defined" will occur.

Part 2

Linker lnk32R

Chapter 1

Overview of the Linker lnk32R

1.1 Overview

The linker lnk32R is included in the cross tool kit M3T-CC32R and has the following functions :

- Generates a load module file (absolute load module file and relocatable load module file)

  The linker combines object module files (following , object module), relocatable load module files (following , relocatable load module) and library files (following , library) into an absolute load module file(an executable load module file).

- Produces a link map

  With the -M option, the linker outputs a link map. A link map consists of “map list” which lists location information about sections and “global symbol list” which lists external symbol information. When the -M option is specified, the linker invokes the map generator and a link map is produced. Details on the map generator are described in Part 3 ”Map Generator map32R”.

1.2 Functions

- Generation of two kinds of load modules

  Either an absolute load module or relocatable load module may be selected.

  - Absolute load module
    With the absolute load module, the start addresses (absolute address) of all of the sections are specified and there is no undefined symbol. The module is executable.

  - Relocatable load module
    This module is generated when the command option -r is selected. With this relocatable load module, the start addresses of the sections are not defined. The relocatable load module can be converted into an absolute load module when it is input again into the linker without the command option -r.

- Creating ROMable programs is supported

  To commit applications to ROM, the following functions are supported :

  - Initial Data Deletion
  - Initial Data Extraction
  - Reserved Labels Generation

  Those are useful for creating an embedded application.

- Invoking by using a Command File

  The parameters (specifying option and input file) of the invoking command lnk32R can be supplied from a command file (see 2.1.3.2).

- Support for overlay facility

  The linker supports what is called the "overlay facility" to allow different sections to be located at the same address. Due to the introduction of this facility, no sections are checked for overlap at all, so be careful when using this facility.

1.3 Compatibility with an old version

1.3.1 About inputting old CC32R's object (V.2.10 Release 1 or older) to new linker

- About inputting old CC32R's object (V.2.10 Release 1 or older) to new linker

  To correspond to the new function, a part of object format has been changed.Accordingly, if you have the object that was made with old CC32R (V.2.10 Release 1 or older), when you input them to new linker (CC32R V.3.00 Release 1 or newer), this linker displays a warning message like the following.

  lnk32R: " filename": warning: old interface module: "revision:01"

  In this case, please remake these objects by using the new CC32R.

- Problems encountered when linking objects of V.1.00 Release 3 or earlier

  An error "relocation out of range " may be encountered when linking some objects generated by CC32R V.1.00 Release 3 or earlier by the linker in V.1.00 Release 4 or later (including this version). In such a case, regenerate the objects using the assembler in V.1.00 Release 4 or later.

1.3.2 About error processing of lnk32R

- Mitigation of the error processing of the -SEC option

Even if the sections specified by the -SEC options are not included in the input files and libraries, the new linker processes not as an error but as a warning.
In this case, if you'd like to let this linker to process an error, please use the following option.

◆[Options]

-Werrsec

Processes as error if the sections specified by the -SEC options are not included in the input files and libraries.
If there is no -Werrorsec option (that is the default), this linker processes as a warning for that case.

- Displaying details of the relocation size overflow

In the linker processing, the attaching messages of the "relocation size overflow (xx-bit)" message are only the section names, a offset in the modules and the referenced symbols. The following option enables display as the more detailed information.

◆[Options]

-Wreloc

Displays the "Position" information and the "Setting" information, when the "relocation size overflow" error happens.

◆[Displaying forms]

(1) "Position" information

[Position: sect"SectionName"(Address)+Offset in module"ModuleName"]

Specifies belonging the section and the module names and allocated address of the relocation address. Actual address of the relocation can be leaded from an addition of displayed address and the offset.
(* The address and offset is displayed with the hexadecimal number that begins from '0x'.)

(2) "Setting" information

[Setting: SettingValue (Referencing-Information)]]

This is the information regarding a setting value. This setting value is displayed with the hexadecimal number.
The information such as the section and symbol that the ordinariness used to the calculation of this setting value to, the R-

eferencing-Information are output.

sect"SectionName"(top=Address), module"ModuleName"

This is the referenced section and the belonging module information.
This Address is expressing the top address of the integrated section from all same name sections.
(* The address is displayed with the hexadecimal number that begins from '0x'.)

"SymbolName"

Referencing symbol name.

in sect"SectionName" module"ModuleName"

Displays this address belonging the section and module name in the case of supposing that the "SettingValue" is an address.

◆[A sample of -Wreloc specified]

```
lnk32R: "c:\mtool\lib32R\m32RcR.lib": error: relocation size overflow (24-bit):
"P", 0x00000011, ""

[Position: sect"P"(0x2FCC)+0x11 in module"stdio_pw"]

[Setting: 0x800001E4 (sect"C"(top=0x80000198), module"stdio_pw")]

lnk32R: "c:\mtool\lib32R\m32RcR.lib": error: relocation size overflow (24-bit):
"P", 0x000001ED, "__100_ctype_tab"

[Position: sect"P"(0x388C)+0x1ED in module"locale"]

[Setting: 0x800001EE ("__100_ctype_tab", in sect"C" module"_C_ctype")]
```

- The number limitation of messages

If the message count of the linker is more than 20 times, the 21th and the next messages are not displayed. By designating the following options this limitation number can be changed, and all messages can be displayed by invalidating this limit.

◆[Options]

-Wlimit=message_max

Setting up the number limitation of messages. If the message count of the linker is more than times specified by the 'message_max', the next messages are not displayed. In the case that 0 is designated to the numerical value restriction has no effect and all the message is displayed.
In the default (there is not -Wlimit), the linker behaves as *Wlimit=20* was specified.

-Wnolimit

Displays all messages.

1.3.3 About error processing of lnk32R(CC32R V.4.30 Release 1 or subsequent one)

- Map output during link error

A change has been made so that if a link map file is specified in the -M option of lnk32R (or the -MAP option of cc32R), even when an error occurs during link processing, a link map will always be output.
The link map that was made when an error occurred is including incomplete information. But this link map can be used to identify the causes of link errors, because the section allocation and symbol addresses in each module can be known.

Chapter 2

Invoke the Linker

2.1 How to Invoke the Linker

2.1.1 Invoking Procedure

To invoke the linker, set the environment variables (see 2.1.2), enter the "lnk32R" command according to the command line rules and execute it (see 2.1.3).

2.1.2 Setting Environment Variables

Set the valid directories for the environment variables M32RBIN, M32RINC, M32RLIB and M32RTMP (This step may be skipped since these variables are normally set during installation.). For the setting procedure, refer to the "M3T-CC32R Cross Tool-Kit V.x.xx Release x Release Note". If you do not set them, the default directories are selected automatically.

Table 2.1 Environment Variables

Environment Variable	Default Directory
M32RBIN	/usr/local/M32R/bin
M32RINC	/usr/local/M32R/include
M32RLIB	/usr/local/M32R/lib
M32RTMP	/tmp

2.1.3 Command Line Format

Figure 1.1 and the following sections shows the format and rule for the linker's invocation command line. To specify options and input files, there are to ways : inputting from a command line or using a command file. Refer to 2.2 for options and 2.1.4 to 2.1.6 for input/output files.

(1) To specify for invocation in the command line :

```
lnk32R [-o output_filename] [-r] [-g] [-V] [-w] [-eentrypoint]
        [-L dir] [-l lib] [-M map_filename ]
        [-SEC name[=addr],name[=addr]…] [-LOC addr1,addr2]
        [-overlap]
        [-Werrsec] [-Wreloc] [-Wlimit=message_max]
        [-Wnolimit]
        object_filenames <RET>
```

(2) To use a command file :

```
lnk32R  command_filename  <RET>
```

where :

• Without [ ]	: Indispensable
• In [ ]	: Optional
• Prefixed by -	: A command option (see 1.3)
• <RET>	: Enter the return key

Figure 2.1 lnk32R Command Line Format

2.1.3.1 Command Line Rules

To invoke the linker by using the information specified in the command line, enter and execute the command by obeying the following rules :

- Write into the command line by following the format given in Figure 1.1 (1). Each of the items (command name, option, input file name) must be separated from adjacent items by at least one space character. Pressing the return key enables the linker to execute the command.

- An option must be separated from the associated parameter by a space character. If options conflict with each other, the last option has priority.

- Only addresses and numerical values specified in hexadecimal are valid.

- Specify one or more input file names in *object_filenames*. One or more space characters must be placed between file names. The number of files allowed is unlimited.

2.1.3.2 Invocation Using Command File

The linker invoking option and the name of the input file can be specified by using a command file. A command file is a text file containing specifying information. This is a convenient invoking method when the number of file names is large or the processes for the linker are already defined.

In the command line, specify a *command_filename* as a parameter,

`lnk32R` *command_filename* `<RET>`

Describe the command file by following the following procedure :

- When writing parameters (option selection, input file name selection) in the command line, follow the parameter input formats (see Figure 2.1 (1)).
- Adjacent parameters can be separated by a carriage return (return key).
- A command file can accommodate up to 255 characters (excluding the carriage return character).

For example, to input 11 files, sin.mo, cos.mo, tan.mo, asin.mo, acos.mo, atan.mo, hsin.mo, hcos.mo, htan.mo, log.mo and log10.mo and output the absolute load module func.abs, prepare the command files shown in Figure 2.2.

```
-o func.abs
sin.mo  cos.mo   tan.mo   asin.mo acos.mo  atan.mo
hsin.mo hcos.mo  htan.mo  log.mo  log10.mo
```

Figure 2.2 Command File Description (Example)

2.1.4 Input File Conditions

Table 2.2 shows the conditions of the input files which can be processed on the linker. Do not input any file that cannot meet these conditions.

Table 2.2 Input File Conditions

Item	Conditions
Valid input files	Object module file(s) Relocatable load module file(s) Library(s)
Maximum number of names	Section names : Up to 65535/file Symbol names : Up to 65535/file Module names : Up to 65535/file The number may be limited by the capacity of development environment system memory.

2.1.5 Output File Conditions

A load module file generated on the linker can contain up to 65535 file names for each item (Note). Do not link files which result in more than 65535 names of a particular item to be contained in the load module. The maximum number 65535 can be obtained only when the development environment memory has enough space.

2.1.6 Output File Naming

The name of the output file is specified by the -o option. If this option is not used, the linker automatically gives name to the file as shown in Table 2.3.

Table 2.3 Output File Naming (Default)

File Name	Description
`am.out`	The load module file to be output as the result of linking.
`a.mout`	The load module file to be output as the result of linking (for EWS version).

Note) Each item: Section name, Symbol name and Module name

2.2 Command Options

Table 2.4 below shows the functions of the command options for the linker.

Table 2.4 Command Options for the Linker (1/4)

Option	Description
`-e` *entrypoint*	Sets the load module entry point to *entrypoint* (symbol). The entry point is used by the debugger to automatically set the initial value of the program counter and to perform some other functions.
`-g`	Outputs the information (debug information) as necessary for debugging, to the load module file.
`-l` *lib*	Specifies a library named *lib*. The library is searched in the following order : (1) The directory specified in the -L option. (2) The directory set for the environment variable M32RLIB (If not set, /usr/local/M32R/lib.).
`-L` *dir*	Specifies the library search directory.

Table 2.4 Command Options for the Linker (2/4)

Option	Description

`-LOC` *addr1,addr2*	This option allows writing of the C program into the ROM by assigning the sections to the appropriate memory locations. This option is a simplified version of the -SEC option and is made effective when the section is composed of P, D, B and/or C and cannot be used if a user made section exists.
	Specify the address in hexadecimal. The hex. number beginning with an alphabetical letter must have a 0 (zero) affixed before the letter.
	The first *addr1* must be assigned the start address of the RAM area (locations for the D and B section). Sections must be linked in the order of D and B. The RAM memory locations specified by *addr1* are reserved but they are not used to store the initial value data.
	The second *addr2* must be assigned the start address of the ROM area (locations for initial value data of the P and C and D sections). Sections must be linked in the order of P, C and D. The D section (initial value data) is output as the section named ROM_D.
	The -LOC option cannot be used together with the -SEC or -r.
	Each of the following options denotes the same process.
	`-LOC 1000,8000`
	`-SEC @D=1000,B,P=8000,C,D`

`-M` *map_filename*	Outputs the link map file named *map_filename*.
`-o` *output_filename*	Gives the name *output_filename* to the output file. If this option is not used,the name of the output file is am.out (in the case of the EWS version, a.mout is used instead of am.out).
`-r`	Creates the load module file in the form of a relocatable one. If this option is not used, the module file is generated as an absolute file. The -r option cannot be used together with -LOC or -SEC.

Table 2.4 Command Options for the Linker (3/4)

Option	Description
`-SEC` *name* `-SEC` *name=addr* `-SEC` *name=addr,name=addr...*	Specifies the linking order of the sections and the start address. Enter the section name into *name*, and the address of the location for the section into *addr*. Next to the = , specify the start address in hexadecimal. Affix 0 (zero) to the first letter of the hexadecimal if the number starts with an alphabetic character. If the start address is not specified, a section is immediately followed by the next section. If the symbol "@" is affixed to the top of the section name, the memory reserve information for that section is output without data (initial data elimination function of the linker). The initial data is not output because of the elimination function of "@" can be output to another area (initial data extraction function of the linker). To output, enter the section name without @ in the command line. The data is output under the section name ROM_*name*. Example : `-SEC  @D=1000,B,P=0c000,C,D` This example assigns the address 1000_{16} and subsequent addresses for the D section and places the D section initial data next to the C section. The initial data is output to the load module file under the section name ROM_D. The -SEC option cannot be used with -LOC or -r.
`-V`	Outputs the invoking message to the standard error output without performing any process.
`-w`	Disables the warning message display.
`-overlap`	Different sections are located at the same address (overlay facility). Once this option is specified, no sections are checked for overlap at all, so be careful when using it.

Table 2.4 Command Options for the Linker (4/4)

Option	Description
-Werrsec	Processes as error if the sections specified by the -SEC options are not included in the input files and libraries.If there is no -Werrorsec option (that is the default), this linker processes as a warning for that case.
-Wreloc	Displays the "Position" information and the "Setting" information, when the "relocation size overflow" error happens.
-Wlimit=message_max	Setting up the number limitation of messages. If the message count of the linker is more than times specified by the 'message_max', the next messages are not displayed. In the case that 0 is designated to the numerical value restriction has no effect and all the message is displayed.In the default (there is not -Wlimit), the linker behaves as *Wlimit=20* was specified.
-Wnolimit	Displays all messages.
-Wmangle	Shows a mangle name after demangle notation in a message.

2.3 Command Line Examples

The following are examples of the linker invoking procedure (% is prompt, <RET> is return key) :

- Example 1 :

```
% lnk32R -o asmd.abs -e _main add.mo sub.mo
mul.mo div.mo <RET>
```

Four files, add.mo, sub.mo, mul.mo and div.mo, are used to generate the absolute load module file asmd.abs. The entry point of the load module is the address of the global symbol _main. The entry point is used to automatically initialize the program counter when the debugger debugs asmd.abs.

- Example 2 :

```
% lnk32R -M map -r -g add.mo sub.mo mul.mo
div.mo <RET>
```

Four files add.mo, sub.mo, mul.mo and div.mo, are used to generate the relocatable load module file a.mout. The load module contains debugging information. The link map is output to the file named map.

- Example 3 :

```
% lnk32R link.cmd <RET>
```

Parameters written in the command file link.cmd will be read and executed.

Chapter 3

Creating load modules

3.1 Creating absolute load modules

The linker regards the object modules as sections, links them and allocates them to generate the load module.

3.1.1 Linking Object modules (Linking Sections)

When an application is programmed by dividing the application into source files, a section is divided into object modules. When generating the load module using these object modules, the linker links the object modules so that the same sections continue. Once linked, object codes are located in a section in the order of input files specified in the command line.

3.1.2 Locating Sections

The linker can specify the location address of a section by using the command option -SEC or -LOC (When the location attribute of a section is absolute, the section is placed on the addresses defined by the section information.).

When generating an embedded application, some sections will be placed in RAM and some sections will be placed in ROM. For example, data to be updated by execution of a program should be placed in RAM while the program section and fixed data sections are placed in ROM (see Figure 3.1).

The next page is followed. →

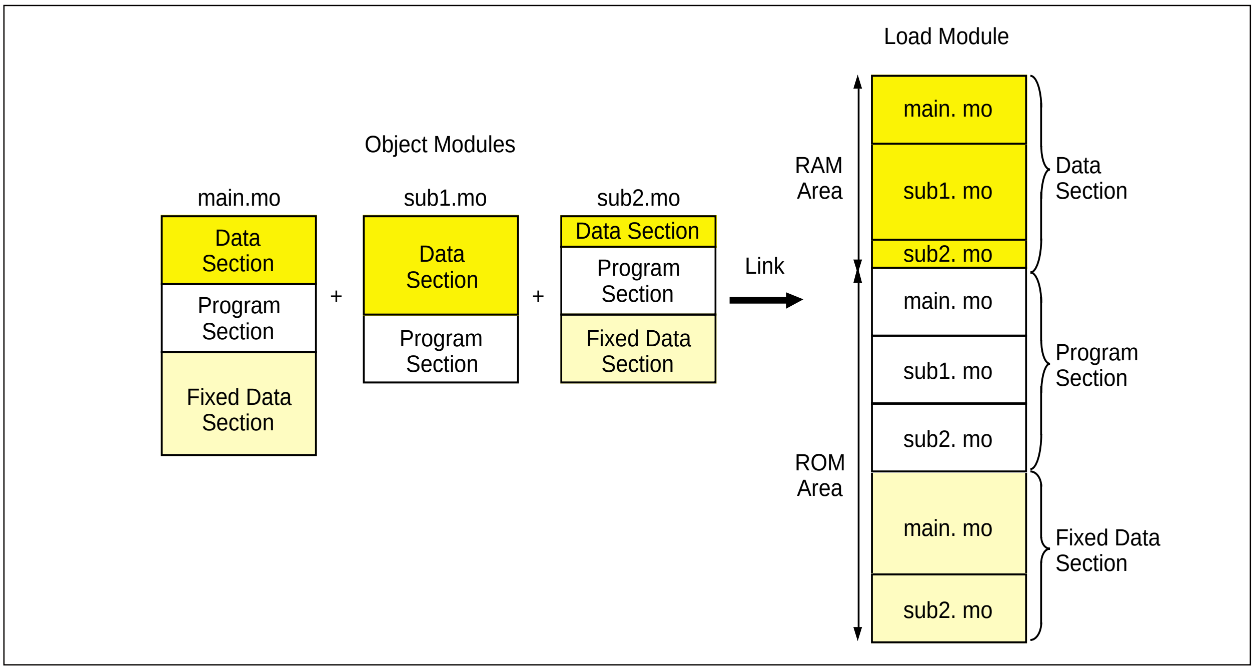


Figure 3.1 Joint Sections and Their Locations

3.2 Creating Relocatable Load Module

Relocatable load modules without absolute addresses can be created as a result of linking. With a relocatable load module, addresses within a section can be assigned with respect to the start address of that section. To create a relocatable load module, specify the invoking option -r. For example, if,

```
% lnk32R -r start.mo file1.mo file2.mo
```

is specified, the relocatable load module "am.out" (in the case of the EWS version, a.mout is used instead of am.out) is output.

3.3 Linking Library Files

The linker performs a resolving process of external reference symbols of all the specified input files. If an external reference symbol exists but it is not defined in any of the input files, the linker searches the specified library to locate the module which defines the unresolved external reference symbol and extracts the module which includes the symbol and links it. If it cannot find such a module, it issues the undefined error.

The library can be specified by using the options -l and/or -L. The library specified by the -l option is searched in the following way and in the following order :

(1) Directory specified by the -L option
(2) Directory set by M32RLIB

Searching specified by -L option is effective on the libraries specified after the -L option. When plural -L options are made, they are used in the order they specified. For example, specifying

```
% lnk32R -l a.lib -L /usr -L /usr/lib -l b.lib file.mo
```

searches the modules contained in the libraries a.lib and b.lib. The a.lib is searched in " the directory set by M32RLIB" . The b.lib is searched in the order /usr, /usr/lib and " the directory set by M32RLIB" .

A library can be directly specified in the command line as an input file :

```
% lnk32R test.mo c.lib d.lib
```

For the libraries specified as input files (e.g. c.lib and d.lib shown above) in the command line, searching specifications (" directory specified by the -L option" and " directory set by M32RLIB") cannot be applied. These libraries are searched before the libraries specified by -l option. Extraction and link of modules containing the external reference symbol are performed in the same way as in the case of libraries specified by -l option.

Chapter 4

Section

4.1 Section Types

The contents of a program are classified into one or more sections. The linker supports the five types of sections as listed in Table 4.1. Any program, code and data will belong to one of the types.

Table 4.1 Types of Sections

Type	Contents
CODE (Code Section)	Program code.
DATA (Data Section)	Data (constvariables, non-const variables, etc.)
STACK (Stack Section)	The stack area.
COMMON (Common Section)	Variables commonly used by more than one module.
DUMMY (Dummy Section)	Member definitions of structure data.

4.2 Section Definitions (Section Information)

A section is defined by the section name, section attribute and location attribute which are called section information (Table 4.2).

Table 4.2 Section Information

Section Information	Description
Section name	Any name
Section attribute	CODE, DATA, STACK, COMMON or DUMMY
Location attribute	Absolute (specifies the start address) or relative (specifies alignment)

The contents of the C language source program are automatically section defined when being compiled by the C compiler cc32R. When using an assembly language source program, define the section of contents by using the pseudo-directive .SECTION and describe the source codes. For further information on defining the method of the section, refer to the “M3T-CC32R V.x.xx User's Manual < C Compiler > Chapter 7 Embedded Applications Programming“.

The linker judges the sections as the same section when information on these section matches with each other.

4.3 Link Functions

The linker supports the following functions:

- Automatic link of sections
- Specifying linking order of sections
- Specifying location address of section

The descriptions of these functions follow.

||||| Note |||||

Sections of the same name but different section attribute or location attribute cause the linker to issue an error message and stop the process.

4.3.1 Automatic Link of Sections

The linker automatically links sections based on section information (section name, section attribute and location attribute). The same sections distributed in two or more input files are linked together in the form specified for the attributes of these sections (see 4..4 Linking Methods).

Only those sections of relative location attribute are linked. Those sections of absolute location attribute are not linked because they are already assigned the absolute addresses.

4.3.2 Specifying Linking Order of Sections

The linking order of the sections is specified by the invoking option -SEC parameter. The sections are linked in the order their names are written. For example, if they are specified in the order of

```
-SEC A,C,B
```

the sections are linked in the order of A, C and B.

The sections not specified upon invoking are linked after all the sections specified to be linked are linked, in the order which they appear in the input file.

Specification of the linking order of sections is effective only when the load module to be generated is the absolute type.

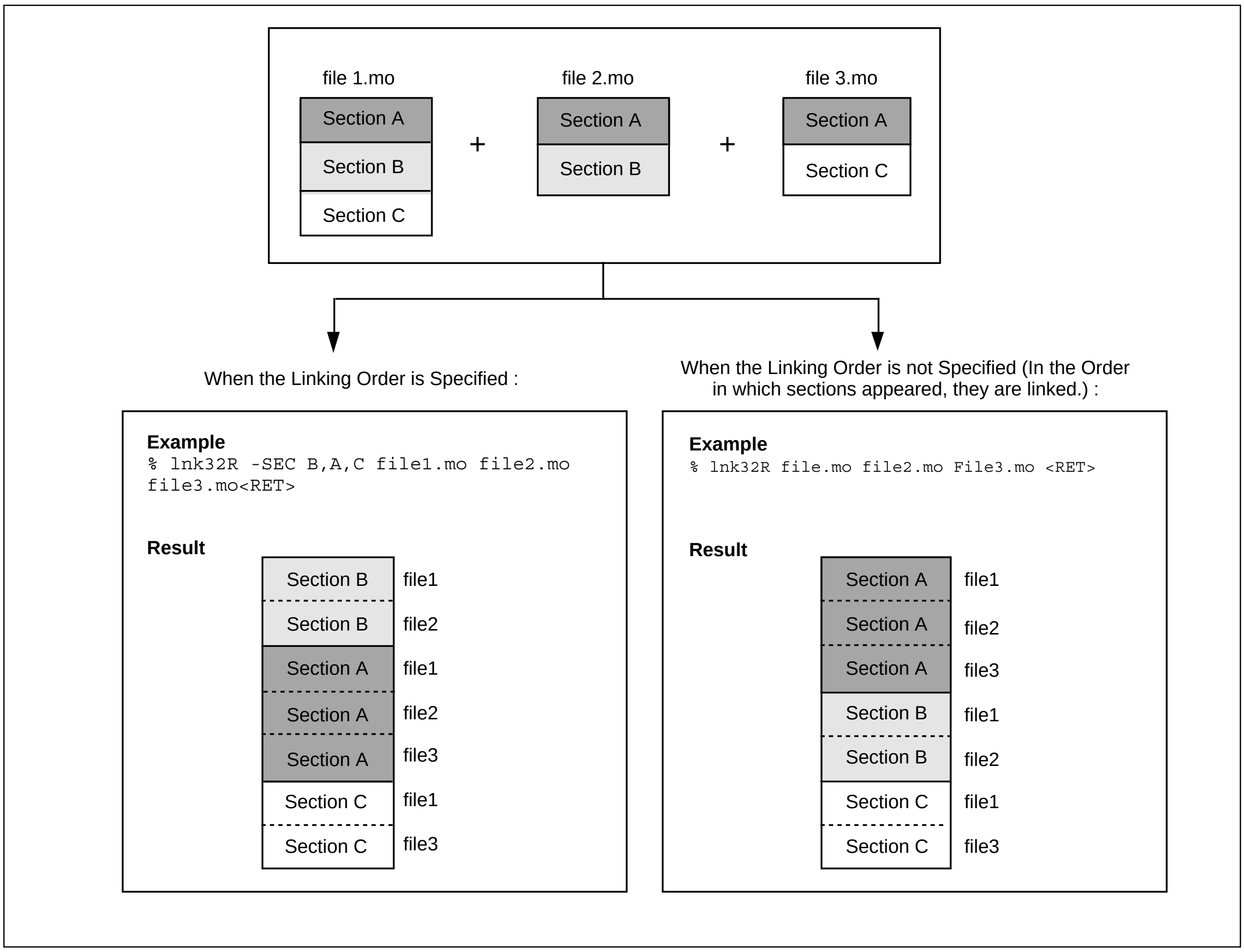


Figure 4.1 Linking Sections

4.3.3 Specifying Location Address of Section

The location addresses (absolute) of the sections are specified by the invoking option -SEC parameter. The starting address (hexadecimal) of a section is specified in the form of = XXXXXX following the section name. For example, specifying

```
-SEC A=1000,C,B
```

assigns the start address 1000_{16} to the section A.

If the section having no location address is the first to be linked, it is assigned the start address 0_{16}. The remaining sections are automatically assigned absolute addresses.

Assigning the same absolute address to two or more sections causes an error.

The next page is followed. →

||||| Note |||||

The options that specify the absolute address are -SEC and -LOC (ROM writing). These options cannot be used together.

4.4 Linking Methods (Specified by section attribute)

The linker joints sections according to their attribute (Table 4.3). Since sections having dummy attribute have no real code, they are not covered by the joint process.

Table 4.3 Section Attribute and Linking Methods

Section Attribute	Linking Method
CODE, DATA, STACK	Simple link
COMMON	Common link

The following describe the linking methods :

- Simple Link (section attribute: CODE, DATA, STACK)

  The same sections are allocated continuous addresses in the order specified by the files input to the linker.

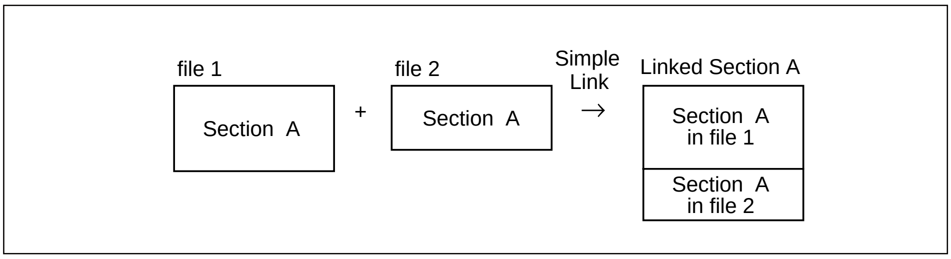


Figure 4.2 Simple Link

- Common Link (section attribute COMMON)

  The same sections are placed at the same address. The size of the section of COMMON attribute is the size of the largest section of these sections.

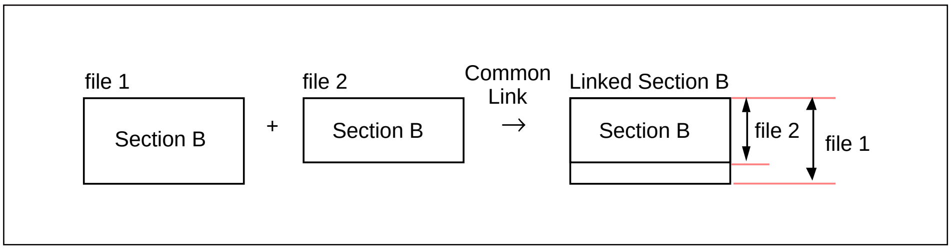


Figure 4.3 Common Link

4.5 Locating Methods (Specified by location attribute)

The linker locates sections either in absolute format or relative format according to the location attributes of individual sections (Table 4.4).

Table 4.4 Location Attribute and Locating Method

Location Attribute	Locating Method
LOCATE=*absolute address*	Absolute format
ALIGN=*alignment*	Relocatable format

The following describe the locating methods :

- Absolute format (LOCATE = *absolute address*)

  Sections whose location attributes are specified as absolute address (LOCATE = *absolute address*) in object modules have the defined location addresses. The linker cannot change these addresses.

- Relocatable format (ALIGN = *alignment*)

  Sections whose location attributes are specified as alignment (ALIGN = *alignment*) in an object module have the relocatable relative addresses. The actual address can be specified by the linker command option(s).

  The start address of a section is adjusted so that its value is a multiple of the alignment value. The alignment is an address adjusting value used when allocating data, etc., to memory locations. For example, a section defined as ALIGN = 4 is always given a start address which is a multiple of 4.

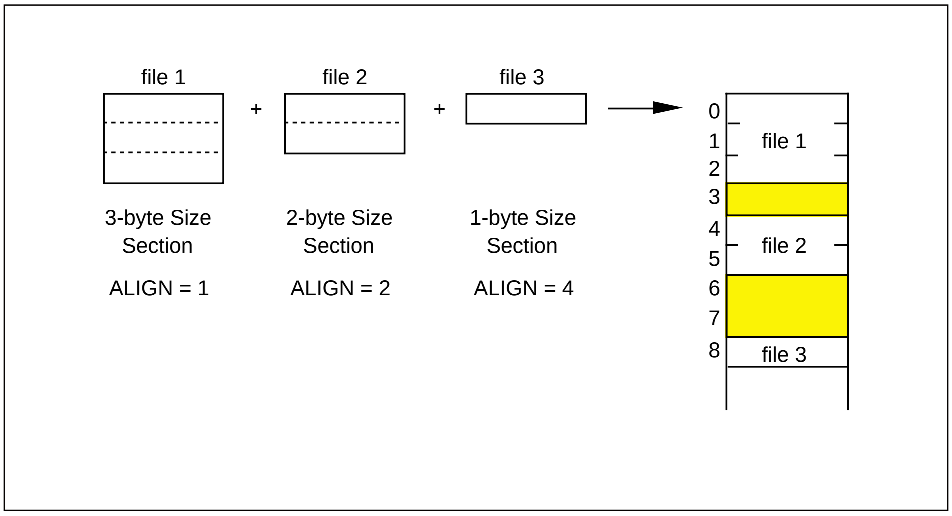


Figure 4.4 Alignment Process

Chapter 5

For ROM Writing

5.1 Processing Sections for ROM Writing

The following describe how to process sections to write the C program into ROM. The C compiler automatically defines the following 4 sections.

Table 5.1 C Compiler Output Sections

Section name	Section attribute	Location attribute	Description
P	CODE	ALIGN=4	Program code area
C	DATA	ALIGN=4	Constant data (variable declared const) area
D	DATA	ALIGN=4	Data area with initial value (global variable area having initial value)
B	DATA	ALIGN=4	Data area without initial value (global variable area having no initial value)

To write the C program into ROM, the following specifications and processes are required :

- Specification of the location(s) area of the section(s) (by the linker)
- Specification of the output area of the D section content (by the linker)
- Initialization of the D and B section contents (in start-up file)

To write into ROM, use the load module converter to convert the load module generated by the linker into Motorola S format (see Part 5 " Load Module Converter lmc32R").

5.1.1 Specifying Location Area of Section (by the linker)

When generating a load module, specify the location of memory in which the contents of each section is to be stored, that is ROM area (read only) or RAM area (read/write). To specify the location area, use the -SEC or -LOC option.

- Section P and C — Store into ROM area since these sections are left as they are during program run.
- Section D and B — Store into RAM since the contents will be updated by the program.

5.1.2 Specifying Output Area of Data (by the linker)

When creating a load module, in general, the contents (program code and data) of each section are output to the specified area. Because the contents of the D section are the initial values which are used to initialize the D section , they should be output to the ROM area. To do so, use the linker's " initial data elimination function" and " initial data extraction function" (see 5.2).

5.1.3 Initializing the Data Sections (in Start-up File)

Data sections to be stored in the RAM area, such as the contents of sections D and B must be initialized before they are used by running the C program. These sections are initialized in the following way and normally by the invoking program (to be executed first to perform initialization) :

- Section D — The initial value of section D written in the ROM area by the Initial data extraction function is transferred to the section D area reserved in the RAM area.
- Section B — Area of section B reserved in RAM area is cleared to zero (all bytes in both areas are reset to zero).

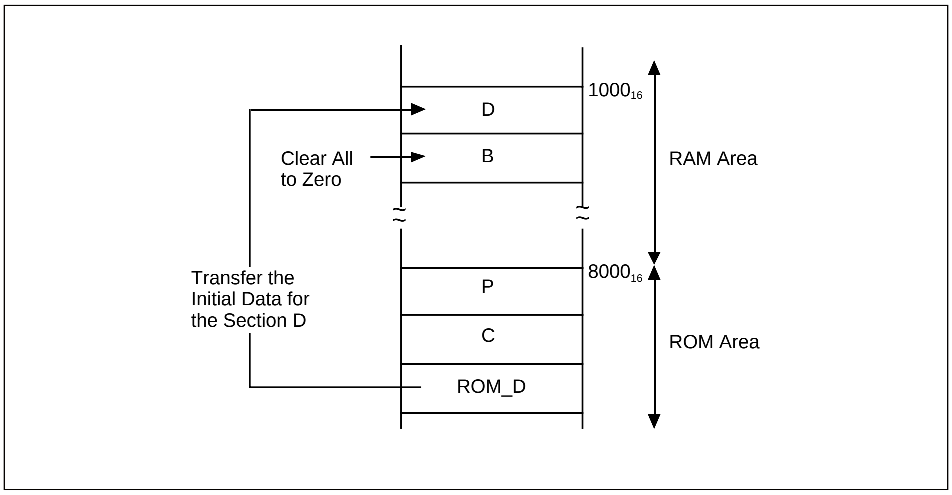


Figure 5.1 Initialization of a Data Section

The next page is followed. →

For easier transfer of data for initialization, use the reserved labels generated by the linker (see 5.2.3).

||||| Note |||||

The invoking program of a built-in application additionally needs processor settings and library initialization. For further information on the invoking program, see the “M3T-CC32R V.3.10 User's Manual < C Compiler > 7.3 Programming the Start-up Program“.

5.2 Committing Applications to ROM

5.2.1 Initial Data Elimination

This function inhibits the contents of the section from being output to the section area reserved for it in memory.

When the location area is specified by the -SEC option, the linker, as a default process, reserves the area for that section in the specified location area, and outputs the contents (code and data) of that section to the reserved area. For example, if

```
-SEC P=8000
```

is specified, an area with size equal to that of the P section is reserved in the section P area with the starting address 8000_{16}. The contents of section P are automatically transferred to this reserved area.

However, sections such as D and B, which are located in the RAM area and are to be initialized before the program run requires reservation of its area which will not require initial data to be loaded. For these sections, apply the initial data elimination function.

To keep the contents of a section from being output by using the initial data elimination feature, place the symbol @ before the section name when specifying the location area of the section by using the -SEC option. By this protection measure, none of data contained in that section will be output. The contents in the area for that section becomes unknown. For example, if

```
-SEC @D=1000,B,P=8000
```

is specified, an area of D section whose size is equal to that of section D is reserved with the starting address at 1000_{16}. Nothing is output to this area (contents are unknown). The section B output by the C compiler contains no initial data, so that the initial data elimination is not required (no need to use the @ symbol when specifying with the -SEC option).

When it is necessary to output the output-inhibited initial data to an area (normally, to the ROM area), use the initial data extraction function (see 5.2.2).

5.2.2 Initial Data Extraction

The initial data extraction feature is to be used in conjunction with the initial data elimination feature. When it is necessary to output the contents of a section previously inhibited from being output, use the initial data extraction to output the contents to the specified area (normally the ROM area).

To write into ROM a program containing a section like section D whose section area is to be located in RAM and whose initial data is to be loaded in ROM, the initial data first must be transferred to the ROM area before writing the load module into ROM. By using the linker's initial data extraction function, this transferring process can be performed during the generation of the load module. This procedure simplifies the procedure necessary to write the program into ROM.

To output the contents of a section to the specified area by using the initial data extraction, use one of the following methods :

- To specify by using the -SEC option :

  Use this option when it is necessary to output the section whose initial data is protected by the initial data elimination function. This option deletes the @ symbol and specifies the destination area.

  Example : `-SEC` **`@D=1000`**`,B,P=8000,C,`**`D`**

  This function is not necessary for the B section defined by the C compiler since the B section contains no initial data.

- To specify by using the -LOC option:

  Specify the start address of the RAM area and the ROM area.

  Example: `-LOC 1000,8000`

  The -LOC option is effective only when the program is composed of sections which are automatically defined by the C compiler and it is automatically used together with the initial data elimination and initial data extraction functions.

The area for the data extracted by the initial data extraction is automatically given the name, ROM_*section name*. This area can be handled in the same as a normal section. For example, the area in which the initial data extracted from the D section is to be stored is called ROM_D section.

The initial data extraction function can be applied to the sections processed by the linker. For example, this function can be used by an application which sends sections P and C from the low speed ROM to the high speed RAM.

The following examples show an application of the initial data extraction :

Example :
```
% lnk32R -SEC @D=1000,B,P=8000,C,D file1.mo
file2.mo
```

or

```
% lnk32R -LOC 1000,8000 file1.mo file2.mo
```

Both of the above examples result in the same output.

In the area starting with address 1000_{16} (RAM area), the D and B sections whose initial data are not output are located. In the area starting with address 8000_{16} (ROM area), sections P, C and ROM_D whose initial data are output are located. To the ROM_D section, the initial data for the D section is output. Again, in this example, the start address of the RAM area is 1000_{16}, and that of the ROM area is 8000_{16}.

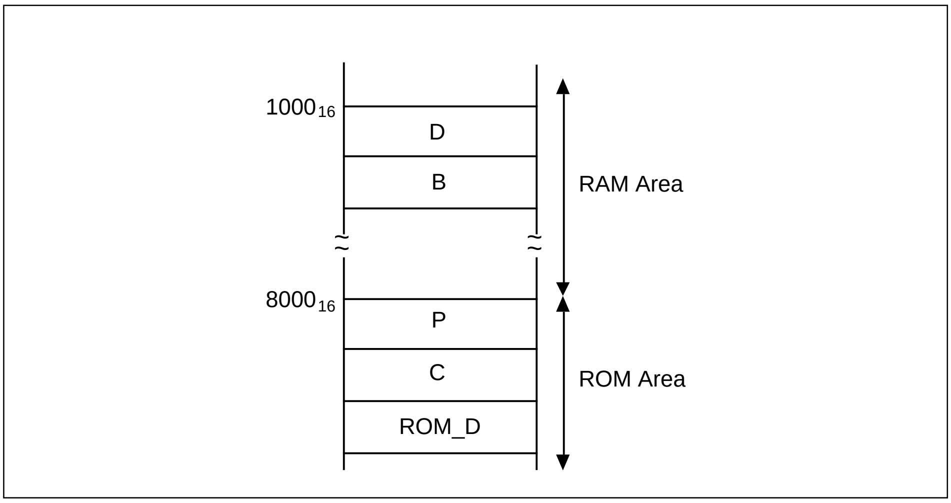


Figure 5.2 Result of initial data extraction

5.2.3 Reserved Labels Generation

The linker automatically generates the labels which indicate the start address and end address of each section. The label indicating the beginning of a section has a name consisting of the symbol _ _TOP_ followed by the section name and the label indicating the end of a section (the address following the last byte of the section) has a name consisting of symbol _ _END_ followed by the section name. For example, the start address of section D is denoted as _ _TOP_D, and the end address is _ _END_D (see Figure 5.3).

The next page is followed. ➔

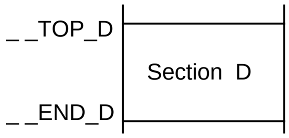


Figure 1.10 Generation of Reserved Labels (Section D)

By using reserve labels, the initial data transfer operation (equivalent of initializing section D) and the zero-clear operation (equivalent of initializing section B) can be described in C language. Reserved labels are automatically output to the sections handled by the linker.

Chapter 6

Messages from the Linker

6.1 Getting Execution Result of the Linker

The execution result of the linker can be judged by checking the message(s) and exit status code.

6.1.1 Message Format

Upon encountering an error condition, the linker outputs the message describing the error status to the standard error output, in the following format :

- Syntax

  tool_name : *input_information* : *message_type* : *message*

  Note) "*input_information* :" is output only when necessary.

- Pattern

  lnk32R: *file_name* : *message_type* : *message*
  lnk32R: *<command_line>* : *message_type* *message*
  lnk32R: *message_type* : *message*

  Note) Underlined items are *input_information* (no the underline is output).

- Example

```
lnk32R: error: cannot open file "abc.mo"
```

  Tool name Message type Message

6.1.2 Message Types

Messages are classified into three types according to the effect.

Table 6.1 Message Types

Message Type	Operation Upon Error
Warning	Outputs a warning message and continues process.
Error	Outputs an error message and stops current process.
Fatal error	Outputs an error message and stops current process.

For details of the messages, see 6.2 “ Message Lists” .

6.1.3 Exit Status

Upon completion of the execution, the linker returns the exit status (value showing the execution result) as shown in Table 1.11.

Table 6.2 Exit Status

Exit Status	Result
0	Complete successfully or warning occurs
1	Error occurs

6.2 Message Lists

6.2.1 Warning Messages

Table 6.3 Warning Messages

Message	Meaning→Linker Action
`external symbol not defined:` "*symbol*"	An undefined external symbol is referenced (with -r option). →The external reference is ignored and regarded as 0.
`option` *option* `specified more than once, last setting taken`	The same option (involving parameters) is specified more than once. →The parameters of the last option are made effective.

6.2.2 Error Messages

Table 6.4 Error Messages (1/3)

Message	Description→Action
`cannot close file` "*filename*"	The file cannot be closed. →Check the disk space.
`cannot create file` "*filename*"	The file *file_name* cannot be created. →Check the file name and disk space.
`cannot execute` *command_name*	The command is not found. →Check the path of the command. Set the environment variable M32RBIN.
`cannot open file` "*filename*"	The file is not found. →Check the file name.
`duplicate symbol` "*symbol*"	Same global symbol is defined more than once. →Check the global symbols for duplication.

Table 6.4 Error Messages (2/3)

Message	Description→Action
external symbol not defined: "*symbol*"	Undefined global symbol is referenced. →Give a definition to the undefined symbol.
illegal file format: ID=*number*	The format of the specified file is illegal. →Check the format of the file.
illegal option "*option*"	An illegal option is specified. →Specify a correct option.
illegal option parameter "*parameter*"	An illegal option parameter is specified. →Specify a correct option parameter.
illegal section name "*section_name*"	An illegal section name is specified. →Specify a correct section name.
illegal section start address: *address*	The section is assigned illegal start address. →Specify the correct section start address.
illegal symbol name "*symbol*"	An illegal symbol name is specified. →Specify a correct symbol name.
multiple entry points exist: *address*	More than one module having the execution start address is specified. →Select only one module among modules having the execution start address.
option *option* and *option* cannot be specified together	The options specified must be specified independently. →Select only one of the options.
option *option* requires parameter	The option *option* has no specified parameter which it must have. →Specify the parameter.

Table 6.4 Error Messages (3/3)

Message	Description→Action
`relocation size overflow:` "*section_name*", *offset*, "*Symbol name*"	The result of operation of undefined symbol exceeds the size specified by the user. •*Section name* : Name of section causing the overflow. •*Offset value* : The portion at which the overflow occurs (offset value from the top of the section). •*Symbol name* : The name of the symbol, if any. →Increase the size definition.
`section address misaligned:` "*section_name*"	Section start address does not match the boundary alignment value. →Check the specified address and the boundary alignment value.
`section attribute inconsistent:` "*section_name*"	The sections have the same section name but different attribute. →Use the same attribute or change one of the section names.
`section address overflow:` "*section_name*"	The number of addresses assigned to the section exceeds the allowable range (00000000_{16}-$FFFFFFFF_{16}$). →Reconfigure the program.
`section form inconsistent:` "*section_name*"	The sections have the same section name but they are of different type. →Use the same type sections or change either of the section names.
`section not found:` "*section_name*"	The specified section is not found. →Check the section name.
`section overlap:` "*section_name*"	The sections overlap. →Change the location address of either section.
`unsupported module type: version` *number*	The type of the module is not supported. →Check to see if the module is correctly generated.

6.2.3 Fatal Error Messages

Table 6.5 Fatal Error Messages

Message	Description→Action
`file seek error`	Cannot seek the file. →Check the content of the disk.
`internal error`	An internal error occurs. →Please contact us immediately.
`out of disk space`	Cannot output to the file. →Check the disk space.
`out of memory`	The capacity of memory is not enough for the linker to operate. →Expand memory space or change the program.

Part 3

Map Generator map32R

Chapter 1

Overview of the Map Generator map32R

1.1 Overview

The map generator map32R is included in the cross tool kit M3T-CC32R.

The map generator generates a link map from an object module, an absolute load module, or a relocatable load module which are generated by the C compiler, assembler or linker.

”Link map” is a list which consists of “map list” and “global symbol list ”. A map list lists sections and their information. A global symbol list shows global (external) symbols and their information in alphabetical order or from lowest address to highest.

“The Access Control File“contains the following information, which is required in order to use the base register function(see “M3T-CC32R V.x.xx User's Manual < C Compiler > Appendix A.1 Base Register Function“.):

(1) Base address for 16-bit register relative indirect addressing
(2) Register storing the base address
(3) Objects to which the base register function is applied (variables and structures)

Chapter 2

Invoke the Map Generator

2.1 How to Invoke the Map Generator

2.1.1 Invoking Procedure

To invoke the map generator, set the environment variables (see 2.1.2), enter the “map32R” command according to the command line rules and execute it (see 2.1.3).

2.1.2 Setting Environment Variables

Set the valid directory for the environment variables M32RBIN, M32RINC, M32RLIB and M32RTMP (This step may be skipped since these variables are normally set during installation.). For the setting procedure, refer to the “M3T-CC32R Cross Tool-Kit V.x.xx Release x Release Note“. If you do not set them, the default directories are selected automatically.

Table 2.1 Environment Variables

Environment Variable	Default Directory
M32RBIN	/usr/local/M32R/bin
M32RINC	/usr/local/M32R/include
M32RLIB	/usr/local/M32R/lib
M32RTMP	/tmp

2.1.3 Command Line Format

The following shows the format and rule for the map generator's invocation command line. For further information on the command options and input and output files, refer to 2.1.4 and the subsequent sections.

```
map32R   [-o output_filename] [-V] [-s] [-n] [-Rn=Address]
         [-Pd] [-Pn[=filename]] [-Ps[=filename]]
         [-c] [-c16]
         [-debug_no] [-debug_sort_name] [-debug_sort_addr]
         [-debug_sort_attr] [-debug_no_func] [-debug_no_label]
         [-debug_no_var] [-debug_no_global] [-debug_no_local]
         [object_filename] <RET>
```

where :

• Without [ ]	: Indispensable
• In [ ]	: Optional
• Prefixed by -	: A command option (see 2.3)
• <RET>	: Enter the return key

Figure 2.1 map32R Command Line Format

- Write the command line in the format shown in Figure 2.1. The items (command name, option, input file name) must be separated from the adjacent items by at least one space character. Press the return key and the map generator starts execution.
- Option and its parameter must be separated by a space character. If conflicting options are used together, the last specified option has the priority.
- Specify only one input file name for object_filename. If the input file name is omitted, am.out (in the case of the EWS version, a.mout is used instead of am.out) is automatically selected as the input file name.
- The input files are recognized as object files (object module, load module) regardless of their dot extension.

||||| Note |||||

If any name (module name, section name or symbol name) is composed of more than 20 characters, it can cause disorder in the map list layout.

2.1.4 Input File Conditions

The Table 2.2 shows the conditions required for input files to be processed by the map generator. Do not input a file which cannot meet these conditions.

Table 2.2 Input File Conditions

Item	Conditions
Valid input files	Object module file(s) Relocatable load module file(s) Absolute load module file(s)
Maximum number of names	Section names : Up to 65535/file Symbol names : Up to 65535/file Module names : Up to 65535/file The number may be limited by the capacity of the development environment system memory.

2.1.5 Output File Naming

The name of the output file is the name specified by the -o option. If it is not specified, it is output to the standard output.

2.2 Command Options

Table 2.3 shows the functions of the command options for the map generator .

Table 2.3(1/2) Command Options for the Map Generator

Option	Description
-n	Outputs the global symbol list in the order of the addresses following the map list.
-o *output_filename*	Outputs a link map (a map list and a global symbol list) to a file named *output_filename* (link map file). If this option is omitted, a link map is output to the standard output.
-s	Outputs the global symbol list in alphabetical order following the map list.
-V	Outputs the invoking message to the standard error output without performing any process.
-Rn=Address	Specifies base register (n=11 to 13) and the base address (hex), and generates the Access Control File. (No link map is generated.)
-Pd	Does not display the total number of data symbols and the number of hit symbols (those that are determined as being able to use the base registers)
-Pn [=filename]	Displays a list of symbols not covered by the base registers (same format as -n option). If "=filename" is specified after the option, the result is output to that file. If not specified, the result is output to standard output.
-Ps [=filename]	Outputs a sample startup program based on the structure of the specified base registers. If "=filename" is specified after the option, the result is output to that file. If not specified, the result is output to standard output.
-c	A csv symbol map is output in the single-address format. This map is output to the map file if the -o option exists, or to the standard output device if the -o option does not exist. When -c is specified, no link map files are output.

Table 2.3(2/2) Command Options for the Map Generator

Option	Description
-c16	A csv symbol map is output in the 16-address format. This map is output to the map file if the -o option exists, or to the standard output device if the -o option does not exist. When -c16 is specified, no link map files are output.
-debug_no	Does not output the DEBUG SOURCE LIST and DEBUG SYMBOL LIST.
-debug_sort_name	Outputs the DEBUG SYMBOL LIST in order the symbol names.
-debug_sort_addr	Outputs the DEBUG SYMBOL LIST in order the symbol address.
-debug_sort_attr	Outputs the DEBUG SYMBOL LIST in order the symbol attributes.
-debug_no_func	Does not output the function names to the DEBUG SYMBOL LIST.
-debug_no_label	Does not output the assembly labels to the DEBUG SYMBOL LIST.
-debug_no_var	Does not output the C source variables to the DEBUG SYMBOL LIST.
-debug_no_global	Does not output the global symbols to the DEBUG SYMBOL LIST.
-debug_no_local	Does not output the local symbols to the DEBUG SYMBOL LIST.
-mangle	Shows a mangle name before demangle notation in a message.
-mangle_only	Shows a mangle name in place of demangle notation.
-old_index	Shows an information list in format compatible with old versions prior to V.4.xx.
-c_demangle	Selects a mangle name index format which is one of the -csv symbol maps.

2.3 Command Line Examples

The following are examples of the map generator invoking procedure (% is prompt, <RET> is return key) :

- Example 1 :

```
% map32R -o sample.lst sample.abs <RET>
```

Outputs the map list of absolute load module sample.abs and global symbol list to the sample.lst.

- Example 2 :

```
% map32R <RET>
```

Outputs the map list of the load module am.out (in the case of the EWS version, a.mout is used instead of am.out) and global symbol list to the standard output.

- Example 3 :

```
% map32R -R13=F78000 -R12=F88000 -R11=FC8000 -o
sample.acc -Ps=startsmp.ms sample.abs<RET>
```

This operation is for making files that utilize base registration function from load module "sample.abs".
In this example, combination list of base registers and addresses are following, access control file is made as "sample.acc",
a program for initializing base registers is made as
"startsmp.ms",and excluded (this means out of base registers) symbols are output to standard output.

0x00F78000 as R13
0x00F88000 as R12
0x00FC8000 as R11

Chapter 3

Link Map File

3.1 Contents of Link Map File

“Map list” and “global symbol list” are output to a link map as shown in Figure 3.1 :

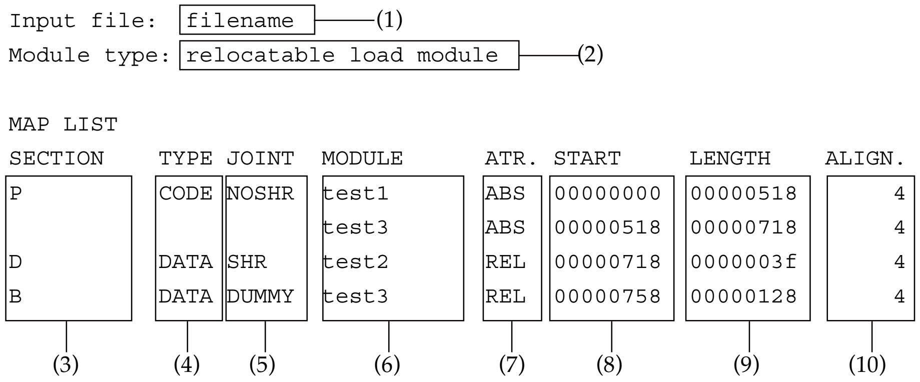
```
Input file:  filename
Module type: relocatable load module

MAP LIST
SECTION    TYPE JOINT  MODULE      ATR. START     LENGTH    ALIGN.
P          CODE NOSHR  test1       ABS  00000000  00000518       4
                       test3       ABS  00000518  00000718       4
D          DATA SHR    test2       REL  00000718  0000003f       4
B          DATA DUMMY  test3       REL  00000758  00000128       4

GLOBAL SYMBOL LIST
SYMBOL     ADDR.      TYPE   SEC.
_func1     00000012   DAT    P
LABEL1     00000d02   DAT    D
LABEL2     00000e12   DAT    D

SYMBOL1    000000ff   EQU    B
SYMBOL2    00000001   EQU    B
```

Figure 3.1 Example of a Link Map

A map list and a global symbol list are described in 3.2 and 3.3, respectively.

3.2 Contents of Map List

The map list shows the information on section location in an input file. Descriptions in the list are as follows :



```
Input file:  filename
Module type: relocatable load module

MAP LIST
SECTION      TYPE JOINT  MODULE      ATR. START     LENGTH    ALIGN.
P            CODE NOSHR  test1       ABS  00000000  00000518       4
                         test3       ABS  00000518  00000718       4
D            DATA SHR    test2       REL  00000718  0000003f       4
B            DATA DUMMY  test3       REL  00000758  00000128       4
```

(1) `Input file` (Input file name)

(2) `Module type` (Input file attribute)

`object module`	: Object module
`relocatable load module`	: Relocatable load module
`absolute load module`	: Absolute load module

(3) `SECTION` (Section name)

(4) `TYPE` (Section attribute)

`DATA`	: Data
`CODE`	: Code
`DUMMY`	: Dummy
`STACK`	: Stack
Character string *“XXXXX”*	: Attribute unknown

(5) `JOINT` (Linking method)

`SHR`	: Common link
`NOSHR`	: Simple link
`DUMMY`	: Dummy link
Character string *“XXXXX”*	: Linking method unknown

(6) `MODULE` (Module name)

(7) `ATR.` (Location attribute)

`REL`	: Relocatable format
`ABS`	: Absolute format
Character string *“XXX”*	: Attribute unknown

(8) `START` (Start address (hex.) of object)

(9) `LENGTH` (Address size (hex.) of object)

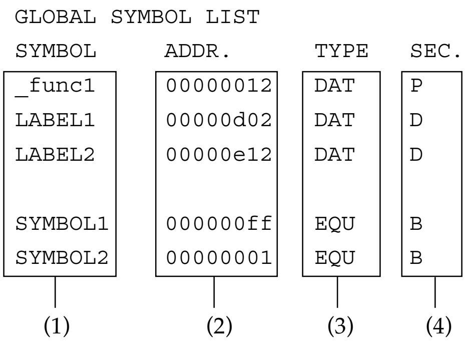
(10) `ALIGN.` (Location counter adjustment value (alignment) during linking)

3.3 Contents of Global Symbol List

The global symbol list shows the name of the global systems and their value and will be output only when the command option -s or -n is specified. The first portion of the list outputs label, name of function, name of variable (TYPE = DAT) and the second portion outputs symbol (TYPE = EQU). If the global symbol is not present, a string, “no symbol”, is output.

Symbols are output in the alphabetical order of the symbol name if the -s option is specified, and in the order of the symbol value when the -n option is specified. Symbol (TYPE = EQU) area is always in alphabetic order.

The descriptions in the global symbol list are as follows :



```
GLOBAL SYMBOL LIST
SYMBOL      ADDR.       TYPE   SEC.
_func1      00000012    DAT    P
LABEL1      00000d02    DAT    D
LABEL2      00000e12    DAT    D

SYMBOL1     000000ff    EQU    B
SYMBOL2     00000001    EQU    B
```

(1) SYMBOL (External symbol name)

(2) ADDR. (Symbol value)
If the attribute of the input file is relative, the value of symbol is not guaranteed.

(3) TYPE (Symbol type)

DAT	: A function name, a variable name, or a label
EQU	: A symbol

(4) SEC. (Name of section having defined symbol)

3.3 About extended output forms of map32R

When the debugging information effective load module are inputted to map32R, this tool outputs to the debug symbol list to the map file.

● **Example:**

[Source file: sample1.c]

```

int global;

void foo1 (int arg)
{
 static int static_local = 10;

 for (global = 0; global < 10; global++)
    static_local += glboal;
}
```

[Source file: sample2.c]

```

static int static_global;

void foo2( int arg )
{
 int local;

 for (static_global=0; static_global < 10; static_global++)
     local += static_global;
}
```

[Command line:]

```
% cc32R -o sample.abs -SEC P=0FC0000,C,D=8000,B sample1.c sample2.c
% map32R -o sample.map sample.abs
```

The next page is followed. →

[Generated map file: sample.map]

```
Input file:  filename
Module type: relocatable load module

Input file : sample.abs
Module type : absolute load module

MAP LIST

SECTION  TYPE  JOINT MODULE    ATR. START     LENGTH    ALIGN.
D        DATA  NOSHR sample1   ABS  00008000  00000004       4
B        DATA  NOSHR sample1   ABS  00008004  00000004       4
                     sample2   ABS  00008008  00000004       4
P        CODE  NOSHR sample1   ABS  00fc0000  00000044       4
                     sample2   ABS  00fc0044  00000040       4

DEBUG SOURCE LIST

[1] sample1.c
[2] sample2.c

DEBUG SYMBOL LIST

SYMBOL             ATTR.      ADDR.         SIZE     SOURCE
static_local       VAR|LOCAL  0x00008000       4     [1] 6
global             VAR|GLOBAL 0x00008004       4     [1] 2
static_global      VAR|LOCAL  0x00008008       4     [2] 2
foo1               FUN|GLOBAL 0x00FC0000       0     [1] 4
foo2               FUN|GLOBAL 0x00FC0044       0     [2] 4
```

Figure 3.2 Example: extended output forms of map32R

[Meaning of each items]

(1) DEBUG SOURCE LIST

This is a list of the source files that the load module file includes. The [number] field means the identity number of a source file, that specifies a source file at the DEBUG SYMBOL LIST.

(2) DEBUG SYMBOL LIST

This is a list of the debug symbols that the load module file includes.

This list shows the symbol of the following attributes.

Attributes	Notation at ATTR
Field Function Names	FUN
Assembly Labels	LAB
Variables of C source	VAR
External Symbols	GLOBAL
Local Symbols	LOCAL

Also, the following informations of each symbol are displayed, to the fields of DEBUG SYMBOL LIST.

SYMBOL	→	Symbol names
ATTR.	→	Attributes
ADDR.	→	Addresses
SIZE	→	Size of the variables
SOURCE	→	Source file identity numbers (on DEBUG SOURCE LIST) and line numbers.

[Options]

-debug_no	Does not output the DEBUG SOURCE LIST and DEBUG SYMBOL LIST.
-debug_sort_name	Outputs the DEBUG SYMBOL LIST in order the symbol names.
-debug_sort_addr	Outputs the DEBUG SYMBOL LIST in order the symbol address.
-debug_sort_attr	Outputs the DEBUG SYMBOL LIST in order the symbol attributes.
-debug_no_func	Does not output the function names to the DEBUG SYMBOL LIST.
-debug_no_label	Does not output the assembly labels to the DEBUG SYMBOL LIST.
-debug_no_var	Does not output the C source variables to the DEBUG SYMBOL LIST.
-debug_no_global	Does not output the global symbols to the DEBUG SYMBOL LIST.
-debug_no_local	Does not output the local symbols to the DEBUG SYMBOL LIST.

Chapter 4

The Access Control File Generation Function

map32R is able to generate the Access Control File from the symbol information in the load module file. See "M3T-CC32R V.x.xx User's Manual < C Compiler > A.1.7 The Access Control File".

The generated the Access Control File can be specified in the cc32R -access option.

4.1 Details of the Access Control File Generation Function

● When the "-Rn=Address" option is specified, the Access Control File is generated from the data in the load module file. This Access Control File can be input in the cc32R -access option. (Note that no map is output.)

● The name of the Access Control File is specified using "-o filename" (if omitted, output is directed to standard output).

● The three types of base registers R11 to R13 can be specified. If the same register is specified two or more times, the last specification is used.

● If there is an overlapping of the areas indicated by the base registers, a warning similar to the following is output:

Base Register Area is Overlapped: R13 and R12.

● map32R lists the base register definitions as well as the data symbols that can be covered by those base registers as variable names after deleting the underbar prefix (_).

[Data symbol conditions:]

Any of the following is accepted as a data symbol:

(1) If it does not belong to any section;

(2) Constant labels defined by .EQU;

(3) Belonging to a section without the attribute 'code', and without the name 'C'.

● By default, the total number of data symbols and the number of hit symbols are displayed after processing.

● The -Pd, -Ps, and -Pn options are ignored unless specified along with -Rn= ..."

● The setup program output by -Ps consists of an assembler subroutine named $_Set_Regbase. If this program is called from the startup routine using either BL or JL instruction, the required base registers can be set up.

- You can select lines with the comment "Must" from the program output using -Ps.

4.2 Example of Using the Access Control File Generation Function

This operation is for making files that utilize base registration function from load module "sample.abs".
In this example, combination list of base registers and addresses are following, access control file is made as "sample.acc", a program for initializing base registers is made as "startsmp.ms",and excluded (this means out of base registers) symbols are output to standard output.

0x00F78000 as R13
0x00F88000 as R12
0x00FC8000 as R11

[Command line specification]

```
% map32R -R13=F78000 -R12=F88000 -R11=FC8000 -o sample.acc -Ps=startsmp.ms sample.abs<RET>
```

[Example screen display:]

```
Count of Data Symbol(s): 10
Data Symbol(s) that hit:   6
```

(In this example display, there are 10 data symbols and six of these are in the ranges of register relative indirect addressing from R13 to R11, and are therefore output to the Access Control File.)

[Example output of The Access Control File sample.acc]

```
@R13  0xF78000
var1
var2
var3

@R12   0xF88000
var4
var5

@R11   0xFC8000
var6
```

The next page is followed. →

[Example output of base register setting program sample startsmp.ms]

```
          .SECTION     P,CODE,ALIGN=4
          .EXPORT      $_Set_Regbase
$_Set_Regbase:
          SETH         R13,#HIGH(__REL_BASE13)              ; Must
          OR3          R13,R13,#LOW(__REL_BASE13)           ; Must
          SETH         R12,#HIGH(__REL_BASE12)              ; Must
          OR3          R12,R12,#LOW(__REL_BASE12)           ; Must
          SETH         R11,#HIGH(__REL_BASE11)              ; Must
          OR3          R11,R11,#LOW(__REL_BASE11)           ; Must
          JMP          R14

          .EXPORT      __REL_BASE13                         ; Must
          .EXPORT      __REL_BASE12                         ; Must
          .EXPORT      __REL_BASE11                         ; Must
__REL_BASE13:          .EQU   0x00F78000                    ; Must
__REL_BASE12:          .EQU   0x00F88000                    ; Must
__REL_BASE11:          .EQU   0x00FC8000                    ; Must
```

4.3 Notes

- Access control files are created by using debugging information. Even when access control files are created from a load module, no symbol names will be output unless the load module has debugging information.

- Base symbols (__REL_BASExx, etc.) are not included in the data symbols.

Chapter 5

Csv symbol map file output

map32R is able to generate the csv symbol map file from the symbol information in the load module file.
A csv symbol map is produced in tabular form, showing addresses in the first column and symbols in the second and subsequent columns. Because the map file is in csv format, it can be input to Microsoft Excel or other spreadsheet software.

5.1 Details of the Csv symbol map file

5.1.1 Generation of the csv symbol map file

If the option -c or -c16 is specified in map32R, a map of addresses and symbols (variable or object and function names) is generated in csv format.

When you specify the -c option, select the "single-address format" that indicates one symbol in one line.
This map is output to the map file if the -o option exists, or to the standard output device if the -o option does not exist.
When -c is specified, no link map files are output.

When you specify the -c16 option, select the "16-address format" that indicates the symbols belonging to a 16-byte area in one line.
This map is output to the map file if the -o option exists, or to the standard output device if the -o option does not exist.
When -c16 is specified, no link map files are output.

5.1.2 Form of the csv symbol map file

[Indicated content of the single-address format]

- The first line indicates the heading "Address, Symbol".
- Indicated in order of addresses that are assigned symbols beginning with the least significant (smallest) address.
- Indicates one symbol in one line.
- Indicates addresses in the first column and symbols in the second column.
- The address moved forward by a size equal to the indicated symbols is the address for the next line.
- If there are contiguous addresses that are not assigned symbols, only one line of a colon (:) is output collectively.

[Indicated content of the 16-address format]

- * First indicates the headline "Address, 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F".
- * Each line indicates the beginning address after being aligned to a multiple of 16.
- * Indicated in order of addresses that are assigned symbols beginning with the least significant (smallest) address.
- * Indicates addresses in the first column and symbols located at +0x0 to +0xF from that address in the second to the 17th columns.
- * The symbol is suffixed by size notation (parenthesized decimal).
- * The next line starts from an address moved forward by 16 bytes. However, if a symbol in sizes overlapping multiple lines is to be indicated, only one line of a colon (:) is output, and the next line starts from an address moved forward by a size equal to the symbol.
- * If there are contiguous addresses that are not assigned symbols, only one line of a colon (:) is output collectively.

[Symbol notation]
In csv symbol maps, a symbol is indicated in the form shown below.

Table 5.1 Symbol Notation in csv Symbol Maps

Global variables Variables that are not declared as static	symbol
Intrafile static variables static functions	File_name@symbol
Intrafunction static variables	File_name@function_ name@symbol

5.2 Example of output the Csv symbol map file

5.2.1 Example of “-c” option

[Command line]

```
map32R -o sample.csv -c sample.abs
```

[Content of sample.csv]

```
Address,Symbol
0x00008000,sample1.c@foo1@static_local
0x00008004,global
0x00008008,sample2.c@static_global
0x0000800C,
:
0x00FC0000,foo1
0x00FC0044,foo2
0x00FC0084,
```

5.2.2 Example of “-c16” option

[Command line]

```
map32R -o sample.csv -c16 sample.abs
```

[Content of sample.csv]

```
Address,0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F
0x00008000,sample1.c@foo1@static_local(4),,,,
global(4),,,,sample2.c@static_global(4),,,,,,,
:
0x00FC0000,foo1(68),,,,,,,,,,,,,,,
:
0x00FC0040,,,,,foo2(64),,,,,,,,,,,
:
0x00FC0080,,,,,,,,,,,,,,,,
:
```

5.3 Notes

- Csv symbol map fileare created by using debugging information. Even when csv symbol map files are created from a load module, no symbol names will be output unless the load module has debugging information.

Chapter 6

Messages from the Map Generator

6.1 Getting Execution Result of the Map Generator

The execution result of the map generator can be judged by checking the message(s) and exit status code.

6.1.1 Message Format

Upon encountering an error condition, the map generator outputs the message describing the error status to the standard error output, in the following format ：

- Syntax

  tool_name： *input_information*： *message_type*： *message*

  Note) “*input_information* :” is output only when necessary.

- Pattern

  map32R: *file_name*： *message_type*： *message*
  map32R: *<command_line>*： *message_type* *message*
  map32R: *message type*： *message*

  Note) Underlined items are *input_information* (no the underline is output).

- Example

```
map32R: error: cannot open file "abc.mo"
```

Tool name Message type Message

6.1.2 Message Types

Messages are classified into three types according to the effect.

Table 6.1 Message Types

Message Type	Operation Upon Error
Error	Outputs an error message and stops current process.
Fatal error	Outputs an error message and stops current process.

For details of the messages, see 6.2 “Message Lists”.

6.1.3 Exit Status

Upon completion of the execution, the map generator returns the exit status (value showing the execution result) as shown in Table 6.2 .

Table 6.2 Exit Status

Exit Status	Result
0	Complete successfully or warning occurs
1	Error occurs

6.2 Message Lists

6.2.1 Error Messages

Table 6.3 Error Messages

Message	Description→Action
`cannot close file` "*filename*"	The file *filename* cannot be closed. →Check the disk space.
`cannot create file` "*filename*"	The file *filename* cannot be created. →Check the disk space. Check the directory permission.
`cannot open file` "*filename*"	The file *filename* is not found. →Check the file name.
`illegal file format`	The format of the specified file is illegal. →Check the content of the file.
`illegal option` "*option*"	The specified option is illegal. →Specify the correct option.
`too many file names given`	More than one input files are specified. →Specify only one file.

6.2.2 Fatal Error Messages

Table 6.4 Fatal Error Massages

Message	Description→Action
`internal error`	An internal error occurs. →Please contact us immediately.
`out of memory`	There is not enough memory. →Check available of memory.

Part 4

Librarian lib32R

Chapter 1

Overview of the Librarian lib32R

1.1 Overview

The librarian lib32R is included in the cross tool kit M3T-CC32R and has the following functions :

- Generating a library

  Generates a library from two or more object modules or relocatable modules. A library can contain up to 32767 modules[Note)].

- Editing a library

  A module can be added to or deleted from the existing library or a module can be replaced. Any module can be extracted from a library and returned back to the pre-registered file (object module).

- Outputting library information (librarian list)

  Outputs the library information (module information and global symbol information, etc.) as a librarian list (when the -l option is specified). Also outputs information on the specified module to the standard output (when the -t option is specified).

1.2 Functions

- Up to 32767 modules can be registered in a library.

- Effective to improve module control

  Two or more modules can be combined into a single library so that these modules can be easily managed.

- Effective to improve the linking process

  By specifying object modules that are specified during linking as a library the number of file operations can be decreased. In this way, the linking process can be effectively performed.

[Note)] A module is a component of a library. A library module is an object module or a load module registered in that library.

- Can be invoked from a command file

  The parameters (option specification and input file specification) of the invoking command lib32R can be specified by using a command file (see 2.1.3.2).

Chapter 2

Invoke the Librarian

2.1 How to Invoke the Librarian

2.1.1 Invoking Procedure

To invoke the librarian, set the environment variables (see 2.1.2), enter the "lib32R" command according to the command line rules and execute it (see 2.1.3).

2.1.2 Setting Environment Variables

Set the valid directory for the environment variables M32RBIN, M32RINC, M32RLIB and M32RTMP (This step may be skipped since these variables are normally set during installation.). For the setting procedure, refer to the "M3T-CC32R Cross Tool-Kit V.x.xx Release x Release Note". If you do not set them, the default directories are selected automatically.

Table 2.1 Environment Variables

Environment Variable	Default Directory
M32RBIN	/usr/local/M32R/bin
M32RINC	/usr/local/M32R/include
M32RLIB	/usr/local/M32R/lib
M32RTMP	/tmp

2.1.3 Command Line Format

Figure 3.1 and the following sections shows the format and rule for the librarian's invocation command line. To specify options and input files, there are to ways : inputting from a command line or using a command file. Refer to 2.2 for options and 2.1.4 to 2.1.6 for input/output files.

(1) To specify for invocation in the command line :

```
lib32R { -c | -m | -q | -r | -d | -x [-s suffix] } [-t]
       [-l list_name] [-v] [-V]
       lib_name [object_filenames | module_names] <RET>
```

(2) To use a command file :

```
lib32R command_filename <RET>
```

where :

• Without [ ]	: Indispensable
• In [ ]	: Optional
• In { }	: Input at least one of the choices in { }
• Prefixed by -	: A command option (see 3.3)
• <RET>	: Enter the return key

Figure 2.1 lib32R Command Line Format

2.1.3.1 Command Line Rules

To invoke the librarian by the information given in the command line, enter and execute the command the obeying to the following rules :

- Write the command in the format shown in Figure 3.1 (1). The items (command name, option, input file name and command file name) must be separated from each other by at least one space character. Upon pressing the return key, the librarian starts executing the command.
- Insert a space character between an option and its parameter. If options conflict with each other, the last specified option takes effect.
- *lib_name* represents the name of the library to be output or edited.
- *object_filenames* represents one or more input file names (object module or relocatable load module). Insert at least one space character between file names. Up to 256 file names can be written in the command line unless an overflow occurs.
- *module_names* represents the name of one or more modules to be processed. Insert at least one space character between module names. Up to 256 module names can be written in the command line unless an overflow occurs.

- The name immediately following the option is recognized as a library name (*lib_name*). The next and subsequent names are recognized as object module names (*object_filenames*) or module name (*module_names*).

||||| Note ||||

The file name first written into the command line is recognized as the library name. The file name immediately following the invoking option must be the library name.

2.1.3.2 Invocation Using Command File

A command file can be used to specify the option or the name of the input file which invokes the librarian. The command file is a text file containing the description of specified file names. This is a convenient way to give the librarian many defined instructions.

In the command line, specify the command file name as a parameter.

```
lib32R command_filename <RET>
```

Describe the command file in the following way :

- Describe the parameters (option, input file name, name of module to be processed) in the format given in Figure 2.1 (1).
- Parameters can be separated from adjacent ones by carriage return (press return key) only in the command file.
- A command line can hold up to 255 characters except for the carriage return.

For example, to create the library `function.lib`, and to register three object modules `sin.mo`, `cos.mo` and `tan.mo` to this library, and then to output the librarian list `function.lis`, prepare the file as shown in Figure 2.2.

```
-l function.lis
-c function.lib
sin.mo cos.mo tan.mo
```

Figure 2.2 Contents of a Command File (Example)

2.1.4 Input File Conditions

Table 2.2 shows the conditions of the input file which allow the librarian to process. Do not input a file which cannot meet these conditions.

Table 2.2 Input File Conditions

Item	Conditions
Valid input files	Object module file(s) Relocatable load module file(s) Library
Maximum number of name	Section names : Up to 65535/file Symbol names : Up to 65535/file Module names : Up to 65535/file The number may be limited by the capacity of the development environment system memory.

2.1.5 Generated Library Conditions

A library generated by the librarian can have the following conditions :

• The number of modules in a library	: Up to 32767 modules
• The number of symbols in a library	: Up to 65535 symbols

2.1.6 Output File Naming

The name of output file depends on the option specified, as shown in Table 2.3.

Table 2.3 Option Specified and Output File

Option	Output File	Output File Name
`-c,-m,-q,-r,-d`	Library	Same as the input library name
`-x`	Object module	Same as the specified module name, or module name with the extension specified by the -s option.
`-l` *list_name*	List file	*list_name*

2.2 Command Options

Table 2.4 describes functions of the command options for the librarian.

Table 2.4 Command Options for the Librarian (1/3)

Option	Description
`-c`	**Creates a new library :** Creates a new library from the specified object module.
`-d`	**Deletes a module :** Deletes the specified module from the library.
`-l` *list_name*	**Creates a librarian list :** Creates a librarian list called *list_name* and outputs to this list the module name, registration date and time of the module and global symbol in the module. The library list is useful to verify the modules contained in the library.
`-m`	**Adds or replaces module :** Adds an object module to the library if this object is not found in the library (the same process with -q option). When the specified object module is found in the library replaces the module (the same process with -r option). When two or more modules are specified, adds or replaces the modules in the order specified.
`-q`	**Adds a module :** Adds the specified object module to the library. If the specified module already exists in the library, outputs a warning message without doing addition.
`-r`	**Replaces modules :** When a module whose name matches the name of the specified module is found in the library, replaces it with the specified module. If the specified module name is not found in the library, outputs a warning message and stops the replacing process.
`-s` *suffix*	Effective only when the -x option is specified. Adds the extension *suffix* (not " . *suffix*") to the name of the output file containing extracted modules. See also "•Example 3" in Section 3.4. This option is ignored if -x is omitted.

Table 2.4 Command Options for the Librarian (2/3)

<table>
<tr><th>Option</th><th>Description</th></tr>
<tr><td><code>-t</code></td><td>

Outputs library information : When a module name is specified, outputs the information on the specified module registered in the library to the standard output in the following format :

Module name   *Data and time of registration*

If no module name is specified, lists information on all modules registered in the library.

</td></tr>
<tr><td><code>-v</code></td><td>

Displays details of processing of options -c, -d, -m, -q, -r, -t and -x on the standard output, in the following format. The -v option is effective only when these options are specified.

- When options -c, -d, -m, -q, -r and -x are specified
  Shows the name of the modules processed and the name of the generated library.

<table>
<tr><th>Process</th><th>Display Format</th></tr>
<tr><td>Add the module</td><td><code>a:</code> <i>module_name</i></td></tr>
<tr><td>Replace the module</td><td><code>r:</code> <i>module_name</i></td></tr>
<tr><td>Delete the module</td><td><code>d:</code> <i>module_name</i></td></tr>
<tr><td>Extract the module</td><td><code>x:</code> <i>module_name</i></td></tr>
<tr><td>Create a new library</td><td><code>c:</code> <i>library_name</i></td></tr>
</table>

- When option -t is specified
  Shows information on the library. The contents of information depend on whether a module is specified or not.

<table>
<tr><th>Module</th><th>Information on the Library</th></tr>
<tr><td>Specified</td><td>Name of global symbols in the modules</td></tr>
<tr><td>Not specified</td><td>• Library name
• Creation date and time
• Date of last update
• Total number of registered modules and total number of registered global symbols
• Name of global symbols in each module</td></tr>
</table>

</td></tr>
</table>

Table 2.4 Command Options for the Librarian (3/3)

Option	Description
`-V`	Outputs the invoking message to the standard error output without performing any process.
`-x`	**Extracts module :** Extracts the specified module from the library. Outputs the extracted modules as object module. The object module name consists of the module name and the extension specified by the -s option. If the -s option is not specified, the name of the object module is the same as that of the module. When no module is specified, it extracts all modules. In any case, contents of the library remain unchanged.

2.3 Command Line Examples

The following are examples of the librarian invoking procedure (% is prompt, <RET> is return key).

- Example 1 : Creating new library file

```
% lib32R -c syslib.lib prog1.mo prog2.mo <RET>
```

Creates a new library file syslib.lib. Registers the object modules prog1.mo and prog2.mo in syslib.lib.

- Example 2 : Adding module

```
% lib32R -l syslib.lis -q syslib.lib prog3.mo
prog4.mo <RET>
```

Additionally registers modules prog3.mo and prog4.mo in the existing library file syslib.lib. Creates the librarian list syslib.lis of the updated syslib.lib.

- Example 3 : Extracting module

```
% lib32R -x -s .mo syslib.lib prog1 prog3 <RET>
```

Extracts registered modules prog1 and prog3 from the existing library syslib.lib and returns them back to the pre-registered module files. Because the dot extension of these files is specified as .mo by the -s option, the names of the output files are prog1.mo and prog3.mo, respectively. The contents of the library file remain unchanged. If the extension without '.' is specified by the -s option like "`-s mo`", there is no '.' between the file name and the extension in the output file name, for example "prog1mo".

- Example 4 : Adding or replacing modules

```
% lib32R -c syslib.lib prog1.mo prog2.mo <RET>
——(1)
% lib32R -m syslib.lib prog3.mo prog1.mo <RET>
——(2)
```

Creates a new library file syslib.lib and registers prog1.mo and prog2.mo in the library (1). Adds prog3.mo to syslib.lib and replaces prog1.mo (2).

- Example 5:

```
% lib32R -m -v syslib.lib prog1.mo prog2.mo
<RET> ——(1)
a: prog1
a: prog2
c: syslib.lib
% lib32R -t syslib.lib——(2)
prog1            22-Jun-1995 14:59:23
prog2            22-Jun-1995 14:59:23
```

Creates a new library file, syslib.lib, and registers prog1.mo and prog2.mo. Because the -v option is specified at that time, shows detailed information (1), and then shows information on the library (2).

Chapter 3

Outputs from the Librarian

The following describe the library output from the librarian, librarian list and library information.

3.1 Library

A library is a file summarizing two or more object modules or relocatable load modules and having index of global symbols.

3.2 Librarian List

When the librarian invoking option -l *list_name* is specified, outputs contents of (librarian list) to the file *list_name* in the format shown in Figure 3.1.

```
M32R FAMILY Librarian V.1.00.00 * LIBRARIAN LIST *

Library file name:  sample.lib
Creation date:      18-May-1995  9:45:38
Revision date:      18-May-1995  9:47:16
Number of modules:  2
Number of symbols:  8

Module name:                            Entry date:
gettoken                                17-May-2000  9:45:38
     _gettoken

getvalue                           (a)  17-May-2000  9:47:16
     _chgbin
     _chgdigit
     _chghex
     _chgoct
     _getvalue
     _one
     _two
```

Figure 3.1 Example of Outputs from the Librarian

The next page is followed. →

Table 3.1 describes the list shown in Figure 3.1.

Table 3.1 Librarian List Contents

Item	Contents
`Library file name:`	Shows the library name.
`Creation date:`	Shows the creation date and time of the library.
`Revision date:`	Shows the date and time of the last updating.
`Number of modules:`	Shows the total number (decimal) of modules registered in the library.
`Number of symbols:`	Shows the total number (decimal) of global symbols registered in the library.
`Module name:`	Lists the names of modules registered in the library in alphabetical order. The edited status of each module is shown in the round brackets ( ). The status is output only when the option -l is used together with one of the options -c, -r, -q or -m. Editing status is shown as follows : •Blank : Module registered in the existing library • `(a)` : Added module • `(r)` : Replaced module
`Entry date:`	Shows date and time the module was registered in the library.
`Others`	The global symbols defined in that module are listed in alphabetical order under a module name.

3.3 Library Information

When the -t option is specified, librarian information is output in the format, as follows : (There are four formats, one of which is selected according to conditions such as whether the module name is specified or not, and whether the -v option is specified or not.)

- Case 1 : Module name is not specified. The -v option is not specified. Outputs the name and registered date and time of each of the modules registered in the library, in the following format :

Module name   Date and time of registration

Example :

```
gettoken        17-May-1995  9:45:38
prog1           22-Jun-1995 13:17:50
```

- Case 2 : Module name is not specified. Option -v is specified.
  Outputs the same contents as in the case of the librarian list.

- Case 3 : Module name is specified. Option -v is not specified.
  Outputs the name and registered date and time of the module registered in the library, in the following format :

  Module name *Date and time of registration*

  Example :
  ```
  gettoken       17-May-1995  9:45:38
  ```

- Case 4 : Module name is specified. Option -v is specified.
  Outputs the name and registered date and time of the specified module registered in the library and the symbols defined in that module in alphabetical order and in the following format :

  Module name *Date and time of registration*
  Symbol name
  Symbol name
  ⋮

Example:
```
module1   22-Jun-2000 13:17:50
_symbol1
_symbol2
_symbol3
```

Chapter 4

Messages from the Librarian

4.1 Getting Execution Result of the Librarian

The execution result of the librarian can be judged by checking the message(s) and exit status code.

4.1.1 Message Format

Upon encountering an error condition, the librarian outputs the message describing the error status to the standard error output, in the following format :

- Syntax

tool_name : *input_information* : *message_type* : *message*

Note) "*input_information* :" is output only when necessary.

- Pattern

`lib32R:` *file_name* : *message_type* *message*
`lib32R:` *<command_line>* : *message_type* : *message*
`lib32R:` *message_type* : *message*

Note) Underlined items are *input_information* (no the underline is output).

- Example

```
lib32R: "sample.mo": error: invalid file format
```

Tool name
Input information (File name)
Message type
Message

4.1.2 Message Types

Messages are classified into three types according to the effect.

Table 4.1 Message Types

Message Type	Operation Upon Error
Warning	Output a warning message and continues process.
Error	Output an error message and stops current process.
Fatal error	Output an error message and stops current process.

For details of the messages, see 4.2 “Message Lists”.

4.1.3 Exit Status

Upon completion of the execution, the librarian returns the exit status (value showing the execution result) as shown in Table 4.2.

Table 4.2 Exit Status

Exit Status	Result
0	Complete successfully or warning occurs
1	Error occurs

4.2 Message Lists

4.2.1 Warning Messages

Table 4.3 Warning Messages

Message	Meaning→Librarian Action
`duplicate module` “*module_name*”	The module is already registered. →Skip the operation on this module.
`duplicate symbol` “*symbol*”	The symbol is already registered. →Skip the operation on this symbol.
`module not found` “*module_name*”	The specified module is not found. →Skip the operation on this module name.

4.2.2 Error Messages

Table 4.4 Error Messages (1/3)

Message	Description→Action
`cannot close file` “*filename*”	The file cannot be closed. →Check the disk space.
`cannot create file` “*module_name*”	The file cannot be created. →Check the file name and disk space.
`cannot open file` “*module_name*”	The file is not found. →Check the file name.
`illegal file format`	The format of the file is illegal. →Check contents of the file.

Table 4.4 Error Messages (2/3)

Message	Description→Action
illegal option "*option*"	An illegal option name is specified. →Specify the correct option.
library file not specified	No library file is specified. →Specify the library file.
only one of [-c,-r,-d,-q,-x,-m,-t] must be specified	None of the options -c, -r, -d, -q, -x, -m or -t is specified. Or two or more options are specified simultaneously. →Specify only one option among -c, -r, -d, -q, -x, -m or -t.
option "*option*" requires parameter	No parameter is specified for the option which must have that parameter. →Specify the necessary parameter.
too many modules given	The number of modules specified in the parameter exceeds the allowable maximum number. →Process a smaller number of modules at one time.
too many modules in library file	The number of modules to be registered exceeds the allowable maximum number for the library. →Allocate the modules over several libraries.
too many symbols in library file	The number of symbols included in the module to be registered exceeds the allowable maximum number for the library. →Allocate the symbols over several libraries.
unsupported module type: version *number*	The specified type of module is not supported. →Check to see if the module is correctly created.
duplicate module "*module_name*"	The module has already been registered. Operation for this module will be skipped. →Change either one of the duplicate module names.
duplicate symbol "*symbol_name*"	The symbol has already been registered. Processing for this symbol will be skipped. →Change either one of the duplicate symbol names.

Table 4.4 Error Messages (3/3)

Message	Description→Action
`module not found` “*module_name*”	The specified module cannot be found. Operation for this module will be skipped. →Check to see if the specified module exists.

4.2.3 Fatal Error Messages

Table 4.5 Fatal Error Messages

Message	Description→Action
`internal error`	An internal error occurs. →Please contact us immediately.
`out of memory`	Memory space is not enough for the librarian to operate. →Expand memory space or reduce the library size.

Part 5

Load Module Converter lmc32R

Chapter 1

Overview of the Load Module Converter lmc32R

1.1 Overview

The lmc32R is the load module converter included n the cross tool kit M3T-CC32R. The lmc32R converts an absolute load module created by the linker to a load module of a Motorola S-format (hereafter, S-format) which can be read by general purpose ROM programmer.

1.2 Functions

- Object diving function

  By following the rules specified in the command line, divides the load module into more than one object data and creates S-format files the number of which corresponds to the division number of the data. In typical target system, several ROMs are used according to the data bus width. Into these ROMs, the divided object data are loaded. By using this function, a file to be loaded onto a specific ROM can be created independently.

- Address range specifying function

  Outputs only the object data located within the specified address range after converting the data into S-format.

- Load address change specifying function

  The load address value of the object data can be changed by specifying an offset value. For example, an object data string starting with address 8000_{16} can be started at address 0_{16}.

Chapter 2

Invoke the Load Module Converter

2.1 How to Invoke the Load Module Converter

2.1.1 Invoking Procedure

To invoke the load module converter, set the environment variables (see 2.1.2), enter the “lmc32R” command according to the command line rules and execute it (see 2.1.3).

2.1.2 Setting Environment Variables

Set the valid directory for the environment variables M32RBIN, M32RINC, M32RLIB and M32RTMP (This step may be skipped since these variables are normally set during installation.). For the setting procedure, refer to the “M3T-CC32R Cross Tool-Kit V.x.xx Release x Release Note“. If you do not set them, the default directories are selected automatically.

Table 2.1 Environment Variables

Environment Variable	Default Directory
M32RBIN	/usr/local/M32R/bin
M32RINC	/usr/local/M32R/include
M32RLIB	/usr/local/M32R/lib
M32RTMP	/tmp

2.1.3 Command Line Format

Figure 4.1 and the following sections show the format and rule for the load module converter's invocation command line. Refer to 2.2 for options, and to 2.1.4 and 2.1.5 for input/output files.

```
lmc32R [-o output_filename ] [-d{1|2|4|8}] [-W{1|2}]
       [-r baddr[,eaddr]] [-c[{+|-}]naddr] [-w] [-V]
       filename <RET>
```

where :

• Without [ ]	: Indispensable
• In [ ]	: Optional
• Prefixed by -	: A command option (see 4.3)
• <RET>	: Enter the return key

Figure 2.1 lmc32R Command Line Format

- Write the command line by following the format given in Figure 2.1. The items (command name, option, input file name) must be separated from each other by at least one space character. After completing the writing, press the return key and the load module converter starts execution.
- Insert a space character between an option and its parameter. If options conflict with each other, the last specified option takes effect.
- Only the addresses and values expressed in hexadecimal are valid.
- *filename* is an input file name and cannot be omitted.

2.1.4 Input File Conditions

Table 2.2 shows the requirement of the input file to be processed on the load module converter. Do not input a file which cannot meet this condition.

Table 2.2 Input File Condition

Item	Condition
Valid input file	Absolute load module file

2.1.5 Output File Naming

The name of an output file is determined according to the name specified in the command line. For the naming rule, see 2.2 "Load module converter invoking option", the -o option. If the command line does not specify the name, the default naming described in Table 2.3 is applied.

Table 2.3 Output File Names (Default)

File name	Description
filename.m*AB*	One of the S-format load modules, if divided *filename* : Input file name *A* : Number of divisions (divisor) (1 digit number) *B* : Figure showing an *n*th file (0, 1, 2…)
filename.mot	S-format load module not divided *filename* : Input file name

2.2 Command Options

Table 2.4 describes functions of the command options for the load module converter.

Table 2.4 Command Option for the Load Module Converter (1/2)

Option	Description
`-c [{+|-}]`*naddr*	Changes the load address to *naddr*. When *naddr* is prefixed by the sign + or -, *naddr* is recognized as an offset value. The *naddr* must be specified in hexadecimal.
`-d {1|2|4|8}`	Specifies the number of divisions of the object data. The default value is 1.
`-o` *output_filename*	Names the output file after the file name specified by *output_filename*. The manner in which the output file is named varies depending on whether or not the load module is divided into multiple object data (by specifying the -d option). For details on how output files are named in the PC version, refer to Table 4.5. • **To divide a module (specify non-1 by the -d option)** Suffixes the extension `.m`*AB* to the output file name. The *A* shows the single number divisor and the *B* shows the order of the files. The output file name is an *output_filename* with the extension `.m`*AB*. For example, if `-o a.mout` is specified, the output files are named `a.mout.m`*AB*. If this option is omitted, the output files are named as the input *filename* with the extension `.m`*AB*. • **Not to divide a module (specify 1 by the -d option, or omit the -d option)** Suffixes the extension `.mot` to the output file name. The output file name is an *output_filename* with the extension `.mot`. For example, if `-o a.mout` is specified, the output file is named `a.mout.mot`. If this option is omitted, the output file is named the same as the input *filename* with the extension `.mot`.

Table 2.4 Command Option for the Load Module Converter (2/2)

Option	Description
`-r` *baddr*`[,`*eaddr*`]`	Specifies the range of data to be converted. This option outputs the data located within the range from the convert start address *baddr* to the convert end address *eaddr*. If the *eaddr* is not specified, all the data located at the convert start address *baddr* and subsequent addresses are output. Specify *baddr* and *eaddr* by using a hexadecimal number.
`-V`	Output the invoking message to the standard error output without performing any process.
`-w`	Disables the warning message display.
`-W {1|2}`	Specifies the data size (bytes) when the object data is to be divided. The default value is 1.

Table 2.5 Naming Rules for Output File in lmc32R (for PC version)

Output object divided? (by the -d option) **Output file name specified? (by the -o option)**	**Not divided** (With -d1 or without the -d option)	**Divided** (With -d but the divisor is not 1) Example : `-d2`
Specified.	The output file name will be the same as the name specified by the -o option. (A suffix is not added freshly.)	If the output file name is specified with a suffix, the suffix is replaced with `.m`*AB* [Note5)]. If the output file name is specified without a suffix, the suffix `.m`*AB* is added.
Examples of `-o` : Case 1) `-o SMP.MOT` Case 2) `-o SMP`	The output file is named as follows : In the case 1) `SMP.MOT` In the case 2) `SMP`	The output file is named as follows : In the case 1) `SMP.m20`, `SMP.m21` In the case 2) `SMP.m20`, `SMP.m21`
Not specified.	If the input file name has a suffix, the suffix is replaced with `.mot`. If the input file name has no suffix, `.mot` is added as the suffix.	If the input file name has a suffix, the suffix is replaced with `.m`*AB* [Note5)]. If the input file name has no suffix, `.m`*AB* is added as the suffix.
Examples of input file name : Case 3) am.out Case 4) am	The output file is named as follows : In the case 3) am.mot In the case 4) am.mot	The output file is named as follows : In the case 3) am.m20, am.m21 In the case 4) am.m20, am.m21

Note) The *A* in the suffix is actually a value indicating the number of divisions (specified with the option -d), and *B* is a number starting with 0 that shows which position this divided object occurs at. For example, "`.m20`" indicates the 1st of two divided objects.

Chapter 3

Usage and Command Line Examples

This section describes the invoking procedure of the load module converter. *%* is prompt, and <RET> is return key.

3.1 Converting into Divided S-format Files (Object Division Function)

The object division function divides a load module converted into S-format into several files and outputs these files. This function is useful to load a load module into two or more ROMs. To divide the output file specify the division process in the command line as follows :

(1) Specify the number of divisions

Using the -d option, specify the number of files into which the divided data are to be loaded. Select among numbers 1, 2, 4 and 8. If the -d option is omitted, or if a value of 1 is selected, the file is not divided.

(2) Specify the size (bytes) of the divided data

Using the -W option, specify the size (1 byte or 2 bytes) of the divided object data to be output to each output file. If this option is omitted, 1 byte is automatically selected.

(3) Specify the output file name

Using the -o option, specify the name of each output file. The extension .m*AB* (*A* is the number of divisions and the *B* is the division number (0, 1, 2…)) is automatically added to the file name to show that the file is a divided S-format file. For example, if

```
% lmc32R -d4 -o file a.mout <RET>
```

the following files are created :

```
file.m40
file.m41
file.m42
file.m43
```

Division number (0, 1, 2 and 3, if divisor is 4)

Number of divisions (divisor is 4)

The next page is followed. →

Therefore, specify the file name without an extension. If the extension is specified, the output file name will have two extensions (the second extension is .m*AB*).

The following is an example of file division.

Example :

```
% lmc32R -d4 -W1 -o file a.mout <RET>
```

When this command is executed, the output file is divided as shown in Figure 3.1. The absolute address after division is the absolute address of the load module to be converted (a.mout in this example) divided by the value of the divisor (H'400- in this example).

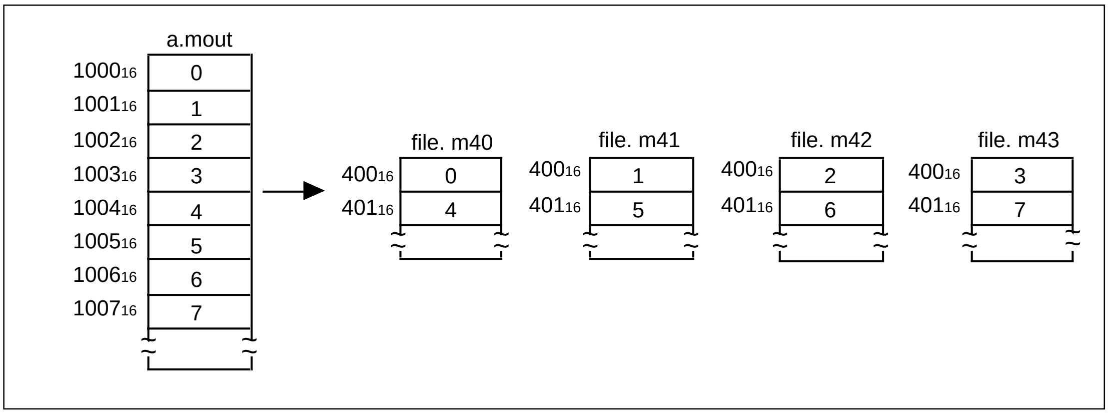


Figure 3.1 Example of Divided Object Module

3.2 Converting a part of the Load Module into S-format (Convert Area Select Function)

The convert area select function converts the specified part of object data in the load module to be converted. To specify this conversion use the -r option and specify the convert area with the start and end addresses.

Example :

```
% lmc32R -o test -r 2000,3000 test.abs <RET>
```

When this command is executed, the specified part of the input file is converted and output as shown in Figure 3.2.

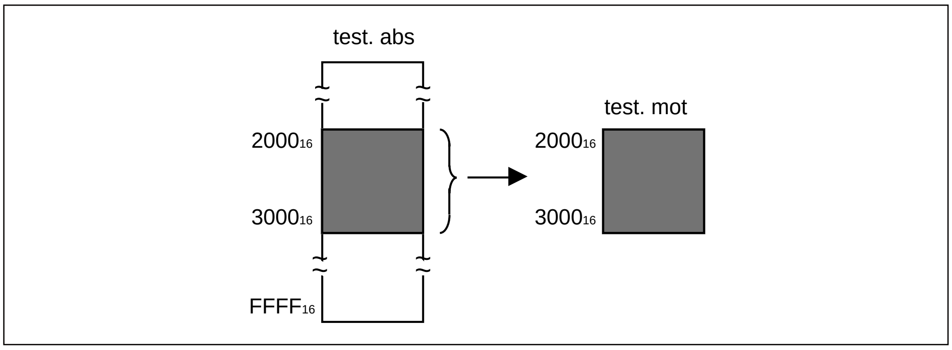


Figure 3.2 Conversion and Output a part of Module

3.3 Changing Addresses of Load Module
(Change Load Address Function)

The load module to be converted is assigned an absolute address. If this address differs from the address to be actually used when loading onto ROM or the like, the address of the output load module can be adjusted by specifying the offset value upon converting the module (load address change function). To specify the offset, use the -c option, that is, `-c {+|-}`*naddr*.

Example :

```
% lmc32R -c -8000 test.abs <RET>
```

By executing this command, the address is adjusted as shown in Figure 3.4.

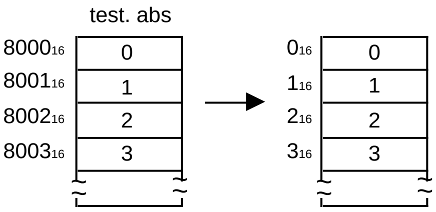


Figure 3.4 Example of Address Offset

Chapter 4

S-format

4.1 Motorola S-format File Structure

The S-format object consists of the following 3 records :

- Header record
- Data record
- End record

Data records are classified into three types as shown in Table 4.1, depending on the value of load address.

Table 4.1 Data Record Type

Address Range	Data Record Type
0_{16} – FFFF_{16}	S1
0_{16} – FFFFFF_{16}	S2
0_{16} – $\mathrm{FFFFFFFF}_{16}$	S3

End records are classified into three types as shown in Table 4.2, depending on the type of data record included in the load module.

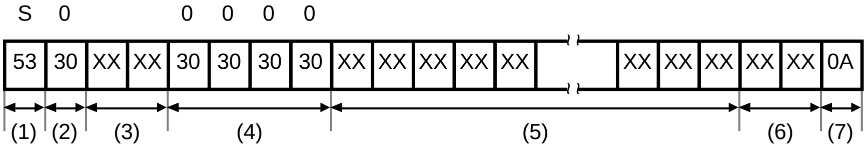
Table 4.2 End Record Type

Type of End Record	End Record Type
Consists of only S1	S9
Included S2	S8
Included S3	S7

The detail of each record structure is described in this section.

4.2 Record Structure

4.2.1 Header Record



(1) Record mark

(2) Record type

(3) Record length (The number of bytes in (4),(5),(6))

(4) Unused

(5) Comment

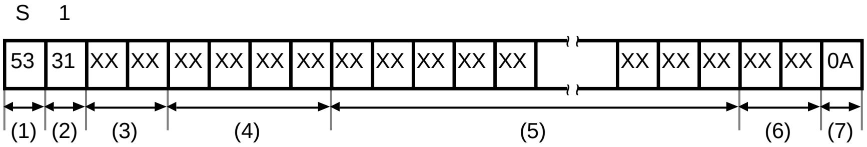
(6) Check sum (1's complement of sum of data value in bytes ((3)+(4)+(5)))

(7) Line feed code

4.2.2 Data Record

The structure of data records differ depending on the load address.

- Load address : 0_{16} – $FFFF_{16}$



(1) Record mark

(2) Record type

(3) Record length (The number of bytes in (4),(5),(6))

(4) Load address (2 bytes)

(5) Object data (1 byte of object data expressed in two hexadecimal characters. Up to 16 bytes of data can be stored.)

(6) Check sum (1's complement of sum of data value in bytes ((3)+(4)+(5)))

(7) Line feed code

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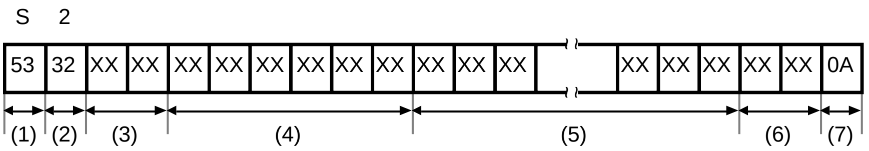
- Load address : 0_{16} – FFFFFF_{16}



(1) Record mark

(2) Record type

(3) Record length (The number of bytes in (4),(5),(6))

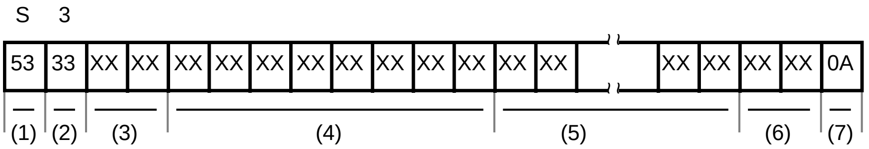
(4) Load address (3 bytes)

(5) Object data (1 byte of object data expressed in two hexadecimal characters. Up to 16 bytes of data can be stored.)

(6) Check sum (1's complement of sum of data value in bytes ((3)+(4)+(5)))

(7) Line feed code

- Load address : 0_{16} – FFFFFFFF_{16}



(1) Record mark

(2) Record type

(3) Record length (The number of bytes in (4),(5),(6))

(4) Load address (4 bytes)

(5) Object data (1 byte of object data expressed in two hexadecimal characters. Up to 16 bytes of data can be stored.)

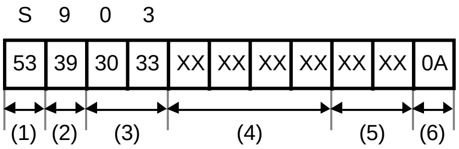
(6) Check sum (1's complement of sum of data value in bytes ((3)+(4)+(5)))

(7) Line feed code

4.2.3 End Record

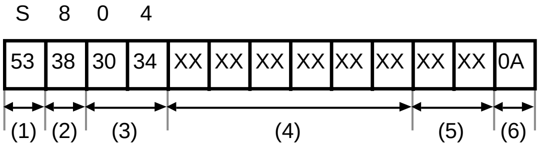
The structure of end records differ depending on the way S1, S2 or S3 is included in the data record.

- Data record : Consists of only S1



(1) Record mark
(2) Record type
(3) Record length (The number of bytes in (4),(5))
(4) Start address (2 bytes)
(5) Check sum (1's complement of sum of data value in bytes ((3)+(4)+(5)))
(6) Line feed code

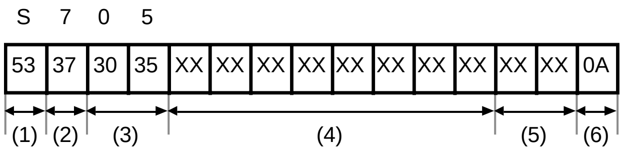
- Data record : Includes S2


S 8 0 4
53 | 38 | 30 | 34 | XX | XX | XX | XX | XX | XX | XX | XX | 0A
(1)
(2)
(3)
(4)
(5)
(6)

(1) Record mark
(2) Record type
(3) Record length (The number of bytes in (4),(5))
(4) Start address (3 bytes)
(5) Check sum (1's complement of sum of data value in bytes ((3)+(4)+(5)))
(6) Line feed code

The next page is followed. →

- Data record : Includes S3



(1) Record mark

(2) Record type

(3) Record length (The number of bytes in (4),(5))

(4) Start address (4 bytes)

(5) Check sum (1’s complement of sum of data value in bytes ((3)+(4)+(5)))

(6) Line feed code

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