

SuperH™ RISC engine C/C++ Compiler, Assembler, Optimizing Linkage Editor

Compiler Package V.9.04 User's Manual

Renesas Microcomputer Development Environment System

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Preface

This manual explains how to use the C/C++ compiler, assembler, and optimizing linkage editor for the SuperH RISC engine microcomputers. This system translates source programs written in C/C++ language, DSP-C language*¹ or assembly language into relocatable object programs for SuperH RISC engine microcomputers.

Be sure to read this manual thoroughly and that you grasp its contents before using the compiler.

Notes on Symbols: The following symbols are used in this manual.

Symbols Used in This Manual

Symbol	Explanation
< >	Indicates an item to be specified.
[]	Indicates an item that can be omitted.
...	Indicates that the preceding item can be repeated.
Δ	Indicates one or more blanks.
	Indicates that one of the items must be selected.

This manual is intended for the software running under Microsoft® Windows® 2000, Windows® XP, Windows® Vista, or Windows® 7*² on IBM PC*³ and compatible computers.

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Section 1 Overview

1.1 Procedures for Developing Programs

Figure 1.1 shows the procedures for developing programs. The shaded part shows software provided in the SuperH RISC engine C/C++ compiler package.

The C/C++ compiler, assembler, optimizing linkage editor, standard library generator, and call walker are explained in this manual.

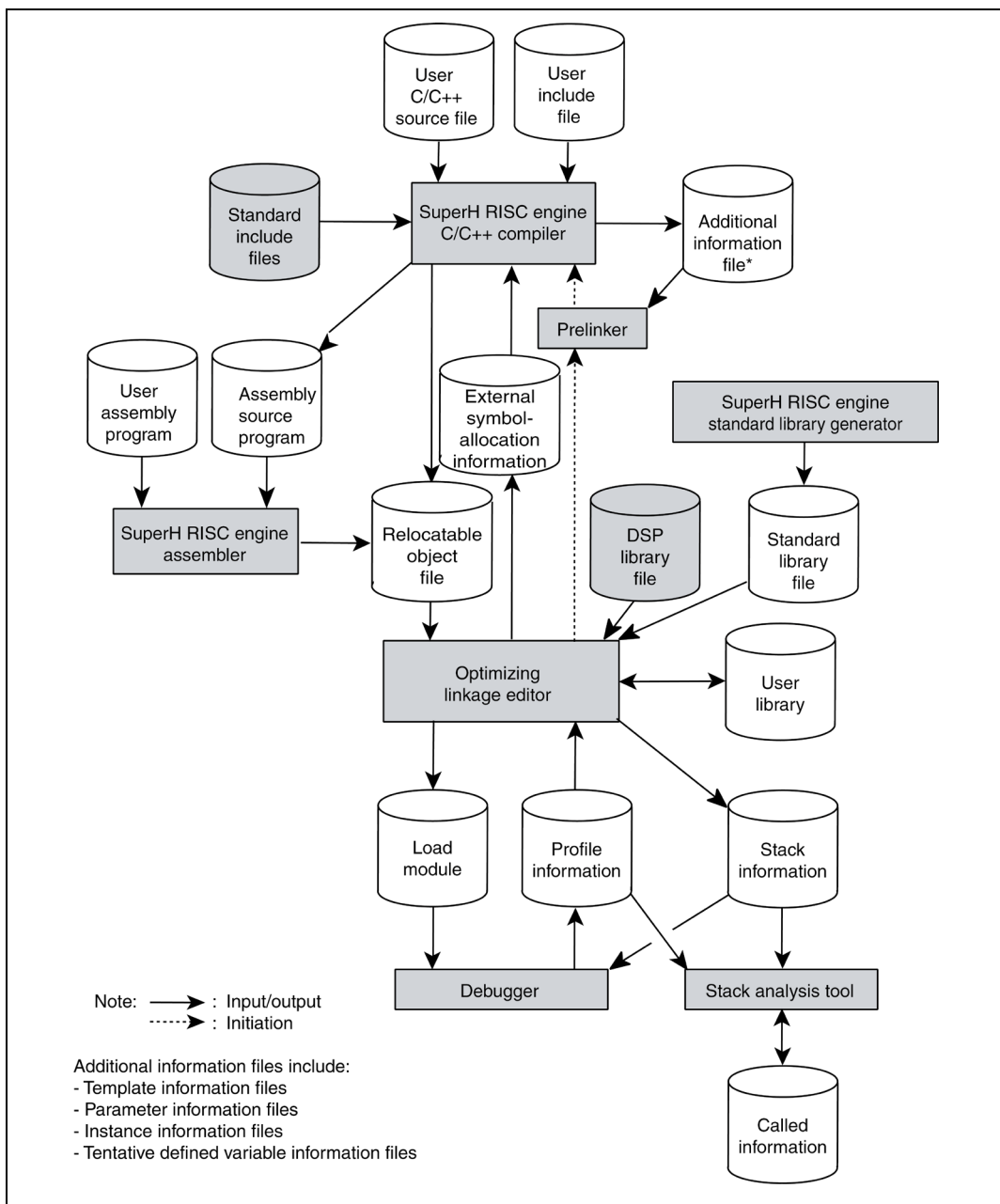


Figure 1.1 Procedures for Developing Programs

Outlines of the C/C++ compiler, assembler, optimizing linkage editor, prelinker, standard library generator, and call walker are given in the following instructions.

1.2 Compiler

The SuperH RISC engine C/C++ compiler (hereinafter referred to as compiler) is software that takes source programs written in C or C++ language as inputs, and produces relocatable object programs or assembly source programs for SuperH RISC engine microcomputers.

Features of this compiler are as follows:

1. Generates an object program that can be written to ROM for installation in a user system.
2. Supports an optimization that improves the speed of execution of object programs and minimizes program size.
3. Supports the C and C++ programming languages.
4. Supports functions that are essential for the programming of embedded programs but are not supported by the C and C++ languages as extended functions. Such functions include interrupt functions and descriptions of system instructions.
5. The output of debugging information to enable C/C++ source-level debugging by the debugger is supported.
6. Either an assembly source program or a relocatable object program can be selected for output.
7. Supports an inter-module optimization information output to execute optimization for the optimizing linkage editor.

1.3 Assembler

The SuperH RISC engine assembler (hereinafter referred to as assembler) is software that takes source programs written in assembly language, and outputs relocatable object programs for SuperH RISC engine microcomputers.

Features of this assembler are as follows:

1. Enables the efficient writing of source programs by providing the preprocessor functions listed below:
 - File include function
 - Conditional assembly function
 - Macro function
2. The mnemonics for execution instruction and assembly directives conform to the naming rules laid out in the IEEE-694 specifications, and the system is uniform.

1.4 Optimizing Linkage Editor

The optimizing linkage editor is software that takes multiple object programs output by the compiler or assembler and produces load modules or library files.

Features of this optimizing linkage editor are as follows:

1. Optimization can be applied to a set of several object files, depending on memory allocation and relations among function calls which cannot be optimized by the compiler.
2. Any of the following five types of load modules can be selected for output:
 - Relocatable ELF format
 - Absolute ELF format
 - S-type format
 - HEX format
 - Binary format
3. Generates and edits library files.
4. Outputs symbol reference count list.
5. Deletes debugging information from library and load module files.
6. Specifies the output of a stack information file for use by the call walker.

1.5 Prelinker

The prelinker is called from the optimizing linkage editor. When a C++ program template or runtime type-detection function is used, the prelinker calls the compiler and instructs it to generate the necessary object files. When neither a C++ program template nor the runtime type-detection function is used, the speed of linkage can be improved by specifying the **noprelink** option for the optimizing linkage editor.

1.6 Standard Library Generator

The SuperH RISC engine standard library generator (hereinafter referred to as the standard library generator) is a software system for the reconfiguration of standard library files provided, using user-specified options.

The standard library functions provided with the compiler include the standard set of C library functions, a set of C++ class library functions for embedded systems, and a set of runtime routines (arithmetic operations that are necessary for the execution of a program). In some cases, runtime routine will be necessary, even though library functions are not used in source programs.

1.7 Call Walker

The call walker is software that takes the stack information file that is output by the optimizing linkage editor and calculates the size of the stack that will be used by C/C++ programs.

Section 2 Compiler Options

2.1 Option Specification Rules

The format of the command line to initiate the compiler is as follows:

```
shc[Δ<option>...] [Δ<file name>[Δ<option>...] ...]  
<option>:-<option>[=<suboption>] [, ...]
```

2.2 Interpretation of Options

In the command line format, uppercase letters indicate the abbreviations and characters underlined indicate the defaults.

The format of the dialog menus that correspond to the integrated development environment is category name [Item].

The order of options corresponds to that of the tabs in the integrated development environment.

Note that conditions apply to the application of some options related to optimization, i.e. some may not be applicable. Check the output code to see whether or not the optimization has actually been performed.

2.2.1 Source Options

Table 2.1 Source Category Options

Item	Command Line Format	Dialog Menu	Specification
Include file directory	Include = <path name>[,...]	Source [Show entries for :] [Include file directories]	Specifies include-file include path name.
Default include file	PREInclude = <file name>[,...]	Source [Show entries for :] [Preinclude]	Includes the specified files at the head of compiling units.
Macro name definition	DEFine = <sub>[,...] <sub>: <macro name> [=<string literal>]	Source [Show entries for :] [Defines]	Defines <string literal> as <macro name>.
Information message	MESsage <u>NOMESsage</u> [= <error number> [- <error number>][,...]]	Source [Show entries for :] [Messages] [Display information level messages]	Output Not output
Inter-file inline expansion directory specification	FILE_INLINE_PATH = <path name>[,...]	Source [Show entries for :] [File inline path]	Specifies the path name where obtains a file for inline expansion between files.
Message level	CHAnge_message =<sub>[,...] <sub>:<level> [=<n>[-m],...] <level>:{Information Warning Error }	Source [Message level :]	Changes message level.

Include: Include File Directory

Source[Show entries for :][Include file directories]

- Command Line Format
Include = <path name>[,...]
- Description
Specifies the name of the path where the include file is stored.
Two or more path names can be specified by separating them with a comma (.).
System include files are retrieved in the order of the **include** option specification directory, the environment variable SHC_INC specification directory, and the environment variable SHC_LIB specification directory. User include files are retrieved in the order of the current directory, the **include** option specification directory, the environment variable SHC_INC specification directory, and the environment variable SHC_LIB specification directory.
- Example

```
shc -include=c:\usr\inc,c:\usr\shc test.c
```

Directories c:\usr\inc and c:\usr\shc are retrieved as include file paths.

PREInclude: Default Include File

Source[Show entries for :][Preinclude]

- Command Line Format
PREInclude = <file name>[,...]
- Description
Includes the specified file contents at the head of the compiling unit. Two or more file names can be specified by separating them with a comma (.).
- Example

```
shc -preinclude=a.h test.c
```

— Contents of <test.c>

```
int a;
main(){...}
```

— Interpretation at compilation

```
#include "a.h"
int a;
main(){...}
```

DEFine: Macro Name Definition

Source[Show entries for :][Defines]

- Command Line Format
DEFine = <sub> [,...]
 <sub>: <macro name> [= <string literal>]
- Description
This option is the same as **#define** described in the C/C++ source file.
When **<macro name>=<string literal>** is specified, **<string literal>** is defined as a macro name.
When only **<macro name>** is specified for a suboption, the macro name is assumed to be defined. Names or integer constants can be written in **<string literal>**.

MESsage, NOMESsage: Information Message

Source[Show entries for :][Messages][Display information level messages]

- Command Line Format
MESsage
NOMESsage [= <error number> [- <error number>][,...]]
- Description
This option specifies whether or not the information-level messages are output.
When the **message** option is specified, the compiler outputs information-level messages.
When the **nomessage** option is specified, the compiler inhibits the output of the information-level messages. When the error number is specified by a suboption, the output of the specified information-level messages will be inhibited.
A range of error numbers to be inhibited can be specified by using a hyphen (-), that is, in the form **<error number> - <error number>**.
The default for this option is **nomessage**.
- Example

```
shc -message test.c
```

Information-level messages will be output.

FILE_INLINE_PATH: Inter-file Inline Expansion Directory Specification

Source[Show entries for :][File inline path]

- Command Line Format

FILE_INLINE_PATH = <path name> [...]

- Description

Specifies the name of the path where a file for inter-file inline expansion is stored.

Two or more path names can be specified by separating them with a comma (,).

Files for inter-file inline expansion are retrieved in the order of the **file_inline_path** option specification directory and the current directory.

- Example

```
shc -file_inline_path=c:\usr\file -file_inline=test2.c test.c
```

Directory c:\usr\file is considered as the inter-file inline expansion specification directory to retrieve test2.c specified by the **file_inline** option.

CHAnge_message: Message Level

Source[Message level :]

- Command Line Format

```
CHAnge_message = <sub>[,...]  
    <sub> : <error level>[=<error number>[- <error number>]][,...]]  
    <error level> : { Information | Warning | Error }
```

- Description

Changes the message level of information-level and warning-level messages.

- Example

```
change_message=information=<error number>
```

Warning level messages with the specified error numbers are changed to **Information** level messages.

```
change_message=warning=<error number>
```

Information level messages with the specified error numbers are changed to **Warning** level messages.

```
change_message=error=<error number>
```

Information and **Warning** level messages with the specified error numbers are changed to **Error** level messages.

```
change_message=information
```

All warning-level messages are changed to **Information** level messages.

```
change_message=warning
```

All information-level messages are changed to **Warning** level messages.

```
change_message=error
```

All information-level and warning-level messages are changed to **Error** level messages.

- Remarks

Output of the messages which were changed to the information-level can be disabled by **nomessage** specification.

2.2.2 Object Options

Table 2.2 Object Category Options

Item	Command Line Format	Dialog Menu	Specification
Pre-processor expansion	PREProcessor [= <file name>]	Object [Output file type :] [Preprocessed source file]	Outputs source program after preprocessor expansion.
	NOLINE	[Suppress #line in preprocessed source file]	Disables #line output at preprocessor expansion.
Object type	Code = { <u>Machinecode</u> <u>Asmcode</u> }	Object [Output file type :] [Machine code] [Assembly source code]	Outputs machine code program. Outputs assembly-source program.
Debugging information	DEBug <u>NO</u> DEBug	Object [Generate debug information]	Output Not output
Section name	S <u>E</u> ction = <sub>[,...] <sub>:{ Program= <section name> Const=<section name> Data=<section name> Bss=<section name> }	Object [Code generation] [Section :] [Program section (P)] [Const section (C)] [Data section (D)] [Uninitialized data section (B)]	Program area section name Constant area section name Initialized data area section name Non-initialized data area section name
Area of string literal to be output	S <u>T</u> ring = { <u>Const</u> <u>Data</u> }	Object [Code generation] [Store string data in :]	Outputs string literal to constant section (C). Outputs string literal to initialized data section (D).
Object file name specification	O <u>B</u> jectfile = <file name>	Object [Output directory:]	Outputs the object file of the specified file name.

Table 2.2 Object Category Options (cont)

Item	Command Line Format	Dialog Menu	Specification
Template instance generation	Template={ None Static Used ALI <u>AUto</u> }	Object [Code generation] [Template :]	Does not generate instances. Generates instances as internal linkage only for referenced templates. Generates instances as external linkage only for referenced templates. Generates instances for templates declared or referenced. Generates instances at linkage.
ABS16/20/28/32 declaration	<ABS>=<sub>[,...] <ABS>: { ABS16 ABS20 ABS28 <u>ABS32</u> <sub>: { Program Const Data Bss Run <u>All</u> }	Object [Code generation2] [Address declaration]	Specifies the memory space where the label addresses or runtime routines belonging to the specified section are to be allocated.
Method of division [except for SH-1]	Dlvision = <u>Cpu</u> = { Inline Runtime}	Object [Code generation] [Division sub-options :]	Uses the CPU's division instruction. Converts division to multiplication and performs inline expansion. Calls run-time routine.
Disabling of save and restore of floating-point registers [SH-2E, SH2A-FPU, SH-4, and SH-4A]	IFUnc	Object [Code generation] [Use no FPU instructions]	Disables save and restore of floating-point registers.

Table 2.2 Object Category Options (cont)

Item	Command Line Format	Dialog Menu	Specification
16-byte or 32-byte alignment of labels	ALIGN16	Object [Code generation] [Alignment of branch destination]	Every first label appear an unconditional branch instruction in a program section is aligned on a 16-byte boundary.
	ALIGN32		Every first label appear an unconditional branch instruction in a program section is aligned on a 32-byte boundary.
	<u>NOALign</u>		Does not necessarily place labels on a 16-byte or 32-byte boundary.
TBR relative function call [SH-2A and SH2A-FPU]	TBR [= <section name>]	Object [Code generation2] [TBR specification]	Calls functions using TBR relative addresses.
Order of uninitialized variables	BSs_order = {DEClaration DEFinition }	Object [Code generation2] [Order of uninitialized variables :]	Outputs in the order of declarations Outputs in the order of definitions
Disposition of variables	STUFF [= {Bss Data Const} [...]] <u>NOSTuff</u>	Object [Code generation2] [Disposition of variables :]	Assigns variables according to the size of variables Do not assign variables
Disposition of variables in \$G0/\$G1	STUFF_GBR	Object [Code generation2] [Disposition of Variables in \$G0/\$G1]	Assigns variables according to the size of variables in \$G0/\$G1
Alignment of branch destination	ALIGN4 = { ALL LOOP INMOSTLOOP }	Object [Code generation] [Alignment of Branch Destination]	Alignment of branch destination: - All branch destination addresses - Start addresses of all loops - Start addresses of the innermost loops
Allocate const volatile variables	CONST_VOLATILE = { <u>DATA</u> CONST }	Object [Code generation] [const volatile variables:]	Allocate const volatile variables to the initialized data area Allocate const volatile variables to the constant area

PREProcessor, NOLINE: Preprocessor Expansion

- Object[Output file type :][Preprocessed source file]

[Suppress #line in preprocessed source file]

- Command Line Format
PREProcessor [= <file name>]

- Description

Outputs a source program processed by the preprocessor.

If no <file name> is specified, an output file with the same file name as the source file and with a standard extension is created. The standard extension after C compilation is p (if the input source program is written in C), and that after C++ compilation is pp (if the input source program is written in C++).

When **preprocessor** is specified, no object file is output from the compiler.

When **noline** is specified, disables **#line** output at preprocessor expansion.

- Remarks

When **preprocessor** is specified, other than the following options become invalid:

show=source, include, expansion, width, length, tab, listfile, define, include, comment, euc, sjis, latin1, subcommand, preinclude, message, lang, logo, cpu, change_message

Code: Object Type

Object[Output file type :][Machine code][Assembly source code]

- Command Line Format
Code = { Machinecode | Asmcode }

- Description

Specifies an object file output type.

When **code=machinecode** is specified, a relocatable object program (machine code) is generated.

When **code=asmcode** is specified, an assembly source program is generated.

The default for this option is **code=machinecode**.

- Remarks

When **code=asmcode** is specified, **show=object** and **goptimize** become invalid.

DEBug, NODEBug: Debugging Information

Object[Generate debug information]

- Command Line Format

DEBug

NODEBug

- Description

When the **debug** option is specified, debugging information will be output to object files.

The **debug** option is valid regardless of whether or not the optimization option is specified.

When **nodebug** option is specified, no debugging information will be output to the object file.

The default for this option is **nodebug**.

SSection: Section Name

Object[Code generation][Section :][Program section (P)][Const section (C)][Data section (D)]
[Uninitialized data section (B)]

- Command Line Format

SSection = <sub> [,...]

<sub>: { Program=<section name>

| Const= <section name>

| Data= <section name>

| Bss= <section name>

}

- Description

Specifies the section name of an object program.

section=program=<section name> specifies the section name in the program area.

section=const=<section name> specifies the section name in the constant area.

section=data=<section name> specifies the section name in the initialized data area.

section=bss=<section name> specifies the section name in the non-initialized data area.

The <section name> must be alphabetic, numeric, or underscore (_) or \$. The first character must not be numeric. The section name must be specified within 8192 characters.

The default for this option is **section=program=P, const=C, data=D, bss=B**.

- Remarks

For details on correspondence between programs and section names, refer to section 9.1, Program Structure. The same section name cannot be specified for different areas of the section.

String: String Literal Output Area

Object[Code generation][Store string data in :]

- Command Line Format
SString = { Const | Data }

- Description

Specifies the destination where string literals are output.

When **string=const** is specified, the compiler outputs the string literals to the constant area.

When **string=data** is specified, the compiler outputs the string literals to the initialized data area.

The string literals output to the initialized data area can be modified at program execution; however, the initialized data area must be allocated in both ROM and RAM in order to transfer the string literals to RAM from ROM at the beginning of program execution. For details on the initial settings of the initialized data area or on memory allocation, refer to section 9.2.1 Memory Allocation.

The default for this option is **string=const**.

Objectfile: Object File Output

Object[Output directory :]

- Command Line Format
OObjectfile = <object file name>

- Description

Specifies an object file name to be output.

If this option is not specified, the object file name becomes the same as that of the source file and the extension becomes **obj** for a relocatable object program and **src** for an assembly source program, which is determined by **code**.

Template: Template Instance Generation

Object[Code generation][Template :]

- Command Line Format

Template = { None

| Static

| Used

| All

| Auto }

- Description

Specifies the condition to generate template instances.

When **template=none** is specified, instances are not generated.

When **template=static** is specified, instances of templates referenced in the compiling unit are generated. However, generated functions contain the internal linkage.

When **template=used** is specified, instances of templates referenced in the compiling unit are generated. However, generated functions contain the external linkage.

When **template=all** is specified, instances of all templates declared or referenced in the compiling unit are generated.

When **template=auto** is specified, instances needed at linkage are generated.

- Remarks

When **code=asmcode** is specified, **template=static** must be specified.

ABs16, ABS20, ABS28, ABS32: ABS16/20/28/32 Declaration

Object[Code generation2][Address declaration]

- Command Line Format

ABs16 = { Program | Const | Data | Bss | Run | All }[,...]

ABS20 = { Program | Const | Data | Bss | Run | All }[,...]

ABS28 = { Program | Const | Data | Bss | Run | All }[,...]

ABS32 = { Program | Const | Data | Bss | Run | All }[,...]

- Description

Specifies the memory space where the label addresses or runtime routines belonging to the section specified by the suboption are to be allocated.

The default for this option is **abs32=all**.

Table 2.3 Address Ranges

Option	Address Range	
	Beginning	End
abs16	0x00000000	0x00007FFF
	0xFFFF8000	0xFFFFFFFF
abs20	0x00000000	0x0007FFFF
	0xFFF80000	0xFFFFFFFF
abs28	0x00000000	0x07FFFF7F*
	0xF8000000	0xFFFFFFFF
abs32	0x00000000	0xFFFFFFFF

Note: * Note that the end of the address range is 0x07FFFF7F.

Table 2.4 Suboptions

Suboption	Description
program	Allocates the program areas to the specified memory space.
const	Allocates the constant areas to the specified memory space.
data	Allocates the initialized data areas to the specified memory space.
bss	Allocates the uninitialized data areas to the specified memory space.
run	Allocates the runtime routines to the specified memory space.
all	Allocates all areas to the specified memory space.

- Example

Program

```
-abs20=program -abs28=const,data
```

→ Same as `-abs20=program -abs28=const,data -abs32=bss,run`

```
-abs20=data -abs16=data
```

→ Outputs a warning message and `-abs16=data` becomes valid

- Remarks

When this option and `#pragma abs16|abs20|abs28|abs32` are specified simultaneously, the `#pragma` specification is valid.

When this option and `#pragma gbr_base|gbr_base1` are specified simultaneously, this option specification is not applied to the variables specified by `#pragma gbr_base|gbr_base1`.

`abs20|abs28` is only valid when `cpu=sh2a|sh2afpu` is specified.

Division: Division Method Selection

Object[Code generation][Division sub-options :]/CPU[Division :]

- Command Line Format

```
DIvision = { Cpu [= { Inline | Runtime } ]
|           Peripheral
|           Nomask           }
```

- Description

Selects the method of integer type division and residue.

When **division=cpu=inline** is specified, division operations on constants are converted into multiplications and inline-expanded, and for division operations on variables, the DIVS or DIVU instruction is selected when **cpu** is SH-2A or SH2A-FPU; otherwise, the runtime routine for the DIV1 instruction is selected. This option is invalid when **cpu=sh1** is specified.

When **division=cpu=runtime** is specified, if a division cannot be performed through shift operations, the DIVS or DIVU instruction is selected when **cpu** is SH-2A or SH2A-FPU; otherwise, the runtime routine for the DIV1 instruction is selected. This option is invalid when **cpu=sh1** is specified.

When only **division=cpu** is specified, either **division=cpu=runtime** is assumed when the **size** option is specified, and **division=cpu=inline** is assumed when the **speed** or **nospeed** option is specified.

When **division=peripheral** is specified, the runtime routine that uses the divider is selected (sets interrupt mask level to 15). Executable only if **cpu** is SH-2 (SH7604).

When **division=nomask** is specified, the runtime routine that uses the divider is selected (no change in interrupt mask level). Executable only if **cpu** is SH-2 (SH7604).

When specifying **peripheral** or **nomask**, note the following:

1. Division by 0 is not checked and **errno** is not set up.
2. When **nomask** is specified, if an interrupt occurs during operation of the divider, and if the divider is used in the interrupt processing routine, the result is not guaranteed.
3. Overflow interrupt is not supported.
4. Results of division by zero and overflow depend on specifications of the divider, and may differ from the results obtained when the **cpu** suboption is specified.

The default for this option is **division=cpu**.

IFUnc: Disabling of Save and Restore of Floating-Point Registers

Object[Code generation][Use no FPU instructions]

- Command Line Format
IFUnc
- Description
Disables saving and restoring of floating-point registers.
- Remarks
This specification can be made for each function unit using **#pragma ifunc**.
When a source program that generates floating-point instructions is compiled with this option specified, an error occurs.
This option is only valid when **cpu=sh2e**, **sh2afpu**, **sh4**, or **sh4a** is specified.

ALIGN16, ALIGN32, NOALign: 16-Byte or 32-Byte Alignment of Labels

Object[Code generation][Align Labels after unconditional branches 16/32 byte boundaries]

- Command Line Format
ALIGN16
ALIGN32
NOALign
- Description
When **align16** is specified, every first label within the program section to appear after an unconditional branch instruction is aligned with a 16-byte boundary.
When **align32** is specified, every first label within the program section to appear after an unconditional branch instruction is aligned with a 32-byte boundary.
When **noalign** is specified, labels appearing after unconditional branch instructions are not aligned with 16- or 32-byte boundaries.
The default for this option is **noalign**.
- Remarks
align16 and **align32** cannot be specified simultaneously.
When the **noalign16** option is specified, it is considered that **noalign** has been specified.

TBR: TBR Relative Function Call

Object[Code generation2][TBR specification]

- Command Line Format
TBR [= <section name>]
- Description
Calls functions using TBR relative addresses.
When <section name> is specified, the function address table for function definitions is output to the **\$TBR<section name>** section.
When <section name> is omitted, the function address table for function definitions is output to the **\$TBR** section.
For details, refer to section 10.3.1 (2), **#pragma tbr**.
- Remarks
This option is only valid when **cpu=sh2a** or **sh2afpu** is specified.
When this option and **#pragma tbr** are specified simultaneously, the **#pragma tbr** specification is valid. When this option and **pic=1** are specified simultaneously, this option is invalid.
When the number of functions to be included in the function address table exceeds 255, an error message will be output.

BSs_order: Order of Uninitialized Variables

Object[Code generation2][Order of uninitialized variables]

- Command Line Format
BSs_order = {declaration | definition}
- Description
When **bss_order=declaration** is specified, uninitialized variables are output in the order of declarations.
When **bss_order=definition** is specified, uninitialized variables are output in the order of definitions.
The default for this option is **bss_order=declaration**.
- Example

```
extern int a1;  
extern int a2;  
int a3;
```

```
extern int a4;  
int a5;  
int a2;  
int a1;  
int a4;
```

<bss_order=declaration is specified>

```
.SECTION B, DATA, ALIGN=4  
_a1:  
.RES.L 1  
_a2:  
.RES.L 1  
_a3:  
.RES.L 1  
_a4:  
.RES.L 1  
_a5:  
.RES.L 1
```

<bss_order=definition is specified>

```
.SECTION B, DATA, ALIGN=4  
_a3:  
.RES.L 1  
_a5:  
.RES.L 1  
_a2:  
.RES.L 1  
_a1:  
.RES.L 1  
_a4:  
.RES.L 1
```

- Remarks

When the **stuff** option is specified, uninitialized variables are output in the order of declarations regardless of the **bss_order** setting.

STuff

NOSTuff: Disposition of Variables

Object[Code generation2][Disposition of variables :]

- Command Line Format

STuff [= <section type>[,...]]

NOSTuff

<section type> : {Bss | Data | Const}

- Description

When the **stuff** option is specified, the variables that belong to the <section type> are assigned to 4-byte, 2-byte, or 1-byte boundary alignment sections depending on the size of the variables (see table 2.5).

When <section type> is omitted, any variable is applicable.

C, D, and B are the section names specified by the **section** option or **#pragma section**. The data assigned to each section are arranged in the order of definitions (**bss_order** option setting is ignored).

Table 2.5 Relationship between Size of Variable and Section Name

	Section Type	Size of Variable (Byte)		
		4n	4n-2	2n-1
const-type variables	const	C\$4	C\$2	C\$1
Initialized variables	data	D\$4	D\$2	D\$1
Uninitialized variables	bss	B\$4	B\$2	B\$1

When the **nostuff** option is specified, all variables are assigned to 4-byte boundary alignment sections.

The data assigned to sections C and D are arranged in the order of definitions, and the data assigned to section B are arranged according to the **bss_order** option.

The default for this option is **nostuff**.

- Example

```
int a;
char b=0;
const short c=0;
struct {
char x;
char y;
} ST;
```

<stuff is specified>

```
.SECTION C$2, DATA, ALIGN=2
_c:
.DATA.W H'0000
.SECTION D$1, DATA, ALIGN=1
_b:
.DATA.B H'00
.SECTION B$4, DATA, ALIGN=4
_a:
.RES.L 1
.SECTION B$2, DATA, ALIGN=2
_ST:
.RES.B 2
```

<nostuff is specified>

```
.SECTION C, DATA, ALIGN=4
_c:
.DATA.W H'0000
.SECTION D, DATA, ALIGN=4
_b:
.DATA.B H'00
.SECTION B, DATA, ALIGN=4
_a:
.RES.L 1
_ST:
.RES.B 2
```


- Remarks

This option is invalid for variables with **#pragma gbr_base | gbr_base1** or **#pragma global_register**.

STUFF_GBR

Description Format: C/C++ <Object> [Code generation2] [Disposition of Variables in \$G0/\$G1]

Command Line Format: STUFF_GBR

Description: Assigns a **#pragma gbr_base|gbr_base1**-specified variable to sections listed in table 2.6 depending on the size of the variable. This reduces the amount of gap area generated by boundary alignment.

Table 2.6 Size of the Variable and Section Names

	Size of the Variable (in Bytes)		
	4n	4n-2	2n-1
With #pragma gbr_base	\$G0\$4	\$G0\$2	\$G0\$1
With #pragma gbr_base1	\$G1\$4	\$G1\$2	\$G1\$1

Note: n is integer.

Remarks: This option is valid only when **gbr=user** has been specified. Sections starting with \$G0 or \$G1 should be assigned as shown in table 2.7.

Table 2.7 Allocation of Sections

Section Name	Allocation
\$G0	The start address should be a multiple of 4.
\$G0\$1, \$G0\$2, \$G0\$4	The section should be within 128 bytes from the start address of \$G0.
\$G1	The start address should be 128 bytes far from the start address of \$G0.
\$G1\$1	The section should be within 256 bytes from the start address of \$G0.
\$G1\$2	The section should be within 512 bytes from the start address of \$G0.
\$G1\$4	The section should be within 1024 bytes from the start address of \$G0.

ALIGN4

Description Format: C/C++ <Object> [Code generation] [Alignment of Branch Destination]

Command Line Format: ALIGN4 = { ALL |
 LOOP |
 INMOSTLOOP }

Description: When **align4=all** is specified, all branch destination addresses are aligned to the 4-byte boundary.

When **align4=loop** is specified, the start addresses of all loops are aligned to the 4-byte boundary.

When **align4=inmostloop** is specified, the start addresses of the innermost loops are aligned to the 4-byte boundary.

Remarks: This option is not available when **align16** or **align32** has already been specified. When **align4** is specified, the start address of the function is always aligned to the 4-byte boundary. All functions with **align4** will not be optimized at linkage.

CONST_VOLATILE

Allocate const volatile variables

Description Format: Object [Code generation] [const volatile variables:]

Command Line Format: `-CONST_VOLATILE={ DATA | CONST}`

Description: This option specifies the area where **const**- and **volatile**-qualified variables should be allocated.

When **const_volatile=const**, the variables will be allocated to the constant area.

When **const_volatile=data**, the variables will be allocated to the initialized data area.

The default for this option is **const_volatile=data**.

[Examples]

- (1) Where variable **c** of **const volatile int c=3;** will be allocated
 - const_volatile=data: Initialized data area (section D)
 - const_volatile=const: Constant area (section C)
 - const_volatile=const -stuff: Constant area (section C\$4)
 - const_volatile=const -section=const=N: Constant area (section N)
- (2) Where variable **x** of **X const volatile __fixed x=0.5r;** will be allocated
 - const_volatile=data: Initialized data area (section \$XD)
 - const_volatile=const: Constant area (section \$XC)

2.2.3 List Options

Table 2.8 List Category Options

Item	Command Line Format	Dialog Menu	Specification
Listing file	Listfile [= <file name>] <u>NOListfile</u>	List [Generate list file]	Output Not output
Listing contents and format	SHow = <sub> [...] <sub>:{ Source <u>NOSource</u> <u>Object</u> NOObject <u>Statistics</u> NOSTatistics Include <u>NOInclude</u> Expansion <u>NOExpansion</u> Width = <numeric value> Length = <numeric value> Tab = {4 <u>8</u> } }	List [Contents]	With/without source list With/without object list With/without statistics information With/without list after include expansion With/without list after macro expansion Maximum characters per line: <u>0</u> or 80 to 132 Maximum lines per page: <u>0</u> or 40 to 255 Number of columns when Tab is used: 4 or <u>8</u>

Listfile, NOListfile: List File

List[Generate list file]

- Command Line Format

Listfile [= <file name>]

NOListfile

- Description

Specifies whether a listing file is output or not.

When **listfile** option is specified, a listing file will be output. By specifying <file name>, a file name can also be specified.

When **nolistfile** is specified, a listing file will not be output.

A listing file name should be specified in accordance with section 8.1, Naming Files.

If no file name is specified, a listing file with the same name as the source and a standard extension (lst/lpp) is created. The standard extension for filenames in C compilation is lst, and that for filenames in C++ compilation is lpp.

The default for this option is **nolistfile**.

SHow: List Contents and Format

List[Contents]

- Command Line Format

```
SHow= <sub>[,...]
      <sub>: { SSource      | NOSSource
            | Object        | NOObject
            | Statistics   | NOStatistics
            | Include      | NOInclude
            | Expansion    | NOExpansion
            | Width= <numeric value>
            | Length= <numeric value>
            | Tab = { 4 | 8 }
      }
```

- Description

Specifies the contents and format of the list output by the compiler, and the cancellation of listing output.

For examples of each list in this section, refer to section 8.2, Compiler Listings.

The default for this option is **show=nosource, object, statistics, noinclude, noexpansion, width=0, length=0, tab=8**.

- Remarks

Table 2.9 shows a list of suboptions.

Table 2.9 List of Suboptions of show Option

Suboption	Description
source	Outputs a list of source programs
nosource	Outputs no list of source programs
object	Outputs a list of object programs
noobject	Outputs no list of object programs
statistics	Outputs a list of statistics information
nostatistics	Outputs no list of statistics information
include	Outputs a source program listing after include file expansion. If the nosource suboption and the include suboption are specified simultaneously, the include suboption will be invalid, and no source program listing will be output to a file.
noinclude	Outputs a source program listing before include file expansion. If the nosource suboption and the noinclude suboption are specified simultaneously, the noinclude suboption will be invalid, and no source program listing will be output to a file.
expansion	Outputs a source program listing after macro expansion. If the nosource suboption and the expansion suboption are specified, simultaneously the expansion suboption will be invalid, and no source program listing will be output to a file.
noexpansion	Outputs a source program listing before macro expansion. If the nosource suboption and the noexpansion suboption are specified simultaneously, the noexpansion suboption will be invalid, and no source program listing will be output to a file.
width=<numeric value>	The number specified by <numeric value> is set as the maximum number of characters in a single line of a listing. The <numeric value> can specify decimal numbers from 80 to 132 or 0. If <numeric value> is specified as 0, the maximum number of characters in a single line is not specified.
length=<numeric value>	The number specified by <numeric value> is set as the maximum number of lines on a single page of a listing. The <numeric value> can specify decimal numbers from 40 to 255 or 0. If <numeric value> is specified as 0, the maximum number of lines on a single page of a listing is not specified.
tab = { 4 8 }	Specifies the tab size when a listing is displayed.

2.2.4 Optimize Options

Table 2.10 Optimize Category Options

Item	Command Line Format	Dialog Menu	Specification
Optimization	Optimize = { 0 1 Debug_only}	Optimize [Optimization]	Outputs object without optimization. Outputs object with optimization. Outputs a code that does not affect the debugging information.
Optimized for speed	SPEED Size <u>NOSPEED</u>	Optimize [Speed or size :] [Optimize for speed] [Optimize for size] [Optimize for both speed and size]	Selects the optimization item.
Inter-module optimization information	Goptimize	Optimize [Generate file for inter-module optimization :]	Outputs information for inter-module optimization.
Optimized for access to external variables	MAP = <file name>	Optimize [Optimization for access to external variables :] [Inter-module]	Optimized for access to external variables.
Optimization of external variable access	SMap	Optimize [Optimization for access to external variables :] [Inner-module]	Optimizes access to external variables defined in the file to be compiled.
Automatic creation of GBR relative access code	GBr = { <u>Auto</u> User}	Optimize [Gbr relative operation :]	Automatically creates GBR-relative access codes. Does not automatically create GBR-relative access codes.
switch statement expansion method	CAse = { Ifthen Table }	Optimize [Switch statement :]	Expands by if_then method. Expands by jumping to a table.
Shift-operation expansion	SHift = { Inline Runtime }	Optimize [Shift operation :]	Performs inline expansion. The runtime routine will be called if shift operations have a large number of instructions to be expanded.

Table 2.10 Optimize Category Options (cont)

Item	Command Line Format	Dialog Menu	Specification
Transfer-code expansion	Blockcopy = { Inline Runtime }	Optimize [Transfer code development :]	Performs inline expansion. The runtime routine will be called when a large block of memory is to be transferred.
Unaligned data transfer	Unaligned = {Inline Runtime}	Optimize [Unaligned move :]	Performs inline expansion. The runtime routine will be called.
Automatic inline expansion	INLine [= <numeric value>] NOINLine	Optimize [Details] [Inline] [Automatic inline expansion]	Performs inline expansion automatically. Does not perform inline expansion automatically.
Inter-file inline expansion	FILE_inline = <file name>[,...]	Optimize [Details] [Inline] [inline file path]	Specifies a file for inter-file inline expansion.
External variables handled as volatile	GLOBAL_Volatile = { 0 1 }	Optimize [Details] [Global variables] [Treat global variables as volatile qualified]	External variables declared with volatile are not handled (excluding external variables declared with volatile). All external variables are handled as if declared with volatile .
External variable optimizing range	OPT_Range = { All NOLoop NOBlock }	Optimize [Details] [Global variables] [Specify optimizing range :]	Optimizes external variables within the entire function. Disables loop control variables or external variables in a loop from being moved outside the loop. Disables optimization of external variables which extend across loops or branches.
Vacant loop elimination	DEL_vacant_loop = { 0 1 }	Optimize [Details] [Miscellaneous] [Delete vacant loop]	Disables elimination of vacant loops. Eliminates vacant loops.
Loop unroll	LOop NOLOop	Optimize [Details] [Miscellaneous] [Loop unrolling :]	Performs loop unrolling. Does not perform loop unrolling.

Table 2.10 Optimize Category Options (cont)

Item	Command Line Format	Dialog Menu	Specification
Maximum number of loop expansions	MAX_unroll = <numeric value> <numeric value>: 1 to 32	Optimize [Details] [Miscellaneous] [Specify maximum unroll factor :]	Specifies the maximum number of times a loop is expanded. Default: 1 (2 when speed or loop is specified)
Elimination of INFinite_loop expression preceding infinite loop	INFinite_loop = { 0 1 }	Optimize [Details] [Global variables] [Delete assignment to global variables before an infinite loop]	Disables elimination of an assignment expression for external variables preceding an infinite loop. Eliminates an assignment expression for external variables preceding an infinite loop.
External variable register allocation	GLOBAL_Alloc = { 0 1 }	Optimize [Details] [Global variables] [Allocate registers to global variables :]	Disables allocation of external variables to registers. Allocates external variables to registers.
Structure/union member register allocation	STRUCT_Alloc = { 0 1 }	Optimize [Details] [Miscellaneous] [Allocate registers to struct/union members :]	Disables allocation of structure/union members to registers. Allocates structure/union members to registers.
const constant propagation	CONST_Var_propagate = { 0 1 }	Optimize [Details] [Global variables] [Propagate variables which are const qualified :]	Disables constant propagation of external constants declared by const . Performs constant propagation of external constants declared by const .
Expansion of constant loading instructions	CONST_Load = { Inline Literal }	Optimize [Details] [Miscellaneous] [Load constant value as :]	Expands instructions for loading constants. Accesses literal pool for loading constants. Default: When size is specified, up to two or three instructions are expanded. In other cases, the default is literal .

Table 2.10 Optimize Category Options (cont)

Item	Command Line Format	Dialog Menu	Specification
Instruction scheduling	SCchedule = { 0 1 }	Optimize[Details] [Global variables] [Schedule instructions :]	Instructions are not scheduled. Instructions are scheduled.
Software pipelining [SH-2A, SH2A-FPU, SH-4, SH-4A and SH4AL-DSP]	SOftpipe	Optimize [Details] [Miscellaneous] [Software pipelining :]	Validates software pipelining.
Division of optimizing ranges	SCOpe NOScope	Optimize [Details] [Miscellaneous] [Not divide the optimization range]	Optimizing ranges are divided. Optimizing ranges are not divided.
GBR relative logic operation generation	LOGlc_gbr	Optimize [Gbr relative operation]	Generates code that uses GBR relative addresses for logic operations of external variables.
Preventing expansion of C++ Inline functions	CPP_NOINLINE	C/C++ <Optimize> [Details] [Inline] [Doesn't Expand C++ Inline Functions]	C++ Inline functions are not expanded
Optimization considering type of object indicated by pointer	ALIAS = {ANSI <u>NOANSI</u> }	Optimize [Details] [Miscellaneous] [Optimization considering type of object indicated by pointer]	Optimization considering type of object indicated by pointer is applied. Optimization considering type of object indicated by pointer is not applied.

OPTimize: Optimization

Optimize[Optimization]

- Command Line Format

OPTimize = { 0 | 1 | Debug_only }

- Description

Specifies the level of compiler optimization for the object program.

When **optimize=debug_only** is specified, the compiler does not optimize the object program. The output has highly accurate debugging information, which eases debugging at the source level.

When **optimize=0** is specified, the compiler optimizes some parts of the object program, allocating automatic variables to registers, consolidating function-exit blocks, consolidating multiple functions where this is possible, etc. Accordingly, the code size may become smaller than that compiled with the **optimize=debug_only** setting. When **optimize=1** is specified, the compiler optimizes the object program.

The default for this option is **optimize=1**.

SPEED, SIZE, NOSPEED: Optimization for Speed

Optimize[Speed or size :][Optimize for speed][Optimize for size]
[Optimize for both speed and size]

- Command Line Format

SPEED

SIZE

NOSPEED

- Description

Table 2.11 is a list of the items optimized for the **speed**, **size**, and **nospeed** options.

These optimization items can be controlled by option.

The default for this option is **nospeed**.

Table 2.11 List of Optimization Items

Option	Automatic Inline Expansion	Optimize for Loop Expansion	Expansion of Shift Code	Expansion of Transfer Code	Expansion of Integer Constant Division	Unaligned Data Transfer
speed	inline=20	loop	inline	inline	inline	inline
size	noinline	noloop	runtime	runtime	runtime	runtime
nospeed	noinline	noloop	inline	inline	inline	inline

Optimize: Inter-Module Optimization

Optimize[Generate file for inter-module optimization]

- Command Line Format
Goptimize
- Description
Outputs the additional information for the inter-module optimization.
For the file specified with this option, the inter-module optimization is performed at linkage.

MAP: External Variable Access Optimization

Optimize[Optimization for access to external variables :][Inter-module]

- Command Line Format
MAP = <file name>
- Description
This option sets the base addresses by using an external symbol-allocation information file created by the optimizing linkage editor and creates code that performs access to external or static variables relative to the base address. When **gbr=auto** is specified, the compiler may set the base address in the **GBR** register, and may create code that performs access to external or static variables relative to the value in **GBR**.
Compile the program before using this option. At linkage, specify **map=<file name>** to create the external symbol-allocation information file. Then specify **map=<file name>** and compile the program again.
- Example
Source program (test.c)

```
int A,B,C;
void main()
{
A = 0;
B = 0;
C = 0;
}
```

(1) Command: shc test.c

<Output code>

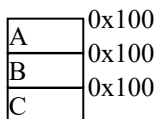
```
_main:
MOV.L    L11,R6    ;_A
MOV     #0,R2
MOV.L    R2,@R6
MOV.L    L11+4,R6  ;_B
MOV.L    R2,@R6
MOV.L    L11+8,R6  ;_C
RTS
MOV.L    R2,@R6
L11:
.DATA.L  _A
.DATA.L  _B
.DATA.L  _C
```

(2) Command: shc test.c

```
optlnk -map=test.bls -start=P/400,B/1000 test.obj
```

```
shc -map=test.bls test.c
```

Data allocation after linkage



<Output code>

```
_main:
```

```
MOV.W    L11,R1 ;_A Sets the address of A as the base address.
```

```
MOV     #0,R0
```

```
MOV.L   R0,@R1
```

```
MOV.L   R0,@(4,R1)
```

```
RTS
```

```
MOV.L   R0,@(8,R1)
```

```
L11:
```

```
.DATA.W  _A           The address of A consists of 2 bytes.
```

- Remarks

When the order of the definitions of external variables has been changed, a new external symbol-allocation information file must be created.

If any option other than the **map** option in the previous compilation differs from the one in the current compilation, or if any contents of a function are changed, the result of the object code is not guaranteed. In such a case, a new external symbol-allocation information file must be created.

SMap: Optimization of External Variable Access

Optimize[Optimization for access to external variables :][Inner-module]

- Format

SMap

- Description

Specifies a base address for external or static variables defined in the file to be compiled, and generates code that uses addresses relative to the base address for access to the variables.

When **gbr=auto** is specified, the compiler specifies a base address in the GBR according to the conditions and generates code that uses GBR relative addresses for access to external or static variables.

- Example

```
int A,B,C;
void main()
{
A = 0;
B = 0;
C = 0;
}
```

```
MOV.L    L11,R6    ; _A
MOV      #0,R2     ; H'00000000
MOV.L    R2,@R6
MOV.L    R2,@(4,R6)
RTS
MOV.L    R2,@(8,R6)
```

- Remarks

When this option and **map=<file name>** are specified simultaneously, the **map** option is valid.

GBr: Automatic Creation of GBR Relative Access Code

Optimize[Gbr relative operation :]

- Command Line Format

GBr = { Auto | User }

- Description

When **gbr=auto** is specified, the compiler will automatically create **GBR**-relative code for logic operations by certain conditions. When **gbr=auto** and **map=<file name>** are specified, the compiler may set a base address in **GBR** and may create code that performs access to external or static variables relative to the value in **GBR** by certain conditions.

When **gbr=user** is specified, the user must specify the setting of and references to **GBR** and access relative to the value in **GBR** by using the **#pragma** extensions **#pragma gbr_base** or **#pragma gbr_base1**, or intrinsic functions that are related to **GBR**. The default for this option is **gbr=auto**.

- Example

Program

```
char A,B,C;
void main()
{
    A |= 1;
    B &= 1;
    C ^= 1;
}
```

<Output code(gbr=auto)>

_main:

```
STC          GBR,@-R15    ; Saves the contents of GBR
MOV          #0,R0
LDC          R0,GBR      ; Sets 0 to GBR
MOV.L       L11+2,R0     ; R0 <- Address of A
OR.B        #1,@(R0,GBR) ; A |= 1
MOV.L       L11+6,R0     ; R0 <- Address of B
AND.B       #1,@(R0,GBR) ; B &= 1
MOV.L       L11+10,R0    ; R0 <- Address of C
XOR.B       #1,@(R0,GBR) ; C ^= 1
RTS
LDC          @R15+,GBR    ; Restores the contents of GBR
```

L11:


```
.RES.W      1
.DATA.L     _A
.DATA.L     _B
.DATA.L     _C
```

- Remarks

When **gbr=auto** is specified in compiling a program in which **#pragma gbr_base** or **#pragma gbr_base1** is used, a warning message will be displayed and the specifications by the **#pragma** extensions will be ignored.

When **gbr=auto** is specified in compiling a program in which intrinsic functions that are related to **GBR** are used, an error will occur.

When **gbr=auto** is specified, the contents of the **GBR** register will be saved and restored

CAse: switch Statement Expansion Method

Optimize[Switch statement :]

- Command Line Format

CAse = { Ifthen | Table }

- Description

Specifies a switch statement expansion method.

When **case=ifthen** is specified, the switch statement is expanded using the **if_then** method, which repeats, for each case label, comparison between the evaluated value of the expression in the switch statement and the case label value. If they match, execution jumps to the statement of the case label. This method increases the object code size depending on the number of case labels in the switch statement.

When **case=table** is specified, the switch statement is expanded using the table method, which stores the case label jump destinations in a jump table and enables a jump to the statement of the case label that matches the expression in the switch statement by accessing the jump table only once. This method increases the jump table size in the literal pool depending on the number of case labels in the switch statement, but the execution speed is always the same.

If this option is not specified, the compiler automatically selects one of the methods for expansion.

SHift: Shift Operation Expansion

Optimize[Shift Operation :]

- Command Line Format
SHift = { Inline | Runtime }

- Description

Selects the method for shift operations where shifting is by a constant number of bits greater than 0 and less than (length in bits of the left operand - 1).

When **shift=inline** is specified, all shift operations are expanded.

When **shift=runtime** is specified, the runtime routine will be called if some instructions are to be expanded.

When the **size** option has been specified, the default for this option is **shift=runtime**. When the **speed** or **nospeed** option has been specified, the default for this option is **shift=inline**.

BLOckcopy: Transfer Code Expansion

Optimize [Transfer code development :]

- Command Line Format
BLOckcopy = { Inline | Runtime }

- Description

When **blockcopy=inline** is specified, (the instructions of) all coding for transfer between areas of memory are expanded.

When **blockcopy=runtime** is specified, the runtime routine will be called when a large block of memory is to be transferred.

When the **size** option has been specified, the default for this option is **blockcopy=runtime**.

When the **speed** or **nospeed** option has been specified, the default for this option is **blockcopy=inline**.

Unaligned: Unaligned Data Transfer

Optimize[Unaligned move :]

- Command Line Format

Unaligned = { Inline | Runtime }

- Description

When **unaligned=inline** is specified, unaligned data transfer are expanded.

When **unaligned=runtime** is specified, the runtime routine will be called if a large block of unaligned data is to be transferred.

When the **size** option has been specified, the default for this option is **unaligned=runtime**.

When the **speed** or **nospeed** option has been specified, the default for this option is **unaligned=inline**.

- Remarks

This option is used for transfer of a structure whose alignment value is 1.

INLine, NOINLine: Automatic Inline Expansion

Optimize[Details][Inline][Automatic inline expansion]

- Command Line Format

INLine=[<numeric value>]

NOINline

- Description

Specifies whether to automatically perform inline expansion of functions.

When the **inline** option is specified, the compiler automatically performs inline expansion.

The user is able to use **inline=<numeric value>**, to specify the allowed increase in the program's size due to the use of inline expansion. For example, when **inline=50** is specified, inline expansion will be applied until the program has grown to 150% of its size (gain of 50%).

When the **noinline** option is specified, automatic inline expansion is not performed.

When the **speed** option has been specified, the default for this option is **inline=20**. When the **nospeed** or **size** option, or **optimize=0** has been specified, the default is **noinline**.

FILE_inline: Inter-file Inline Expansion

Optimize[Details][Inline][Inline file path]

- Command Line Format
FILE_inline=<file name>[,...]
- Description
Performs inline expansion for functions that extend across files for the files specified with <file name>.

- Example

```
<a.c>
func () {
g ()
}
<b.c>
g () {
h ();
}
```

By compiling a program with **shc -file_inline=b.c a.c** specified, calling of function g() in a.c is expanded as follows:

```
func () {
h ();
}
```

- Remarks

If the **file_inline** option and **noinline** option are specified simultaneously, inline expansion is performed for only the functions specified with **#pragma inline**.

If an **extern** function is defined with the same name in more than one function specified with the **file_inline** option, no operation is guaranteed (using a single function definition randomly selected for inline expansion).

The extension of the file name specified by <file name> cannot be omitted.

A file to be compiled cannot be specified with the **file_inline** option.

A wild card (* or ?) cannot be specified for <file name>.

GLOBAL_Volatile: Handling External Variables as volatile

Optimize[Details][Global variables][Treat global variables as volatile qualified]

- Command Line Format

GLOBAL_Volatile = { 0 | 1 }

- Description

When **global_volatile=0** is specified, the external variables not declared with **volatile** are optimized. Accordingly, the access count and access order for external variables may differ from those in the written C/C++ program.

When **global_volatile=1** is specified, all external variables are handled as if they were declared with **volatile**. Accordingly, the access count and access order for external variables are exactly the same as those in the written C/C++ program.

The default for this option is **global_volatile=0**.

OPT_Range: External Variable Optimizing Range Specification

Optimize[Details][Global variables][Specify optimizing range :]

- Command Line Format

OPT_Range = { All | NOLoop | NOBlock }

- Description

When **opt_range=all** is specified, the compiler optimizes external variables within the entire function.

When **opt_range=noloop** is specified, external variables in a loop and external variables used in a loop iteration condition are not to be optimized.

When **opt_range=noblock** is specified, external variables extending across branches (including loops) are not to be optimized.

When **optimize=0** or **optimize=debug_only** is specified, the default for this option is **opt_range=noblock**. For any other case, the default for this option is **opt_range=all**.

- Examples

(1) Optimization extending across a branch (done when **opt_range=all** or **opt_range=noloop** is specified)

```
int A,B,C;
```

```
void f(int a) {
```

```
A = 1;
```

```
if (a)
```

```
B = 1;
```

```
C = A;
```

```
}
```

<Source program image after optimization>

```
int A,B,C;
```

```
void f(int a) {
```

```
A = 1;
```

```
if (a)
```

```
B = 1;
```

```
C = 1; /* Reference of A is eliminated and A = 1 is propagated */
```

```
}
```

(2) Optimization in a loop (done when **opt_range=all** is specified)

```
int A,B,C[100];
void f {
int i;
for (i=0;i<A;i++) {
C[i] = B;
}
}
```

<Source program image after optimization>

```
int A,B,C[100];
void f {
int i;
int temp_A, temp_B;
temp_A = A; /* Reference of A by loop iteration condition is moved outside the loop */
temp_B = B; /* Reference of B in the loop is moved outside the loop */
for (i=0;i< temp_A;i++) { /* Reference of A in the loop is eliminated */
C[i] = temp_B; /* Reference of B in the loop is eliminated */
}
}
```

• Remarks

When **opt_range=noloop** is specified, **max_unroll=1** is always the default.

When **opt_range=noblock** is specified, **max_unroll=1**, **const_var_propagate=0**, and **global_alloc=0** are always the default.

DEL_vacant_loop: Vacant Loop Elimination

Optimize[Details][Miscellaneous][Delete vacant loop]

- Command Line Format
DEL_vacant_loop = { 0 | 1 }
- Description
When **del_vacant_loop=0** is specified, even when there is no loop internal processing, a loop is not eliminated.
When **del_vacant_loop=1** is specified, loops with no internal processing are eliminated.
The default for this option is **del_vacant_loop=0**.
- Remarks
Note that the default differs from that for earlier versions of Ver. 7.0 (up to Ver. 7.0.04) of the SH C/C++ compiler.
 - Up to Ver. 7.0.04: Vacant loops are eliminated.
 - Ver. 7.0.06 or later: Vacant loops are not eliminated.

LOop, NOLOop: Loop Unrolling

Optimize[Details][Miscellaneous][Loop unrolling :]

- Command Line Format
LOop
NOLOop
- Description
Specifies whether to perform loop unrolling.
When the **loop** option is specified, optimization is performed in compiling loop statements (for, while, and do-while).
When the **noloop** option is specified, optimization is not performed in compiling loop statements.
When **optimize=1** and **speed** are specified, the default for this option is **loop**. For any other case, the default for this option is **noloop**.

MAX_unroll: Loop Expansion Maximum Number Specification

Optimize[Details][Miscellaneous][Specify maximum unroll factor :]

- Command Line Format

MAX_unroll = <numeric value>

- Description

Specifies the maximum number of loops to be expanded. An integer from 1 to 32 can be specified for <numeric value>. If any other value is specified, an error will occur.

If **speed** or **loop** is specified, the default for this option is **max_unroll=2**. For any other case, the default for this option is **max_unroll=1**.

- Remarks

When **opt_range=noloop** or **opt_range=noblock** is specified, the default for this option is **max_unroll=1**.

INFinite_loop: Elimination of Expression Preceding Infinite Loop

Optimize[Details][Global variables][Delete assignment to global variables before an infinite loop]

- Command Line Format

INFinite_loop = { 0 | 1 }

- Description

When **infinite_loop=0** is specified, an assignment expression for external variables, which is located immediately before an infinite loop is not eliminated.

When **infinite_loop=1** is specified, an assignment expression that is located immediately before an infinite loop and is for external variables that are not referenced from the infinite loop is eliminated.

The default for this option is **infinite_loop=0**.

- Example

```
int A;
void f()
{
A = 1;    /* Assignment expression for external variable A */
while(1) {} /* A is not referenced */
}
<Source program image when infinite_loop=1 is specified>
void f()
{
/* Assignment expression for external variable A is eliminated */
while(1) {}
}
```

- Remarks

Note that the default differs from that for earlier versions of Ver. 7.0 (up to Ver. 7.0.04) of the SH C/C++ compiler.

— Up to Ver. 7.0.04: An assignment expression that is located immediately before an infinite loop and is for external variables that are not referenced from the infinite loop are eliminated.

— Ver. 7.0.06 or later: An assignment expression for external variables, which is located immediately before an infinite loop is not eliminated.

GLOBAL_Alloc: External Variable Register Allocation

Optimize[Details][Global variables][Allocate registers to global variables :]

- Command Line Format
GLOBAL_Alloc = { 0 | 1 }
- Description
When **global_alloc=0** is specified, allocation of external variables to registers is disabled.
When **global_alloc=1** is specified, external variables are allocated to registers.
- Remarks
When **opt_range=noblock** or **optimize=debug_only** is specified, the default for this option is **global_alloc=0**.
Note that when **optimize=0** is specified, the default differs from that for earlier versions of Ver. 7.0 (up to Ver. 7.0.04) of the SH C/C++ compiler.
— Up to Ver. 7.0.04: External variables are allocated to registers.
— Ver. 7.0.06 or later: Allocation of external variables to registers is disabled.
For any other case, the default for this option is **global_alloc=1**.

STRUCT_Alloc: Structure/Union Member Register Allocation

Optimize[Details][Miscellaneous][Allocate registers to struct/union members]

- Command Line Format
STRUCT_Alloc = { 0 | 1 }
- Description
When **struct_alloc=0** is specified, allocation of structure or union members to registers is disabled.
When **struct_alloc=1** is specified, structure or union members are allocated to registers.
- Remarks
If **struct_alloc=1** is specified when **opt_range=noblock** or **global_alloc=0** is specified, only local structure or union members are allocated to registers.
When **optimize=debug_only** is specified, the default for this option is **struct_alloc=0**. Note that when **optimize=0** is specified, the default differs from that for earlier versions of Ver. 7.0 (up to Ver. 7.0.04) of the SH C/C++ compiler.
— Up to Ver. 7.0.04: Structure or union members are allocated to registers.
— Ver. 7.0.06 or later: Allocation of structure or union members to registers is disabled.
For any other case, the default for this option is **struct_alloc=1**.

CONST_Var_propagate: const Constant Propagation

Optimize[Details][Global variables][Propagate variables which are const qualified :]

- Command Line Format

```
CONST_Var_propagate = { 0 | 1 }
```

- Description

When **const_var_propagate=0** is specified, constant propagation for external variables declared by **const** is disabled.

When **const_var_propagate=1** is specified, constant propagation is performed for even external variables declared by **const**.

- Example

```
const int x = 1;
int A;
void f() {
  A = x;
}
```

<Source program image when **const_var_propagate=1** is specified>

```
void f() {
  A = 1; /* x = 1 is propagated */
}
```

- Remarks

Variables declared by **const** in a C++ program cannot be controlled by this option (constant propagation is always performed).

When **optimize=0**, **optimize=debug_only**, or **opt_range=noblock** is specified, the default for this option is **const_var_propagate=0**. For any other case, the default for this option is **const_var_propagate=1**.

CONST_Load: Constant Loading Instruction Expansion

Optimize[Details][Miscellaneous][Load constant value as :]

- Command Line Format

CONST_Load = { Inline | Literal }

- Description

When **const_load=inline** is specified, the instructions for loading constants within 2 bytes with a sign are expanded.

When **const_load=literal** is specified, the literal pool is accessed for loading constants of two bytes or more.

The following shows the default for this option.

Option Specified	Default
-optimize=1 and -speed	const_load=inline
-optimize=1 and -size	The default for this option is const_load=inline when instruction expansion for a 2-byte constant is possible with two instructions or when instruction expansion for a 4-byte constant is possible with three instructions. For any other case, the default for this option is const_load=literal .
-optimize=1 and -nospeed	
-optimize=0 or -optimize=debug_only	const_load=literal

- Example

```
int f(){
return (257);
}
```

(1) const_load=inline or speed is specified

```

MOV #1,R0      ; R0 <- 1
SHLL8         R0      ; R0 <- 256 (1<<8)
RTS
ADD #1,R0     ; R0 <- 257 (256+1)

```

(2) const_load=literal, or size or nospeed is specified

```

MOV.W        #L11,R0
RTS
NOP
L11:
.DATA.W      H'0101

```

Schedule: Instruction Scheduling

Optimize[Details][Global variables][Schedule instructions :]

- Command Line Format

Schedule = { 0 | 1 }

- Description

When **schedule=0** is specified, instructions are not scheduled. Accordingly, processing is performed in the same order the instructions have been written in the C/C++ program.

When **schedule=1** is specified, instructions are scheduled taking into consideration pipeline processing and superscalar (SH-2A, SH2A-FPU, SH-4, SH-4A, or SH4AL-DSP).

The default for this option is **schedule=0** when **optimize=0** or **optimize=debug_only** is specified, and **schedule=1** otherwise.

SOftpipe: Software Pipelining

Optimize[Details][Miscellaneous][Software pipelining :]

- Command Line Format

SOftpipe

- Description

Validates software pipelining.

- Remarks

This option is only valid when **cpu=sh2a**, **cpu=sh2afpu**, **cpu=sh4**, **cpu=sh4a**, or **cpu=sh4aldsp** is specified.

SCOpe, NOScope: Division of Optimizing Ranges

Optimize[Details][Miscellaneous][Not divide the optimization range :]

- Command Line Format

SCOpe

NOScope

- Description

When the **scope** option is specified, the compiler divides the optimizing ranges of the large-size functions into many sections.

When the **noscope** option is specified, the compiler does not divide the optimizing ranges.

When the optimizing range is expanded, the object performance is generally improved although the compilation time is delayed. However, if registers are not sufficient, the object performance may be lowered.

Use this option at performance tuning because it affects the object performance depending on the program.

LOGic_gbr: GBR Relative Logic Operation Generation

Optimize[Gbr relative operation]

- Format

LOGic_gbr

- Description

Generates code that uses GBR relative addresses for logic operations of external variables.

- Remarks

When **gbr=auto** is specified, this option is invalid.

When using this option, specify the \$G0 section start address by intrinsic function **set_gbr()**.

CPP_NOINLINE

Description Format: C/C++ <Optimize> [Details] [Inline] [Doesn't Expand C++ Inline Functions]

Command Line Format: CPP_NOINLINE

Description: In compilation of a C++ source program, this option prevents inline expansion of an inline-specified function or a member function defined in a class or structure and generates a code as a calling static function with internal linkage.

Remarks: This option is valid only in compilation of C++ source programs. If the **inline** or **speed** option is specified or **#pragma inline** is used, the inline expansion of a function that is supposed to be prevented by **CPP_NOINLINE** may be carried out.

ALIAS: Optimization considering type of object indicated by pointer

Optimize[Details][Miscellaneous][Optimization considering type of object indicated by pointer]

• Command Line Format

ALIAS = {ANSI | NOANSI }

• Description

When alias=ansi is specified, the compiler performs optimization considering type of object indicated by pointer in compliance with the ANSI standard. Although, this generally produces object code with better performance than that when alias=noansi is specified, the results of execution may differ from those for code produced by old versions of the compiler.

When alias=noansi is specified, the compiler does not perform ANSI-complaint optimization considering type of object indicated by pointer. The default for this option is alias=noansi.

• Examples

```
long x,n;
void func(short * ps)
{
n = 1;
*ps = 2;
x = n;
}
```

[alias=noansi is specified]

```
;; The possibility of the value of n being overwritten by *ps = 2;
;; is considered, so the value of n is reloaded by (A)
MOV      #1,R2      ; H'00000001
MOV.L    L11+2,R6   ; _n
MOV.L    R2,@R6    ; n
MOV      #2,R2      ; H'00000002
MOV.W    R2,@R4    ; *(ps)
MOV.L    @R6,R2    ; n          (A) n is reloaded
MOV.L    L11+6,R6  ; _x
RTS
MOV.L    R2,@R6    ; x
```

```
[alias=ansi is specified]
;; Since the types of *ps and n are different, we assume that the
;; n value will not be overwritten by *ps = 2, and n = 1 is reused at
;; (B). Accordingly, the results will differ if the value of n was
;; overwritten by *ps = 2;.
```

```
MOV          #1,R2          ; H'00000001
MOV.L        L11+2,R6      ; _n
MOV.L        R2,@R6        ; n
MOV          #2,R2          ; H'00000002
MOV.W        R2,@R4        ; *(ps)
MOV          #1,R2          ; H'00000001 (B) n = 1 is reused
MOV.L        L11+6,R6      ; _x
RTS
MOV.L        R2,@R6        ; x
```

- Remarks

This option is only valid when `optimize=1` has been specified.

2.2.5 Other Options

Table 2.12 Other Category Options

Item	Command Line Format	Dialog Menu	Specification
Embedded C++ language	ECpp	Other [Miscellaneous options :] [Check against EC++ language specification]	Checks syntax according to the Embedded C++ language specifications.
DSP-C language [SH2-DSP, SH3-DSP and SH4AL-DSP]	DSpC	Other [Miscellaneous options :] [Check against DSP-C language specification]	Checks syntax according to the DSP-C language specifications.
Comment nesting	COMment = { Nest <u>NONest</u> }	Other [Miscellaneous options :] [Allow comment nest]	Permits comment (<i>/* */</i>) nesting. Does not permit comment (<i>/* */</i>) nesting.
MAC register	Macsave = { 0 <u>1</u> }	Other [Miscellaneous options :] [Callee saves/restores MACH and MACL registers if used]	Does not guarantee the MAC register contents before and after a function is called. Guarantees the MAC register contents before and after a function is called.
Saving and restoring SSR and SPC registers [SH-3 to SH-4]	SAve_cont_reg = { 0 <u>1</u> }	Other [Miscellaneous options :] [Saves/restores SSR and SPC registers]	Does not save or restore SSR and SPC registers. Saves and restores SSR and SPC registers.
Extension of return value	RTnext <u>NORTnext</u>	Other [Miscellaneous options :] [Expand return value to 4 byte]	Creates a sign-extension or zero-extension of the return value Creates no sign-extension or zero-extension of the return value

Table 2.12 Other Category Options (cont)

Item	Command Line Format	Dialog Menu	Specification
Converting the floating-point constant divisions to multiplications	APproxdiv	Other [Miscellaneous options :] [Approximate a floating-point constant division]	Converts the division of floating-point constant to multiplication
Avoiding SH7055 illegal operation [SH-2E]	PAtch=7055	Other [Miscellaneous options :] [Avoid illegal SH7055 instructions]	Avoids the creation of a program that includes operations that are illegal for the SH7055 due to the order of instructions.
FPSCR register switching [SH2A-FPU, SH-4, and SH-4A]	FPScr = { Safe <u>Aggressive</u>	Other [Miscellaneous options :] [Change FPSCR register if double data used]	The FPU is guaranteed to be in single-precision mode before and after function calls. The FPU is not guaranteed to be in single-precision mode before and after function calls.
Suppress optimization of loop iteration condition	Volatile_loop	Other [Miscellaneous options :] [Treats loop condition as volatile qualified]	Suppresses optimization of loop iteration condition
Enumeration data size	AUto_enum	Other [Miscellaneous options :] [enum size is made the smallest]	Automatically selects the enumeration data size.
Preferential allocation of register storage class variables	ENABle_register	Other [Miscellaneous options :] [Enable register declaration]	Allocates preferentially the variables with register storage class specification to registers.

Table 2.12 Other Category Options (cont)

Item	Command Line Format	Dialog Menu	Specification
ANSI conformance	STRlct_ansi	Other [Miscellaneous options :] [Obey ansi specifications more strictly]	Conforms to the ANSI standard for the following processing: <ul style="list-style-type: none"> • unsigned int and long type operations • Associativity of floating-point operations
Conversion to floating-point division [SH-2E, SH2A-FPU, SH-4, and SH-4A]	FDIV	Other [Miscellaneous options :] [Change integer division into floating-point]	Converts integer division to floating-point division.
Floating-point to fixed-point conversion [SH2-DSP, SH3-DSP and SH4AL-DSP]	FIXED_Const	Other [Miscellaneous options :] [Floating-point constant is handled as a fixed-point constant]	Handles floating-point values as fixed-point values.
Conversion of 1.0 to __fixed type maximum value [SH2-DSP, SH3-DSP and SH4AL-DSP]	FIXED_Max	Other [Miscellaneous options :] [treats 1.0 as maximum number of fixed type]	Handles 1.0r (1.0R) as the maximum value of __fixed (long __fixed) type.
Omitting type conversion for __fixed multiplication result [SH2-DSP, SH3-DSP and SH4AL-DSP]	FIXED_Noround	Other [Miscellaneous options :] [delete type conversion after fixed multiple]	Omits type conversion for the operation result of __fixed type multiplication.
DSP repeat loop [SH3-DSP and SH4AL-DSP]	REPeat	Other [Miscellaneous options :] [DSP repeat loop is used]	Uses a DSP-expansion repeat loop.

Table 2.12 Other Category Options (cont)

Item	Command Line Format	Dialog Menu	Specification
Omitting range check for conversion between floating-point number and integer [SH-2E, SH2A-FPU, SH-4, and SH-4A]	SIMple_float_conv	Other [Miscellaneous options :] [Not check the range in conversion between floating point number and integer]	Generates a code that does not include a check of the target value range for the type conversion between an unsigned integer and a floating-point number
Suppress DIVS and DIVU instruction generation	NOUSE_DIV_INS T	Other [Miscellaneous options :] [Suppress DIVS and DIVU instruction generation]	Suppress generation of the DIVU and DIVS instructions
Change operation order for floating-point expression	FLOAT_ORDER	Other [Miscellaneous options :] [Change operation order for floating-point expression aggressively]	Change operation order for floating-point expression aggressively

ECpp: Embedded C++ Language

Other[Miscellaneous options:][Check against EC++ language specification]

- Command Line Format

ECpp

- Description

The compiler checks the syntax of the C++ source program according to the Embedded C++ language specifications. The Embedded C++ language specifications do not support such keywords as **catch**, **const_cast**, **dynamic_cast**, **explicit**, **mutable**, **namespace**, **reinterpret_cast**, **static_cast**, **template**, **throw**, **try**, **typeid**, **typename**, and **using**. Therefore, if these keywords are written in the source program, the compiler will output an error message.

- Remarks

The Embedded C++ language specifications do not support a multiple inheritance or virtual base class. If a multiple inheritance or virtual base class is written in the source program, the compiler will display error message "C5882 (E) Embedded C++ does not support multiple or virtual inheritance" at compilation.

This option and the **exception** option cannot be specified simultaneously.

DSPc: DSP-C Language

Other[Miscellaneous options :][Check against DSP-C language specification]

- Command Line Format

DSPc

- Description

The compiler checks the syntax of the DSP-C source program according to the DSP-C language specifications. For details on the DSP-C language specifications, refer to section 10.2, DSP-C Specifications.

- Remarks

This option can only be specified for **cpu=sh2dsp**, **sh3dsp**, or **sh4aldsp**.

This option cannot be specified for a C++ source program.

COMment: Comment Nesting

Other[Miscellaneous options :][Allow comment nest]

- Command Line Format
COMment={Nest | NONest}

- Description

When **comment=nest** is specified, nested comments are allowed to be written in the source program.

When **comment=nonest** is specified, and if nested comments are written, an error will occur.

The default for this option is **comment=nonest**.

- Example

```
/* This is an example of/* nested */ comment */
                        ↑
                        (1)
```

When **comment=nest** is specified, the compiler handles the above line as a nested comment; however, when **comment=nonest** is specified, the compiler assumes (1) as the end of the comment.

Macsave: MAC Register

Other[Miscellaneous options :][Callee saves/restores MACH and MACL registers if used]

- Command Line Format

Macsave = { 0 | 1 }

- Description

Specifies whether or not to guarantee the contents of the MACH and MACL registers before and after a function call.

When **macsave=0** is specified, the contents of the MACH and MACL registers before and after a function call are not guaranteed.

When **macsave=1** is specified, the contents of the MACH and MACL registers before and after a function call are guaranteed.

Functions compiled with **macsave=0** specified cannot be called from functions compiled with **macsave=1** specified. On the contrary, functions compiled with **macsave=1** specified can be called from functions compiled with **macsave=0** specified.

The default for this option is **macsave=1**.

SAve_cont_reg: Saving and Restoring SSR and SPC Registers

Other[Miscellaneous options :][Saves/restores SSR and SPC registers]

- Command Line Format

SAve_cont_reg = { 0 | 1 }

- Description

Specifies whether or not to save and restore the contents of the SSR and SPC registers.

When **save_cont_reg=0** is specified, the contents of the SSR and SPC registers are not saved or restored.

When **save_cont_reg=1** is specified, the contents of the SSR and SPC registers are saved and restored.

This option is only valid when **cpu=sh3**, **sh3dsp**, **sh4**, **sh4a**, or **sh4ldsp** is specified and **#pragma interrupt** is specified.

The default for this option is **save_cont_reg=1**.

RTnext, NORTnext: Return Value Extension

Other[Miscellaneous options :][Expand return value to 4 byte]

- Command Line Format

RTnext

NORTnext

- Description

Specifies whether to perform sign or zero extension of a return value in register R0 when a type of a return value is char, signed char, unsigned char, short, signed short, or unsigned short in a function where function prototype has been declared.

When the **rtnext** option is specified, sign or zero extension of the function return value is performed.

When the **nortnext** option is specified, sign or zero extension of the function return value is not performed.

The default for this option is **nortnext**.

Approxdiv: Converting Floating-point Constant Division to Multiplication

Other[Miscellaneous options :][Approximate a floating-point constant division]

- Command Line Format
A**P**proxdiv
- Description
Converts divisions of floating-point constants into multiplications of the corresponding reciprocals as constants.
- Remarks
When this option is specified, the speed of execution of floating-point constant division will be improved. The precision of operation may, however, be changed, so take care on this point.

PA**t**ch: Avoiding SH7055 Illegal Operation

Other[Miscellaneous options :][Avoid illegal SH7055 instructions]

- Command Line Format
P**A**tch = 7055
- Description
Avoids the output of a program that includes operations that are illegal for the SH7055 due to the order of instructions.
- Remarks
This option is only valid when **cpu=sh2e** has been specified.

FP**S**cr: FPSCR Register Precision Mode Switching

Other[Miscellaneous options :][Change FPSCR register if double data used]

- Command Line Format
FP**S**cr = { Safe | Aggressive }
- Description
Specifies whether or not to guarantee the precision mode for the FPSCR register before and after a function call.
In the SH2A-FPU, SH-4, or SH-4A, single or double precision mode is specified for the FPSCR register when executing float or double operation.
When **fpscr=safe** is specified, the compiler always switches the precision-mode setting of the FPSCR register to single precision after return from function calls.
When **fpscr=aggressive** is specified, the contents of the FPSCR register in terms of precision mode after return from function calls are not guaranteed.

This option is valid when **cpu=sh2afpu|sh4|sh4a** is specified and neither **fpu=single** nor **fpu=double** is specified.

The default for this option is **fpscr=aggressive**.

Volatile_loop: Disabling Loop Iteration Condition Optimization

Other[Miscellaneous options :][Treats loop condition as volatile qualified]

- Command Line Format

Volatile_loop

- Description

Disables optimization of the loop iteration condition if the loop iteration condition includes an external variable.

Note however that if type conversion is performed, if two or more external variables are included, or if composite operation is performed, optimization may be performed.

- Remarks

Without this option, if the loop iteration condition is invariant in the loop, the loop iteration condition may be eliminated.

AUto_enum: Enumeration Data Size

Other[Miscellaneous options :][enum size is made the smallest]

- Command Line Format
AUto_enum
- Description
Processes the enum data as the minimum data type with which the enum value can fit in. The default for this option is to process the enum value as the int type. Table 2.13 shows the relationship between the possible enum values and data types.

Table 2.13 Relationship between enum Values and Data Types

Enumerator		
Minimum Value	Maximum Value	Data Type
-128	127	signed char
0	255	unsigned char
-32768	32767	signed short
0	65535	unsigned short
Other than above	Other than above	int

ENAbLe_register: Preferential Allocation of register Storage Class Variables

Other[Miscellaneous options :][Enable register declaration]

- Format
ENAbLe_register
- Description
Allocates preferentially the variables with register storage class specification to registers.
- Remarks
If a variable cannot be allocated to a register, message C0102 (I) Register is not allocated to "variable name" in "function name" will be output. Note, however, that this message will not be output if a parameter is not allocated to a register.

STRict_ansi: ANSI Conformance

Other[Miscellaneous options :][Obey ansi specifications more strictly]

- Format
STRict_ansi
- Description
Conforms to the ANSI standard for the following processing:
— unsigned int and long type operations
Example:

```
long s1;  
unsigned int ui;  
s1 /= ui;    /* When strict_ansi has been specified, unsigned int is applied for  
              operation. Otherwise, long is applied. */
```


— Associativity of floating-point operations
- Remarks
When this option is specified, the operation results may be different from those of former-version compilers.

FDIv: Conversion to Floating-Point Division

Other[Miscellaneous options :][Change integer division into floating-point]

- Format
FDIv
- Description
Converts integer division to floating-point division, which improves the speed of division operation.
- Remarks
This option is only valid when **cpu=sh2e**, **sh2afpu**, **sh4**, or **sh4a** is specified.
This option is invalid when the **ifunc** option is specified and is invalid for the function specified with **#pragma ifunc**.
When **cpu=sh2afpu**, **sh4**, or **sh4a** and **fpu=double** are specified, this conversion is applied to division when divisor and dividend are both four bytes or less. In other cases, this conversion is applied to division when divisor and dividend are both two bytes or less.

FIXED_Const: Floating-Point Values to Fixed-Point Values Conversion

Other[Miscellaneous options :][Floating-point constant is handled as a fixed-point constant]

- Command Line Format
FIXED_Const
- Description
Generates an object with converting floating-point values to fixed-point values.
- Remarks
This option is only valid when **cpu=sh2dsp**, **cpu=sh3dsp** or **cpu=sh4aldsp** and **dspe** are specified.
When the expression format of the floating-point constant is explicitly used, an object is generated as the floating-point constant even if this option is specified.

FIXED_Max: Conversion of 1.0 to __fixed Type Maximum Value

Other[Miscellaneous options :][treats 1.0 as maximum number of fixed type]

- Command Line Format
FIXED_Max
- Description
Generates an object with converting 1.0r to the maximum value of the __fixed type, and converting 1.0R to the maximum value of the long __fixed type.
For details on the maximum value, refer to the description on fixed.h in section 10.4.1 (8), Standard C Libraries.
- Remarks
This option is only valid when **cpu=sh2dsp**, **cpu=sh3dsp** or **cpu=sh4aldsp**, and **dspe** are specified.

FIXED_Noround: Omitting Type Conversion for __fixed Multiplication Result

Other[Miscellaneous options :][delete type conversion after fixed multiple]

- Command Line Format
FIXED_Noround
- Description
Omits converting the long __fixed type result obtained from __fixed type multiplication to the __fixed type.
- Remarks
When this option is specified, the precision of operation may be changed.
This option is only valid when **cpu=sh2dsp**, **cpu=sh3dsp** or **cpu=sh4aldsp**, and **dspe** are specified.
When the expression format of the floating-point constant is explicitly used, an object is generated as the floating-point constant even if this option is specified.

REPeat: DSP-expansion Repeat Loop

Other[Miscellaneous options :][DSP repeat loop is used]

- Command Line Format
REPeat
- Description
When the **repeat** option is specified, the loop may be expanded as the code that uses the DSP-expansion repeat loop.
- Remarks
The expansion-repeat loop is only available for the CPU that supports the LDRC instruction.
This option is only valid when **cpu=sh3dsp** or **cpu=sh4aldsp** has been specified

SIMple_float_conv: Omitting Range Check for Conversion between Floating-Point Number and Integer

Other[Miscellaneous options :][Not check the range in conversion between floating point number and integer]

- Command Line Format
SIMple_float_conv

- Description

The compiler generates a code that does not include a check of the target value range for the type conversion between unsigned integers and floating-point numbers.

- Examples

(1) unsigned long func(float f)

```
{
return ((unsigned int)f);
}
```

[Without **simple_float_conv** setting]

```
MOV          #79,R2    ; 0x0000004F
SHLL8       R2
SHLL16      R2        ; 0x4F000000
LDS         R2,FPUL
FSTS        FPUL,FR8
FCMP/GT     FR4,FR8
BT          L12
FADD        FR8,FR8   ; When f ≥ 0x4F000000,
FSUB        FR8,FR4   ; (f - 0x4F800000) is used as the value before conversion.
L12:
FTRC        FR4,FPUL  ; Conversion from float to signed long
STS         FPUL,R0
```

[With **simple_float_conv** setting]

```
FTRC        FR4,FPUL  ; Conversion from float to signed long
STS         FPUL,R0
```


(2) float func2(unsigned long u)

```
{
return ((float)u);
}
```

[Without **simple_float_conv** setting]

```
LDS          R4, FPUL
CMP/PZ      R4
BT/S        L12
FLOAT       FPUL, FR0 ; Conversion from signed long to float
MOVA        L13+2, R
FMOV.S      @R0, FR9 ; When u ≥ 0x80000000u,
FADD        FR9, FR0 ; 0x4F800000 is added to the value after conversion.
L12:
RTS
NOP
L13:
RES.W       1
DATA.L      H'4F800000
```

[With **simple_float_conv** setting]

```
LDS          R4, FPUL
RTS
FLOAT       FPUL, FR0 ; Conversion from signed long to float
```

- Remarks

This option is valid when **cpu** is sh2e, sh2afpu, sh4, or sh4a.

Correct operation is not guaranteed when the value before type conversion is not an integer from 0 to 2147483647 or a floating-point number from 0.0 to 2147483647.0. When using a value outside of these ranges, do not specify this option.

NOUSE_DIV_INST: Inhibiting generation of the DIVU and DIVS instructions

Other[Miscellaneous options :][Suppress DIVS and DIVU instruction generation]

- Command Line Format
-NOUSE_DIV_INST
- Description
Expands all integer-type division operations and remainder operations into code which does not use the DIVU and DIVS instructions.
This option is only valid when the `cpu=sh2a | sh2afpu` specification has been made.

FLOAT_ORDER: Change operation order for floating-point expression aggressively

Other[Miscellaneous options :][Change operation order for floating-point expression aggressively]

- Command Line Format
-FLOAT_ORDER
- Description
The compiler aggressively optimizes floating-point expressions by changing the order of operations.
Although the object code generally has better performance than when `float_order` is not specified, the precision of operations may differ from that for code produced by earlier versions of the compiler.
- Examples


```
/* -float_order is specified, performed as * (b + c) * 100.0f */
float a,b,c;
f()
{
    a = b * 100.0f + c * 100.0f;
}
```
- Remarks
This option is only valid when **optimize=1** is specified.

2.2.6 CPU Options

Table 2.14 CPU Tab Options

Item	Command Line Format	Dialog Menu	Specification
CPU/operating mode	CPU = { <u>SH1</u> SH2 SH2E SH2A SH2AFPU SH2DSP SH3 SH3DSP SH4 SH4A SH4ALDSP } }	CPU [CPU :]	Generates SH-1 object. Generates SH-2 object. Generates SH-2E object. Generates SH-2A object. Generates SH2A-FPU object. Generates SH2-DSP object. Generates SH-3 object. Generates SH3-DSP object. Generates SH-4 object. Generates SH-4A object. Generates SH4AL-DSP object.
Byte order [SH-3 to SH-4]	ENdian = { <u>Big</u> Little }	CPU [Endian :]	Specifies big endian. Specifies little endian.
Floating-point operation mode [SH2A-FPU, SH-4, and SH-4A]	FPu = { Single Double }	CPU [FPU :]	Processes double-precision floating-point operation in single precision. Processes single-precision floating-point operation in double precision.
Rounding mode [SH2A-FPU, SH-4, and SH-4A]	Round = { <u>Zero</u> Nearest }	CPU [Round to :]	Rounds to zero. Rounds to nearest.
Denormalized numbers [SH4 and SH-4A]	DENormalize = { <u>OFF</u> ON }	CPU [Denormalized number allowers as a result]	Processes denormalized numbers as zeros. Processes denormalized numbers as they are.
Program section position independent [other than SH-1]	Pic= { <u>0</u> 1 }	CPU [Position independent code (PIC)]	Generates no position independent codes for the program section. Generates position independent codes for the program section.

Table 2.14 CPU Tab Options (cont)

Item	Command Line Format	Dialog Menu	Specification
double to float conversion [other than SH2A-FPU, SH-4, or SH-4A]	DOuble=Float	CPU [Treat double as float]	Handles a double-type variable as a float-type variable.
Bit field order specification	Blt_order={ <u>Left</u> <u>Right</u> }	CPU [Bit field's members are allocated from the lower bit]	Stores bit-field members from the upper bit. Stores bit-field members from the lower bit.
Boundary alignment of structure, union, and class members	PACK = { 1 <u>4</u> }	CPU [Pack struct, union and class]	Assumes the boundary alignment value to be 1. Follows the boundary alignment.
Exception handling	EXception <u>NOEXception</u>	CPU [Use try, throw and catch of C++]	Enables exception handling function Disables exception handling function.
Runtime type information	RTTI= {ON <u>OFF</u> }	CPU [Enable/disable runtime information]	Enables dynamic_cast and typeid. Disables dynamic_cast and typeid.
Method of division* [SH-2]	DIVision = { <u>Cpu</u> Peripheral Nomask }	CPU [Division :]	Uses the CPU's division instruction. Uses a divider (interrupts are masked). Uses a divider (interrupts are not masked).

Note: For details of this option, see section 2.2.2, Object Options.

CPu : CPU

CPu[CPU :]

- Command Line Format

```
CPu =      { SH1
           | SH2
           | SH2E
           | SH2A
           | SH2AFPU
           | SH2DSP
           | SH3
           | SH3DSP
           | SH4
           | SH4A
           | SH4ALDSP
           }
```

- Description

Specifies the CPU type for the object program to be generated. Suboptions are listed in table 2.15.

The default for this option is **cpu=sh1**.

Table 2.15 Suboptions for cpu Option

Suboption	Description
sh1	Generates SH-1 object.
sh2	Generates SH-2 object.
sh2e	Generates SH-2E object.
sh2a	Generates SH-2A object.
sh2afpu	Generates SH2A-FPU object.
sh2dsp	Generates SH2-DSP object.
sh3	Generates SH-3 object.
sh3dsp	Generates SH3-DSP object.
sh4	Generates SH-4 object.
sh4a	Generates SH-4A object.
sh4aldsp	Generates SH4AL-DSP object.

ENdian: Memory Byte Order

CPU[Endian :]

- Command Line Format
ENdian = { **B**ig | Little }

- Description

When **endian=big** is specified, data bytes are arranged in the big endian order.

When **endian=little** is specified, data bytes are arranged in the little endian order.

Little endian object programs do not run on the SH-1, SH-2, SH-2E, SH-2A, SH2A-FPU, or SH2-DSP.

The default for this option is **endian=big**.

FPU: Floating-point Operation Mode

CPU[FPU :]

- Command Line Format
FPU = { Single | Double }

- Description

When **fpu=single** is specified, double-precision floating-point operation is carried out in single precision.

When **fpu=double** is specified, single-precision floating-point operation is carried out in double precision.

Specify **fpu=single** if floating point calculations are not used in the program.

This option is valid only when **cpu=sh2afpu|sh4|sh4a** is specified.

- Note

When the **fpu** option is not specified or when **fpu=single** is specified, the precision mode might need to be set to perform single-precision floating-point operation in an interrupt function. For details, see section 9.4.1 (6) Interrupt Functions When the CPU Type Is SH2A-FPU, SH4, or SH4A.

Round: Rounding Mode

CPU[Round to :]

- Command Line Format
Round = { Zero | Nearest }
- Description
Specifies the rounding method when floating-point constants are converted to object codes.
When **round=zero** is specified, values are rounded to zero.
When **round=nearest** is specified, values are rounded to nearest.
This option is valid only when **cpu=sh2afpu|sh4|sh4a** is specified.
The default for this option is **round=zero**.

DENormalize: Denormalized Numbers

CPU[Denormalized number allow as a result]

- Command Line Format
DENormalize = { OFF | ON }
- Description
Specifies the operation when denormalized numbers are used to describe floating-point constants.
When **denormalize=off** is specified, denormalized numbers are treated as zeros.
When **denormalize=on** is specified, denormalized numbers as treated as they are.
This option is valid only when **cpu=sh4|sh4a** is specified.
The default for this option is **denormalize=off**.

Pic: Position Independent Code

CPU[Position independent code (PIC)]

- Command Line Format

Pic = { 0 | 1 }

- Description

When **pic=1** is specified, a program section after linkage can be allocated to any address and executed. A data section can only be allocated to an address specified at linkage. When using this option as a position independent code, a function address cannot be specified as an initial value. At C++ compilation, a pointer to a virtual function or function member requires a function address as the initial value. Therefore, C++ programs containing virtual functions and pointers to member functions cannot be executed as position independent codes.

Example 1:

extern int f ();

int (*fp) () = f; <-- Cannot be specified

Example 2:

struct A {virtual void f();}; <-- Cannot be specified

void (A::*ap) () = &A::f; <-- Cannot be specified

When **cpu=sh1** is specified, **pic=1** is ignored.

The default for this option is **pic=0**.

DOuble=Float: double to float Conversion

CPU[Treat double as float]

- Command Line Format
DOuble=Float
- Description
Generates an object with converting double-type (double-precision floating-point) values to float-type (single-precision floating-point) values.
- Remarks
This option is invalid when **cpu=sh2afpu|sh4|sh4a** is specified, and assumes that **fpu=single** is specified.

Bit_order: Bit Field Order Specification

CPU[Bit field's members are allocated from the lower bit :]

- Command Line Format
Bit_order={ Left | Right }
- Description
Specifies the order of bit field members.
When **bit_order=left** is specified, members are allocated from the upper bit.
When **bit_order=right** is specified, members are allocated from the lower bit.
The default for this option is **bit_order=left**.
- Remarks
For details on allocation of bit field members, refer to section 10.1.2, Internal Data Representation, and the description on **#pragma bit_order** in section 10.3.1, #pragma Extension Specifiers.

PACK: Boundary Alignment of Structure, Union, and Class Members

CPU[Pack struct, union and class]

- Command Line Format

PACK = { 1 | 4 }

- Description

Specifies the boundary alignment value for structure, union, and class members.

The boundary alignment of structure members can also be specified by the **#pragma pack** extension. If both this option and a **#pragma** extension are specified, the **#pragma** specification is valid.

The boundary alignment value for structures, unions, and classes equals the maximum boundary alignment of members.

For details, refer to section 10.1.2 (2), Compound Type (C), Class Type (C++).

- Remarks

When the **iodefine.h** file created by the Renesas High-Performance Embedded Workshop is in use, if **#pragma** or an option is used to set the alignment value to 1, the members of I/O register structures will not specify the correct addresses. To avoid this problem, place **#pragma pack4** at the start of **iodefine.h** and place **#pragma unpack** at the end of **iodefine.h**. Table 2.16 shows the boundary alignment values for structure, union, and class members when **pack** is specified.

Table 2.16 Boundary Alignment for Structure, Union, and Class Members when the pack Option is Specified

Member Type	pack=1	pack=4	Not Specified
(unsigned) char	1	1	1
(unsigned) short, and long __fixed	1	2	2
(unsigned) int, (unsigned) long, (unsigned) long long, long __fixed, __accum, long __accum, floating-point type, and pointer type	1	4	4
Structures, unions, and classes aligned to a 1-byte boundary	1	1	1
Structures, unions, and classes aligned to a 2-byte boundary	1	2	2
Structures, unions, and classes aligned to a 4-byte boundary	1	4	4

EXception, NOEXception: Exception Handling

CPU[Use try, throw and catch of C++]

- Command Line Format

EXception

NOEXception

- Description

When the **exception** option is specified, the C++ exceptional handling function (try, catch, throw) becomes valid.

When the **noexception** option is specified, the C++ exceptional handling function (try, catch, throw) becomes invalid.

When the **exception** option is specified, the code performance may be reduced.

The default for this option is **noexception**.

- Remarks

In order to use the C++ exceptional handling function among files, specify **rtti=on** at compilation, and do not specify the **noprelink** option at linkage.

The **exception** option and **ecpp** option cannot be specified simultaneously.

Object files created by using the **exception** option must not be registered with libraries or output as relocatable files by the optimizing linkage editor. Doing so will lead to a duplicate-definition or no-definition error.

RTTI: Runtime-Type Information

CPU[Enable/disable runtime information]

- Command Line Format

RTTI = { ON
| OFF }

- Description

Enables or disables runtime type information.

When **rtti=on** is specified, `dynamic_cast` and `typeid` are enabled.

When **rtti=off** is specified, `dynamic_cast` and `typeid` are disabled.

The default for this option is **rtti=off**.

- Remarks

Do not define object files which are created by specifying this option in a library, and do not output files with this information as relocatable object files through the optimizing linkage editor. A symbol double definition error or symbol undefined error may occur.

2.2.7 Options Other Than Above

Table 2.17 Options Other Than Above

Item	Command Line Format	Dialog Menu	Specification
Selecting C or C++ language	LAng = { C Cpp }	— (Determined by an extension)	Compiled as C source program. Compiled as C++ source program.
Disable of copyright output	LOGO NOLOGO	— (nologo is always valid)	Outputs copyright. Disables output of copyright.
Character code select in string literals	Euc SJis LATin1	—	Selects euc code. Selects sjis code. Selects latin1 code.
Japanese character code specified within object	OUtcode = { EUc SJis }	—	Selects euc code. Selects sjis code.
Subcommand file specified	SUBcommand = <file name>	—	Command option is fetched from the file specified with <file name>.

LANG: Selecting C or C++ Language

None (Always determined by an extension)

- Command Line Format

LANG = { C | Cpp }

- Description

Specifies the language of the source program.

When **lang=c** is specified, the compiler will compile the program file as a C source program.

When **lang=cpp** is specified, the compiler will compile the program file as a C++ source program.

If this option is not specified, the compiler will determine whether the source program is a C or a C++ program by the extension of the file name. If the extension is `c`, the compiler will compile it as a C source program. If the extension is `cpp`, `cc`, or `cp`, the compiler will compile it as a C++ source program. If there is no extension, the compiler will compile the program as a C source program.

- Example
 - shc test.c Compiled as a C source program.
 - shc test.cpp Compiled as a C++ source program.
 - shc -lang=cpp test.c Compiled as a C++ source program.
 - shc test Assumed to be test.c and thus be compiled as a C source program.
- Remarks
 - If **lang=c** is specified, **ecpp** is invalid.

LOGO, NOLOGO: Copyright Output Control

None (**nologo** is always available)

- Command Line Format
 - LOGO
 - NOLOGO
- Description
 - Disables the copyright output.
 - When the **logo** option is specified, copyright display is output.
 - When the **nologo** option is specified, the copyright display output is disabled.
 - The default for this option is **logo**.

Euc, SJis, LATIn1: Character Code Select in String Literals

None

- Command Line Format
 - Euc
 - SJis
 - LATIn1
- Description
 - Use this option to specify the Japanese character code or ISO-Latin1 code written in a string literal, a character constant, or a comment.
 - Table 2.18 shows character code in the string literals for three types of host computers.

Table 2.18 Relationship between the Host Computer and Character Code in String Literals

Host Computer	Option Specification			
	euc	sjis	latin1	Not Specified
PC	euc	sjis	latin1	sjis
SPARC	euc	sjis	latin1	euc
HP9000/700	euc	sjis	latin1	sjis

- Remarks

When the **latin1** option is specified, the **outcode** option will become invalid.

Outcode: Japanese Code Conversion in Object Code

None

- Command Line Format
OOutcode = { EUc | SJis }
- Description

Specifies the Japanese character code to be output to the object program when Japanese is written in string literals and character constants.

When **outcode=euc** is specified, the compiler outputs the Japanese character code in the **euc** code.

When **outcode=sjis** is specified, the compiler outputs the Japanese character code in the **sjis** code.

Option **euc** or **sjis** can be specified for the Japanese character code in a source program.

Subcommand: Subcommand File

None

- Format

SUBcommand = <file name>

- Description

Specifies the subcommand file where options used at compiler initiation are stored. The command format in the subcommand file is the same as that on the command line.

- Example

opt.sub: -listfile -show=object -debug

Command line specification: shc -cpu=sh4 -subcommand=opt.sub test.c

Interpretation at compilation: shc -cpu=sh4 -listfile -show=object -debug
test.c

Section 3 Assembler Options

3.1 Command Line Format

The format of the command line to initiate the assembler is as follows:

```
asmsh [Δ<option> ...] [Δ<file name> [,...]] [Δ<option> ...]  
      <option>:-<option> [=<suboption> [,...]]
```

Note: When the user specifies multiple source files, the assembler will merge and assemble these files as one unit in the order they were specified. In this case, the user must write `.END` only in the file that was specified last.

3.2 List of Options

In the command line format, uppercase letters indicate the abbreviations. Characters underlined indicate the default assumptions.

The format of the dialog menus for the integrated development environment is as follows:

Category [Item]

Options are described in the order of tabs in the integrated development environment's option dialog box.

3.2.1 Source Options

Table 3.1 Source Category Options

Item	Command Line Format	Dialog Menu	Specification
Include file directory	Include = <path name>[,...]	Source [Show entries for:] [Include file directories]	Specifies include-file destination path name.
Replacement symbol definition	DEFine = <sub>[, ...] <sub>: <replacement symbol> = "<string literal>"	Source [Show entries for:] [Defines]	Defines replacement string literal.
Integer preprocessor variable definition	ASsignA = <sub>[, ...] <sub>: <variable name> = <integer constant>	Source [Show entries for:] [Preprocessor variables]	Defines integer preprocessor variable.
Character preprocessor variable definition	ASsignC = <sub>[, ...] <sub>: <variable name> = "<string literal>"	Source [Show entries for:] [Preprocessor variables]	Defines character preprocessor variable.

Include

Source [Show entries for:] [Include file directories]

- Command Line Format
Include = <path name> [...]

- Description

The **include** option specifies the include file directory. The directory name depends on the naming rule of the host machine used. As many directory names as can be input in one command line can be specified. The current directory is searched first, and then the directories specified by the **include** option are searched in the specified order.

Example: `asmsh aaa.src -include=C:\common,C:\local`
(.INCLUDE "file.h" is specified in aaa.src.)

The current directory, C:\common,C:\local are searched for file.h in that order.

Relationship with Assembler Directives

Option	Assembler Directive	Result
include	(regardless of any specification)	(1) Directory specified by .INCLUDE (2) Directory specified by include*
(no specification)	.INCLUDE <file name>	Directory specified by .INCLUDE

Note: The directory specified by the **include** option is added before that specified by **.INCLUDE**.

DEFine

Source [Show entries for:] [Defines]

- Command Line Format
DEFine = <sub>[...]
<sub>:<replacement symbol>=<string literal>

- Description

The **define** option defines the specified symbol as the corresponding string literal to be replaced by the preprocessor.

Differences between **define** and **assignc** are the same as those between **.DEFINE** and **.ASSIGNC**.

Relationship with Assembler Directives

Option	Assembler Directive	Result
define	.DEFINE *	String literal specified by define
	(no specification)	String literal specified by define
(no specification)	.DEFINE	String literal specified by .DEFINE

Note: When a string literal is assigned to a replacement symbol by the **define** option, the definition of the replacement symbol by **.DEFINE** is invalidated. This replacement is not applied to the **.AENDI**, **.AENDR**, **.AENDW**, **.AIFDEF**, **.END**, and **.ENDM** directives.

ASsignA

Source[Show entries for:][Preprocessor variables]

- Command Line Format
ASsignA = <sub>[,...]
<sub>:<preprocessor variable>=<integer constant>

- Description

The **assigna** option sets an integer constant to a preprocessor variable. The naming rule of preprocessor variables is the same as that of symbols. An integer constant is specified by combining the radix (B', Q', D', or H') and a value. If the radix is omitted, the value is assumed to be decimal. An integer constant must be within the range from -2,147,483,648 to 4,294,967,295. To specify a negative value, use a radix other than decimal.

Relationship with Assembler Directives

Option	Assembler Directive	Result
assigna	.ASSIGNA*	Integer constant specified by assigna
	(no specification)	Integer constant specified by assigna
(no specification)	.ASSIGNA	Integer constant specified by .ASSIGNA

Note: When a value is assigned to a preprocessor variable by the **assigna** option, the definition of the preprocessor variable by **.ASSIGNA** is invalidated.

Example: `asmsh aaa.src -assigna=_$=H'FF`

Value H'FF is assigned to preprocessor variable `_$`. All references (`\&_$`) to preprocessor variable `_$` in the source program are set to H'FF.

ASsignC

Source [Show entries for:][Preprocessor variables]

- Command Line Format

ASsignC = <sub>[,...]
<sub>:<preprocessor variable>=<string literal>"

- Description

The **assignc** option sets a string literal to a preprocessor variable.

The naming rule of preprocessor variables is the same as that of symbols.

A string literal must be enclosed with double-quotation marks (").

Up to 255 characters (bytes) can be specified for a string literal.

Relationship with Assembler Directives

Option	Assembler Directive	Result
assignc	.ASSIGNC*	String literal specified by assignc
	(no specification)	String literal specified by assignc
(no specification)	.ASSIGNC	String literal specified by .ASSIGNC

Note: When a string literal is assigned to a preprocessor variable by the **assignc** option, the definition of the preprocessor variable by **.ASSIGNC** is invalidated.

Example: `asmsh aaa.src -assignc=_$="ON!OFF"`

String literal ON!OFF is assigned to preprocessor variable `_$`. All references (`\&_$`) to preprocessor variable `_$` in the source program are set to ON!OFF.

3.2.2 Object Options

Table 3.2 Object Category Options

Item	Command Line Format	Dialog Menu	Specification
Debugging information	Debug NODebug	Object [Debug information:]	Controls output of debugging information.
Pre-processor expansion result	EXPand [= <output file name>]	Object [Generate assembly source file after preprocess]	Outputs preprocessor expansion result.
Literal pool output point	LITERAL = <point> [, ...] <point>: {Pool Branch Jump Return}	Object [Generate literal pool after:]	Specifies the point to output literal pool.
Object module output	Object [= <output file name>] NOObject	Object [Output file directory:]	Controls object module output.
Unresolved symbol size [SH-2A and SH2A-FPU]	Dlssize = {4 12}	Object [Selects displacement size]	Specifies the size of unresolved symbols.

Debug, NODebug

Object [Debug information:]

- Command Line Format

Debug

NODebug

- Description

When the **debug** option is specified, debugging information is output. When the **nodebug** option is specified, no debugging information is output. The **debug** and **nodebug** options are only valid in cases where an object module is generated. The default is **nodebug**.

- Remarks

Debugging information is required when debugging a program with the debugger. Debugging information includes information about source statement lines and symbols.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result
debug	(regardless of any specification)	Debugging information is output.
nodebug	(regardless of any specification)	Debugging information is not output.
(no specification)	.OUTPUT DBG	Debugging information is output.
	.OUTPUT NODBG	Debugging information is not output.
	(no specification)	Debugging information is not output.

EXPand

Object [Generate assembly source file after preprocess]

- Command Line Format

EXPand [= <output file name>]

- Description

The **expand** option outputs an assembler source file for which macro expansion, conditional assembly, and file inclusion have been performed.

When this option is specified, no object will be generated.

When the output file parameter is omitted, the assembler takes the following actions:

— If the file extension is omitted:

The file extension will be **exp**.

— If the specification is completely omitted:

The source file name will be the same name as that of the input source file (the source file specified first) and the file extension will be **exp**.

Note: Do not specify the same file name for the input and output files.

LITERAL

Object [Generate assembly source file after preprocess]

- Command Line Format

LITERAL = <point>[,...]

<point>: {Pool|Branch|Jump|Return}

- Description

The **literal** option specifies the point where the literal pool that was created by the automatic literal pool creation function is placed.

— pool: The literal pool is output at the location of **.POOL**.

— branch: The literal pool is output after the **BRA/BRAF** instruction.

— jump: The literal pool is output after the **JMP** instruction.

— return: The literal pool is output after the **RTS/RTE** instruction.

The default is **literal = pool, branch, jump, return**.

Object, NOObject

Object [Output file directory:]

- Command Line Format

Object [= <object output file>]

NOObject

- Description

When the **object** option is specified, an object module is output.

When the **noobject** option is specified, no object module is output.

When the object output file parameter is omitted, the assembler takes the following actions:

— If the file extension is omitted:

The file extension will be obj.

— If the specification is completely omitted:

The source file name will be the same name as that of the input source file (the source file specified first) and the file extension will be obj.

The default is **object**.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result
object	(regardless of any specification)	An object module is output.
noobject	(regardless of any specification)	An object module is not output.
(no specification)	.OUTPUT OBJ	An object module is output.
	.OUTPUT NOOBJ	An object module is not output.
	(no specification)	An object module is output.

Note: Do not specify the same file name for the input source file and the output object module. If the same file is specified, the contents of the input source file will be lost.

DIspsize

Object [Selects displacement size]

- Command Line Format

DIspsize = {4 | 12}

- Description

Specifies the size of external reference symbols and unresolved symbols.

This specification is applied to instructions that accept both 4 and 12 as the displacement size for the addressing mode; it is not applied to instructions that only accept displacement size 4.

This option is only valid when the CPU type is SH-2A or SH2A-FPU.

The default is **dispsize=12**.

- Remarks

The allocation size specification (:12) overrides this option specification.

3.2.3 List Options

Table 3.3 List Category Options

Item	Command Line Format	Dialog Menu	Specification
Assemble listing output control	LISt [= <output file name>] <u>NOLIS</u> t	List [Generate list file]	Controls output of assemble listing
Source program listing output control*	<u>S</u> ource NOSource	List [Source program:]	Controls output of source program listing.
Part of source listing output control and tab size setting*	<u>S</u> How [= <item>[, ...]] NOSHHow [= <item>[, ...]] <item>: {CONditionals Definitions CALLs ExpansionS CODe TAB={ 4 8 } }	List [Source program list Contents:] [Conditions:] [Definitions:] [Calls:] [Expansions:] [Code:] [Tab Size:]	Controls output of parts of source program listing and sets the size of tabs.
Cross-reference listing output control*	<u>C</u> Ross reference NOCross_reference	List [Cross reference:]	Controls output of cross-reference listing.
Section information listing output control*	<u>S</u> Ection NOSEction	List [Section:]	Controls output of section information listing.

Note: These options are valid only if the **list** option is specified.

LISt, NOLISt

List [Generate list file]

- Command Line Format
LISt [= <listing output file>]
NOLISt

- Description

When the **list** option is specified, an assemble listing is output.

When the **nolist** option is specified, no assemble listing is output.

When the listing output file parameter is omitted, the assembler takes the following actions:

— If the file extension is omitted:

The file extension will be `lis`.

— If the specification is completely omitted:

The source file name will be the same name as that of the input source file (the source file specified first) and the file extension will be `lis`.

The default is **nolist**.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result
<code>list</code>	(regardless of any specification)	An assemble listing is output.
<code>nolist</code>	(regardless of any specification)	An assemble listing is not output.
(no specification)	<code>.PRINT LIST</code>	An assemble listing is output.
	<code>.PRINT NOLIST</code>	An assemble listing is not output.
	(no specification)	An assemble listing is not output.

Note: Do not specify the same file for the input source file and the output object file. If the same file is specified, the contents of the input source file will be lost.

Source, NOSource

List [Source program:]

- Command Line Format

Source

NOSource

- Description

When the **source** option is specified, a source program listing is output to the assemble listing.

When the **nosource** option is specified, no source program listing is output to the assemble listing.

The **source** and **nosource** options are only valid in cases where an assemble listing is being output.

The default is **source**.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result (When an Assemble Listing Is Output)
source	(regardless of any specification)	A source program listing is output.
nosource	(regardless of any specification)	A source program listing is not output.
(no specification)	.PRINT SRC	A source program listing is output.
	.PRINT NOSRC	A source program listing is not output.
	(no specification)	A source program listing is output.

SHow, NOSHow

List [Source program list Contents:] [Conditions:], [Definitions:], [Calls:], [Expansions:], [Code:], [Tab size:]

- Command Line Format

SHow [= <output type>[,...]]

NOSHow [=<output type>[,...]]

<output type>: {CONditionals | Definitions | CALLS | Expansions | CODE | TAB = { 4 | 8 } }

- Description

When the **show** option is specified, preprocessor source statements in the source program listing and lines of object code are output in the specified tab size. When <output type> is specified, only those items of the specified type are output. If no specification is made for the tab size, the default value will be applied.

When the **noshow** option is specified, neither preprocessor source statements in the source program listing nor lines of object code are output. When <output type> is specified, only the specified items are not output.

The **show** and **noshow** options are only valid if an assembler listing is output. The following items are available for <output type>:

Output Type	Object	Description
conditionals	Unsatisfied condition	Unsatisfied .AIF or .AIFDEF statements
definitions	Definition	Macro definition parts, .AREPEAT and .AWHILE definition parts, .INCLUDE, .ASSIGNA, and .ASSIGNC
calls	Call	Macro call statements, .AIF, .AIFDEF, and .AENDI
expansions	Expansion	Macro expansion statements .AREPEAT and .AWHILE expansion statements
code	Object code lines	The object code lines exceeding the source statement lines
tab={4 8}	Tab size	Size of a tab to display a listing

The default is **show**.

- Remarks

When specifying more than two output types, enclose the types with parentheses.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result
show[=<output type>]	(regardless of any specification)	The object code is output.
noshow[=<output type>]	(regardless of any specification)	The object code is not output.
(no specification)	.LIST <output type> (output)	The object code is output.
	.LIST <output type> (suppress)	The object code is not output.
	(no specification)	The object code is output.

CRoss_reference, NOCRoss_reference

List [Cross reference:]

- Command Line Format

CRoss_reference

NOCross_reference

- Description

When the **cross_reference** option is specified, a cross-reference listing is output to the assemble listing.

When the **nocross_reference** option is specified, no cross-reference listing is output to the assemble listing.

The **cross_reference** and **nocross_reference** options are valid only if an assemble listing is being output.

The default is **cross_reference**.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result (When an Assemble Listing Is Output)
cross_reference	(regardless of any specification)	A cross-reference listing is output.
nocross_reference	(regardless of any specification)	A cross-reference listing is not output.
(no specification)	.PRINT CREF	A cross-reference listing is output.
	.PRINT NOCREF	A cross-reference listing is not output.
	(no specification)	A cross-reference listing is output.

S`Section`, NO`Section`

List [Section:]

- Command Line Format

S`Section`

NO`Section`

- Description

When the **section** option is specified, a section information listing is output to the assemble listing.

When the **nosection** option is specified, no section information listing is output to the assemble listing.

The **section** and **nosection** options are valid only if an assemble listing is being output.

The default is **section**.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result (When an Assemble Listing Is Output)
section	(regardless of any specification)	A section information listing is output.
nosection	(regardless of any specification)	A section information listing is not output.
(no specification)	.PRINT SCT	A section information listing is output.
	.PRINT NOSCT	A section information listing is not output.
	(no specification)	A section information listing is output.

3.2.4 Other Option

Table 3.4 Other Category Option

Item	Command Line Format	Dialog Menu	Specification
Size mode specification for automatic literal pool generation	AUTO_literal	Other [Miscellaneous options:] [Automatically generate literal pool for immediate value]	Specifies size mode for automatic literal pool generation.
Preventing output of information on unreferenced external symbols	<u>Exclude</u> NOExclude	Other [Miscellaneous options:] [Remove unreferenced external symbols]	Selects whether or not to prevent output of information on unreferenced symbol information.
Specification to check privileged-mode instructions	CHKMd	Other [Miscellaneous options:] [check privileged instructions]	Specifies to check privileged-mode instructions.
Specification to check LDTLB instructions	CHKTlb	Other [Miscellaneous options:] [check LDTLB instruction]	Specifies to check LDTLB instructions.
Specification to check cache-related instructions.	CHKCache	Other [Miscellaneous options:] [check cache instructions]	Specifies to check cache-related instructions.
Specification to check DSP-related instructions.	CHKDsp	Other [Miscellaneous options:] [check DSP instructions]	Specifies to check DSP-related instructions.
Specification to check FPU-related instructions.	CHKFpu	Other [Miscellaneous options:] [check FPU instructions]	Specifies to check FPU-related instructions.
Specification to check 8-byte boundary alignment of .FDATA.	CHKAlign8	Other [Miscellaneous options:] [check 8-byte alignment]	Specifies to check 8-byte boundary alignment of .FDATA.

AUTO_literal

Other [Miscellaneous options:] [Automatically generate literal pool for immediate value]

- Command Line Format

AUTO_literal

- Description

The **auto_literal** option specifies the size mode for automatic literal pool generation.

When this option is specified, automatic literal pool generation is performed in size selection mode, and the assembler checks the **imm** value in the data transfer instruction without operation size specification (MOV #imm,Rn) and automatically generates a literal pool if necessary.

When this option is not specified, automatic literal pool generation is performed in size specification mode, and the data transfer instruction without size specification is handled as a 1-byte data transfer instruction.

In the size selection mode, the **imm** value in the data transfer instruction without operation size specification is handled as a signed value. Therefore, a value within the range from H'00000080 to H'000000FF (128 to 255) is regarded as word-size data.

imm Value Range	Selected Size or Error	
	Size Selection Mode	Size Specification Mode
H'80000000 to H'FFFF7FFF (-2,147,483,648 to -32,769)	Longword	Warning 835
H'FFFF8000 to H'FFFFFF7F (-32,768 to -129)	Word	Warning 835
H'FFFFFF80 to H'0000007F (-128 to 127)	Byte	Byte
H'00000080 to H'000000FF (128 to 255)	Word	Byte
H'00000100 to H'00007FFF (256 to 32,767)	Word	Warning 835
H'00008000 to H'7FFFFFFF (32,768 to 2,147,483,647)	Longword	Warning 835

Note: The value in parentheses () is in decimal.

Exclude, NOExclude

Other [Miscellaneous options:] [Remove unreferenced external symbols]

- Command Line Format

Exclude

NOExclude

- Description

When the **exclude** option is specified, no information on unreferenced external symbols is output.

When the **noexclude** option is specified, information on unreferenced external symbols is output.

The size of an object module can be smaller if output of information on unreferenced external symbols is prevented.

Examples:

```
asmsh aaa.mar -exclude
```

No information on unreferenced external symbols is output.

```
asmsh aaa.mar -noexclude
```

Information on unreferenced external symbols is output.

CHKMd

Other [Miscellaneous options:] [check privileged instructions]

- Command Line Format

CHKMd

- Description

When this option is specified for the CPU type SH-3, SH3-DSP, SH-4, SH-4A, or SH4AL-DSP, only user-mode instructions of the CPU are valid. If a privileged-mode instruction is written, warning 704 occurs.

- Remarks

When the CPU type is SH3-DSP or SH4AL-DSP with the CHKDSP option not specified, the following privileged-mode instructions will be handled as user-mode instructions.

LDC Rm,SR

LDC.L @Rm+,SR

STC SR,Rm

STC.L SR,@-Rn

CHKTLb

Other [Miscellaneous options:] [check LDTLB instruction]

- Command Line Format
CHKTLb
- Description
When this option is specified for the CPU type SH-3, SH3-DSP, SH-4, SH-4A, or SH4AL-DSP, warning 705 occurs if an LDTLB instruction is written.

CHKCache

Other [Miscellaneous options:] [check cache instructions]

- Command Line Format
CHKCache
- Description
When this option is specified for the CPU type SH-3, SH3-DSP, SH-4, SH-4A, or SH4AL-DSP, warning 706 occurs if a cache-related instruction is written.

CHKDsp

Other [Miscellaneous options:] [check DSP instructions]

- Command Line Format
CHKDsp
- Description
When this option is specified for the CPU type SH3-DSP or SH4AL-DSP, warning 707 occurs if a DSP-related instruction is written.

CHKFpu

Other [Miscellaneous options:] [check FPU instructions]

- Command Line Format
CHKFpu
- Description
When this option is specified for the CPU type SH2A-FPU, SH-4, or SH-4A, warning 708 occurs if an FPU-related instruction is written.

CHKAlign8

Other [Miscellaneous options:] [check 8-byte alignment]

- Command Line Format

CHKAlign8

- Description

When this option is specified for the CPU type SH-4A or SH4AL-DSP, 8-byte boundary alignment of .FDATA is checked. Warning 816 occurs if double-precision floating-point constant data specified by .FDATA is not aligned to an 8-byte boundary.

3.2.5 CPU Options

Table 3.5 CPU Tab Options

Item	Command Line Format	Dialog Menu	Specification
Target CPU specification	CPU = <target CPU>	CPU [CPU:]	Specifies target CPU.
Endian type specification	ENdian = {Big Little}	CPU [Endian:]	Specifies the endian type.
Rounding direction of floating-point data	Round = {Nearest Zero}	CPU [Round to:]	Specifies the rounding mode for floating-point data.
Handling denormalized numbers in floating-point data	DENormalize = {ON OFF}	CPU [Denormalized number allow as a result:]	Specifies how to handle denormalized numbers in floating-point data.

CPU

CPU [CPU:]

- Command Line Format

CPU = <target CPU>

- Description

The **cpu** option specifies the target CPU for the source program to be assembled.

The following CPUs can be specified.

- SH1 (for SH-1)
- SH2 (for SH-2)
- SH2E (for SH-2E)
- SHDSP (for SH2-DSP)
- SH2A (for SH-2A)
- SH2AFPU (for SH2A-FPU)
- SH3 (for SH-3)
- SH3DSP (for SH3-DSP)
- SH4 (for SH-4)
- SH4A (for SH-4A)
- SH4ALDSP (for SH4AL-DSP)

Relationship with Assembler Directives

Option	Assembler Directive	SHCPU Environment Variable	Result
cpu= <target CPU>	(regardless of any specification)	(regardless of any specification)	Target CPU specified by cpu
(no specification)	.CPU <target CPU>	(regardless of any specification)	Target CPU specified by .CPU
	(no specification)	SHCPU = <target CPU>	Target CPU specified by SHCPU environment variable
		(no specification)	SH1

ENdian

CPU [Endian:]

- Command Line Format

ENdian = {Big | Little}

- Description

The **endian** option selects big endian or little endian for the target CPU.

The default is **endian=big**.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result
endian=big	(regardless of any specification)	Assembles in big endian
endian=little	(regardless of any specification)	Assembles in little endian
(no specification)	.ENDIAN BIG	Assembles in big endian
	.ENDIAN LITTLE	Assembles in little endian
	(no specification)	Assembles in big endian

Round

CPU [Round to:]

- Command Line Format
Round = {Nearest | Zero}

- Description

The **round** option specifies the rounding mode used when converting constants in floating-point data assembler directives into object codes.

When **round=nearest** is specified, **round to NEAREST even** is selected.

When **round=zero** is specified, **round to ZERO** is selected.

When this option is omitted, the rounding mode depends on the target CPU as follows:

Target CPU	Rounding Mode
SH1	round to NEAREST even
SH2	round to NEAREST even
SH2E	round to ZERO
SH2A	round to NEAREST even
SH2AFPU	round to ZERO
SHDSP	round to NEAREST even
SH3	round to NEAREST even
SH4	round to ZERO
SH3DSP	round to NEAREST even
SH4A	round to ZERO
SH4ALDSP	round to NEAREST even

Note: When the target CPU is SH2E and **round to NEAREST even** is selected as the rounding mode, warning 818 occurs at the first floating-point data assembler directive in the source program, and object code is output in the selected "round to NEAREST even" rounding mode.

DENormalize

CPU [Denormalize:]

- Command Line Format
DENormalize = {ON | OFF}

- Description

The **denormalize** option specifies whether to handle the denormalized numbers in floating-point data assembler directives as valid values.

The object code differs when denormalized numbers are specified as valid values (ON) and invalid values (OFF).

When **denormalize=on** is specified, the denormalized numbers are valid.

When **denormalize=off** is specified, the denormalized numbers are invalid.

— Valid: Warning 842 occurs and the object code is output.

— Invalid: Warning 841 occurs and zero is output for the object code.

When this option is omitted, whether the denormalized numbers are valid depends on the target CPU as follows:

Target CPU	Denormalized Numbers
SH1	Valid (ON)
SH2	Valid (ON)
SH2E	Invalid (OFF)
SH2A	Valid (ON)
SH2AFPUP	Invalid (OFF)
SHDSP	Valid (ON)
SH3	Valid (ON)
SH3DSP	Valid (ON)
SH4	Invalid (OFF)
SH4A	Invalid (OFF)
SH4ALDSP	Valid (ON)

Note: When the target CPU is SH2E or SH2AFPUP and denormalized numbers are specified as valid, warning 818 occurs at the first floating-point data assembler directive in the source program, and object code is output with the denormalized numbers handled as valid values as specified.

3.2.6 Options Other than Above

Table 3.6 Options Other than Above

Item	Command Line Format	Dialog Menu	Specification
Change of error level at which the assembler is abnormally terminated	ABort = {Warning <u>Error</u> }	-	Changes the error level at which the assembler is abnormally terminated.
Western code character enabled	LATIN1	-	Enables the use of Western code characters in source file.
Interpretation of Japanese character as Shift JIS code	SJIS	-	Interprets Japanese character in source file as shift JIS code.
Interpretation of Japanese character as EUC code	EUC	-	Interprets Japanese character in source file as EUC code.
Specification of Japanese character	OUtcode = {SJIS EUC}	-	Specifies the Japanese character for output to object code.
Setting of the number of lines in the assemble listing	LINes = <number of lines>	-	Specifies the number of lines in assemble listing.
Setting of the number of digits in the assemble listing	COLumns = <number of digits>	-	Specifies the number of digits in assemble listing.
Copyright	<u>LOGO</u> NOLOGO	- (nologo is always valid)	Output Not output
Specification of subcommand	SUBcommand = <file name>	-	Inputs command line from a file.

ABort

None

- Command Line Format
ABort = {Warning|Error}

- Description

The **abort** option controls the error level at which the assembler will be abnormally terminated.

When **abort=warning** is specified, processing is aborted by a warning.

When **abort=error** is specified, processing is aborted by an error.

When the return value to the OS becomes 1 or larger, the object module is not output.

The **abort** option is valid only if the object module is output.

The return value to the OS is as follows:

Number of Cases			Return Value to OS when Option Specified	
Warning	Error	Fatal Error	abort=warning	abort=error
0	0	0	0	0
1 or more	0	0	2	0
—	1 or more	0	2	2
—	—	1 or more	4	4

The default is **abort=error**.

LATIN1

None

- Command Line Format
LATIN1

- Description

The **latin1** option enables the use of Western code characters in string literals and in comments.

Do not specify this option together with the **sjis**, **euc**, or **outcode** option.

SJIS

None

- Command Line Format

SJIS

- Description

The **sjis** option interprets Japanese characters in string literals and comments as shift **JIS** code.

When both of **sjis** and **euc** options are omitted, Japanese characters in string literals and comments are interpreted as Japanese characters depending on the host computer.

Do not specify this option together with the **latin1** or **euc** option.

EUC

None

- Command Line Format

EUC

- Description

The **euc** option interprets Japanese characters in string literals and comments as EUC code.

When both of **euc** and **sjis** options are omitted, Japanese characters in string literals and comments are interpreted as Japanese characters depending on the host computer.

Do not specify this option together with the **latin1** or **sjis** option.

OUtcode

None

- Command Line Format
OUtcode = {SJIS | EUC}

- Description

When **outcode=sjis** is specified, this option converts Japanese characters in the source file to the shift JIS code for output to the object file.

When **outcode=euc** is specified, this option converts Japanese characters in the source file to the EUC code for output to the object file.

The Japanese character output to the object file depends on the **outcode** specification and the Japanese character (**sjis** or **euc**) in the source file as follows:

outcode Option	Japanese Character in Source File		
	sjis	euc	No Specification
sjis	Shift JIS code	Shift JIS code	Shift JIS code
euc	EUC code	EUC code	EUC code
No specification	Shift JIS code	EUC code	Default code

Default code is as follows.

Host Computer	Default Code
SPARC station	EUC code
HP9000/700 series	Shift JIS code
PC	Shift JIS code

LINes

None

- Command Line Format

LINes = <Number of lines>

- Description

The **lines** option sets the number of lines on a single page of the assemble listing. The range of valid values for the line count is from 20 to 255.

This option is valid only if an assemble listing is being output.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result
lines=<number of lines>	(regardless of any specification)	The number of lines on a page is given by lines.
(no specification)	.FORM LIN=< number of lines>	The number of lines on a page is given by .FORM.
	(no specification)	The number of lines on a page is 60 lines.

COLUMNS

None

- Command Line Format
COLUMNS = <Number of digits>

- Description

The **columns** option sets the number of digits in a single line of the assemble listing. The range of valid values for the column count is from 79 to 255.

This option is valid only if an assemble listing is being output.

Relationship with Assembler Directives

The assembler gives priority to specifications made by options.

Option	Assembler Directive	Result
columns= <number of digits>	(regardless of any specification)	The number of digits in a line is given by columns.
(no specification)	.FORM COL=<number of digits>	The number of digits in a line is given by .FORM.
	(no specification)	The number of digits in a line is 132.

LOGO, NOLOGO

None (nologo is always available)

- Command Line Format

LOGO

NOLOGO

- Description

Controls the copyright output.

When the **logo** option is specified, copyright display is output.

When the **nologo** option is specified, the copyright display output is disabled.

The default is **logo**.

SUBcommand

None

- Command Line Format
SUBcommand = <file name>

- Description

The **subcommand** option inputs command line specifications from a file.

Specify input file names and command line options in the subcommand file in the same order as for normal command line specifications.

Only one input file name or one command line option can be specified in one line in the subcommand file.

This option must not be specified in a subcommand file.

Example:

```
asmsh aaa.src -subcommand=aaa.sub
```

The subcommand file contents are expanded to a command line and assembled.

```
----- aaa.sub contents -----  
    bbb.src  
    -list  
    -noobj
```

The above command line and file aaa.sub are expanded as follows:

```
asmsh aaa.src,bbb.src -list -noobj
```

Note

A subcommand file must be no larger than 65,535 bytes.

Section 4 Optimizing Linkage Editor Options

4.1 Option Specifications

4.1.1 Command Line Format

The format of the command line is as follows:

```
optlnk[{\Δ<file name>|\Δ<option string>}...]
      <option string>:-<option>[=<suboption>[,...]]
```

4.1.2 Subcommand File Format

The format of the subcommand file is as follows:

```
<option>{=|\Δ} [<suboption>[,...]] [\Δ&] [;<comment>]
&: means line continuous.
```

For details, refer to section 4.2.8, Subcommand File Option.

4.2 List of Options

In the command line format in the following sections, uppercase letters indicate abbreviations. Underlined characters indicate the default settings.

The format of the corresponding dialog menus in the High-performance Embedded Workshop is as follows:

```
Tab name <Category>[Item]....
```

The order of option description corresponds to that of the tabs and the categories in the High-performance Embedded Workshop.

The file name and path name should not include a parenthesis ("(" or ")").

4.2.1 Input Options

Table 4.1 Input Category Options

Item	Command Line Format	Dialog Menu	Specification
Input file	Input = <sub>{[, \Δ}...] <sub>: <file name> [(<module name>[,...])]	Link/Library <Input> [Show entries for :] [Relocatable files and object files]	Specifies input file. (Input file is specified without input on the command line.)
Library file	LIBrary = <file name>[,...]	Link/Library <Input> [Show entries for :] [Library files]	Specifies input library file.
Binary file	Binary = <sub> [,...] <sub>: <file name>(<section name> [:<boundary alignment>] [/<section attribute>] [,<symbol name>])	Link/Library <Input> [Show entries for :] [Binary files]	Specifies input binary file.
Symbol definition	DEFine = <sub>[,...] <sub>: <symbol name> = {<symbol name> <numerical value>}	Link/Library <Input> [Show entries for :] [Defines:]	Defines undefined symbols forcedly. Defined as the same value of symbol name. Defined as a numerical value.
Execution start address	ENTry = { <symbol name> <address>}	Link/Library <Input> [Use entry point :]	Specifies an entry symbol. Specifies an entry address.
Prelinker	NOPRElink	Link/Library <Input> [Prelinker control :]	Disables prelinker initiation.

Input	Input File
Link/Library <Input>[Show entries for :][Relocatable files and object files]	
Format:	Input = <suboption>[{, Δ}...] <suboption>: <file name>[(<module name>[,...])]
Description:	<p>Specifies an input file. Two or more files can be specified by separating them with a comma (,) or space.</p> <p>Wildcards (* or ?) can also be used for the specification. String literals specified with wildcards are expanded in alphabetical order. Expansion of numerical values precedes that of alphabetical letters. Uppercase letters are expanded before lowercase letters.</p> <p>Specifiable files are object files output from the compiler or the assembler, and relocatable or absolute files output from the optimizing linkage editor. A module in a library can be specified as an input file using the format of <library name>(<module name>). The module name is specified without an extension.</p> <p>If an extension is omitted from the input file specification, obj is assumed when a module name is not specified and lib is assumed when a module name is specified.</p>
Examples:	input=a.obj lib1(e) ; Inputs a.obj and module e in lib1.lib . input=c*.obj ; Inputs all .obj files beginning with c .
Remarks:	<p>When form=object or extract is specified, this option is unavailable.</p> <p>When an input file is specified on the command line, input should be omitted.</p>

LIBrary

Library File

Link/Library <Input>[Show entries for :][Library files]

Format: LIBrary = <file name>[,...]

Description: Specifies an input library file. Two or more files can be specified by separating them with a comma (,).

Wildcards (* or ?) can also be used for the specification. String literals specified with wildcards are expanded in the alphabetical order. Expansion of numerical values precedes that of alphabetical letters. Uppercase letters are expanded before lowercase letters.

If an extension is omitted from the input file specification, **lib** is assumed.

If **form=library** or **extract** is specified, the library file is input as the target library to be edited.

Otherwise, after the linkage processing between files specified for the input files are executed, undefined symbols are searched in the library file.

The symbol search in the library file is executed in the following order: user library files with the library option specification (in the specified order), the system library files with the library option specification (in the specified order), and then the default library (environment variable **HLNK_LIBRARY1,2,3**).

Examples: `library=a.lib,b` ; Inputs **a.lib** and **b.lib**.
`library=c*.lib` ; Inputs all files beginning with **c** with the extension **.lib**.

Binary

Binary File

Link/Library <Input>[Show entries for :][Binary files]

Format: Binary = <suboption>[,...]
 <suboption>: <file name><section name>
 [:<boundary alignment>][/<section attribute>][,<symbol name>]
 <section attribute>: CODE | DATA
 <boundary alignment>: 1 | 2 | 4 | 8 | 16 | 32 (default: 1)

Description: Specifies an input binary file. Two or more files can be specified by separating them with a comma (,).

If an extension is omitted for the file name specification, **bin** is assumed.

Input binary data is allocated as the specified section data. The section address is specified with the **start** option. That section cannot be omitted.

When a symbol is specified, the file can be linked as a defined symbol. For a variable name referenced by a C/C++ program, add an underscore (**_**) at the head of the reference name in the program.

The section specified with this option can have its section attribute and boundary alignment specified.

CODE or DATA can be specified for the section attribute.

When section attribute specification is omitted, the write, read, and execute attributes are all enabled by default.

A boundary alignment value can be specified for the section specified by this option. A power of 2 can be specified for the boundary alignment; no other values should be specified.

When the boundary alignment specification is omitted, 1 is used as the default.

Examples: `input=a.obj`
`start=P,D*/200`
`binary=b.bin(D1bin),c.bin(D2bin:4,_datab)`
`form=absolute`

Allocates **b.bin** from 0x200 as the **D1bin** section.

Allocates **c.bin** after **D1bin** as the **D2bin** section (with boundary alignment = 4).

Links **c.bin** data as the defined symbol **_datab**.

Remarks: When **form={object | library}** or **strip** is specified, this option is unavailable.

If no input object file is specified, this option cannot be specified.

DEFine

Symbol Definition

Link/Library <Input>[Show entries for :][[Defines]

Format: DEFine = <suboption>[,...]

<suboption>: <symbol name>={<symbol name> | <numerical value>}

Description: Defines an undefined symbol forcedly as an externally defined symbol or a numerical value.

The numerical value is specified in the hexadecimal notation. If the specified value starts with a letter from A to F, symbols are searched first, and if no corresponding symbol is found, the value is interpreted as a numerical value. Values starting with 0 are always interpreted as numerical values.

If the specified symbol name is a C/C++ variable name, add an underscore (`_`) at the head of the definition name in the program. If the symbol name is a C++ function name (except for the **main** function), enclose the definition name with the double-quotes including parameter strings. If the parameter is **void**, specify as "`<function name>()`".

Examples: `define=_sym1=data` ; Defines **_sym1** as the same value as
; the externally defined symbol **data**.

`define=_sym2=4000` ; Defines **_sym2** as 0x4000.

Remarks: When **form={object | relocate | library}** is specified, this option is unavailable.

ENTry	Execution Start Address
-------	-------------------------

Link/Library <Input>[Use entry point :]

Format: ENTry = {<symbol name> | <address>}

Description: Specifies the execution start address with an externally defined symbol or address.

The address is specified in hexadecimal notation. If the specified value starts with a letter from A to F, symbols are searched first, and if no corresponding symbol is found, the value is interpreted as an address. Values starting with 0 are always interpreted as addresses.

For a C function name, add an underscore (`_`) at the head of the definition name in the program. For a C++ function name (except for the **main** function), enclose the definition name with double-quotes in the program including parameter strings. If the parameter is **void**, specify as "`<function name>()`".

If the **entry** symbol is specified at compilation or assembly, this option precedes the entry symbol.

Examples: `entry=_main` ; Specifies **main** function in C/C++ as the execution
; start address.

`entry="init() "` ; Specifies **init** function in C++ as the execution
; start address.

`entry=100` ; Specifies 0x100 as the execution start address.

Remarks: When **form={object | relocate | library}** or **strip** is specified, this option is unavailable.

When optimization with undefined symbol deletion (**optimize=symbol_delete**) is specified, the execution start address should be specified. If it is not specified, the specification of the optimization with undefined symbol deletion is unavailable. Optimization with undefined symbol deletion is not available when an address is specified with this option.

NOPRElink

Prelinker

Link/Library <Input>[Show entries for :][Prelinker control :]

Format: NOPRElink

Description: Disables the prelinker initiation.

The prelinker supports the functions to generate the C++ template instance automatically and to check types at run time. When the C++ template function and the run-time type test function are not used, specify the **noprelink** option to reduce the link time.

Remarks: When **extract** or **strip** is specified, this option is unavailable.

If **form=lib** or **form=rel** is specified while the C++ template function and run-time type test are used, do not specify **noprelink**.

4.2.2 Output Options

Table 4.2 Output Category Options

Item	Command Line Format	Dialog Menu	Specification
Output format	FOrm = { <u>Absolute</u> Relocate Object Library [= {S U}] Hexadecimal Stype Binary }	Link/Library <Output> [Type of output file :]	Absolute format Relocatable format Object format Library format HEX format S-type format Binary format
Debugging information	<u>DEBug</u> SDEbug NODEBug	Link/Library <Output> [Debug information :]	Output (in output file) Debugging information file output Not output
Record size unification	REcord= { H16 H20 H32 S1 S2 S3 }	Link/Library <Output> [Data record header :]	HEX record Expansion HEX record 32-bit HEX record S1 record S2 record S3 record
ROM support function	ROm = <sub>[,...] <sub>:<ROM section name> =<RAM section name>	Link/Library <Output> [Show entries for :] [ROM to RAM mapped sections:]	Reserves an area in RAM for the relocation of a symbol with an address in RAM.
Output file	OUtput = <sub>[,...] <sub>:<file name> [=<output range>] <output range>: {<start address> -<end address> <section name>[,...]}	Link/Library <Output> [Show entries for :] [Output file path/ Messages] or [Divided output files:]	Specifies output file (range specification and divided output are enabled)
External symbol-allocation information file	MAp [= <file name>]	Link/Library <Output> [Generate external symbol-allocation information file]	Specifies output of the external symbol-allocation information file (for SuperH Family and RX Family)
Output to unused area	SPOace [= {<numerical value> Random}]	Link/Library <Output> [Specify value filled in unused area] [Output padding data]	Specifies a value to output to unused area

Item	Command Line Format	Dialog Menu	Specification
Information message	Message <u>NOMessage</u> [= <sub>[,...]] <sub>:<error code> [-<error code>]	Link/Library <Output> [Show entries for :] [Output file path/ Messages] [Repressed information level messages:]	Output No output (error number specification and range specification are enabled)
Notification of unreferenced defined symbol	MSg_unused	Link/Library <Output> [Show entries for :] [Notify unused symbol:]	Notifies the user of the defined symbol which is never referenced
Reduce empty areas of boundary alignment	DAta_stuff	Link/Library <Output> [Show entries for :] [Reduce empty areas of boundary alignment:]	Reduces empty areas generated as the boundary alignment of sections after compilation (for SuperH Family and H8, H8S, H8SX Family)
Specification of data record byte count	BYte_count=<numerical value>	Link/Library <Output> [Length of data record :]	Specifies the maximum byte count of a data record
CRC	CRC = <suboption> <suboption>: <address where the result is output>=<target range> [/<polynomial expression>] [:<endian>] <address where the result is output>: <address> <target range>: <start address>-<end address>[,...] <polynomial expression>: { <u>CCITT</u> 16 } <endian>: {BIG LITTLE}	Link/Library <Output> [Show entries for :] [Generate CRC code]	Calculates the cyclic redundancy check (CRC) value for the target range at linkage and outputs the result to the specified address.
Filling padding data at section end	PADDING	Link/Library <Output> [Padding]	Outputs padding data to the end of a section to make the section match the boundary alignment.
Address setting for specified vector number	VECTN=<suboption>[,...] <suboption>: <vector number>=<symbol> <address>}	Link/Library <Output> [Show entries for :] [Vector] [Specific vector :]	Assigns an address to the specified vector number in the variable vector table (for RX Family and M16C Series).
Address setting for unused variable vector area	VECT={<symbol> <address>}	Link/Library <Output> [Show entries for :] [Vector] [Empty vector :]	Assigns an address to an unused area in the variable vector table (for RX Family and M16C Series).

Item	Command Line Format	Dialog Menu	Specification
utl30 information output	UTL	Link/Library <Output> [UTL information]	Outputs information for UTL30 (for M16C Series)
Jump table output	JUMP_ENTRIES_FOR_PIC =<section name>[...]	Link/Library <Output> [Jump table output]	Outputs a jump table (for the PIC function of RX Family)

FOrM

Output Format

Link/Library <Output>[Type of output file :]

Format: FOrM = {Absolute | Relocate | Object | Library[={S | U]}
| Hexadecimal | Stype | Binary}

Description: Specifies the output format.

When this option is omitted, the default is **form=absolute**. Table 4.3 lists the suboptions.

Table 4.3 Suboptions of Form Option

Suboption	Description
absolute	Outputs an absolute file
relocate	Outputs a relocatable file
object	Outputs an object file. This is specified when a module is extracted as an object file from a library with the extract option.
library	Outputs a library file. When library=s is specified, a system library is output. When library=u is specified, a user library is output. Default is library=u .
hexadecimal	Outputs a HEX file. For details of the HEX format, refer to appendix 13.1.2, HEX File Format.
stype	Outputs an S -type file. For details of the S -type format, refer to appendix 13.1.1, S-Type File Format.
binary	Outputs a binary file.

Remarks: Table 4.4 shows relations between output formats and input files or other options.

Table 4.4 Relations Between Output Format And Input File Or Other Options

Output Format	Specified Option	Enabled File Format	Specifiable Option*1
Absolute	strip specified	Absolute file	input, output
	Other than above	Object file Relocatable file Binary file Library file	input, library, binary, debug/nodebug, sdebug, cpu, ps_check, start, rom, entry, output, map, hide, optimize/nooptimize, samesize, symbol_forbid, samecode_forbid, variable_forbid, function_forbid, section_forbid, absolute_forbid, profile, cachesize, sbr, compress, rename, delete, define, fsymbol, stack, noprelink, memory, msg_unused, data_stuff*5, show=symbol, reference, xreference, jump_entries_for_pic, aligned_section
Relocate	extract specified	Library file	library, output
	Other than above	Object file Relocatable file Binary file Library file	input, library, debug/nodebug, output, hide, rename, delete, noprelink, msg_unused, data_stuff*5, show=symbol, xreference
Object	extract specified	Library file	library, output
Hexadecimal Stype Binary		Object file Relocatable file Binary file Library file	input, library, binary, cpu, ps_check, start, rom, entry, output, map, space, optimize/nooptimize, samesize, symbol_forbid, samecode_forbid, variable_forbid, function_forbid, section_forbid, absolute_forbid, profile, cachesize, sbr, rename, delete, define, fsymbol, stack, noprelink, record, s9*2, byte_count*3, memory, msg_unused, data_stuff*5, show=symbol, reference, xreference, jump_entries_for_pic, aligned_section
		Absolute file	input, output, record, s9*2, byte_count*3, show=symbol, reference, xreference
Library	strip specified	Library file	library, output, memory*4, show=symbol, section
	extract specified	Library file	library, output
	Other than above	Object file Relocatable file	input, library, output, hide, rename, delete, replace, noprelink, memory*4, show=symbol, section

- Notes:
1. **message/nomessage**, **change_message**, **logo/nologo**, **form**, **list**, and **subcommand** can always be specified.
 2. **s9** can be used only when **form=stype** is specified for the output format.
 3. **byte_count** can be used only when **form=hexadecimal** is specified for the output format.
 4. **memory** cannot be used when **hide** is specified.
 5. **data_stuff** cannot be used when **form=relocate** is specified for the output format.

DEBug, SDEbug, NODEBug

Debugging Information

Link/Library <Output>[Debug information :]

Format: DEBug

SDEbug

NODEBug

Description: Specifies whether debugging information is output.

When **debug** is specified, debugging information is output to the output file.

When **sdebug** is specified, debugging information is output to **<output file name>.dbg** file.

When **nodebug** is specified, debugging information is not output.

If **sdebug** and **form=relocate** are specified, **sdebug** is interpreted as **debug**.

If **debug** is specified and if two or more files are specified to be output with **output**, they are interpreted as **sdebug** and debugging information is output to **<first output file name>.dbg**.

When this option is omitted, the default is **debug**.

Remarks: When **form={object | library | hexadecimal | stype | binary}**, **strip** or **extract** is specified, this option is unavailable.

REcord

Record Size Unification

Link/Library <Output>[Data record header :]

Format: REcord = { H16 | H20 | H32 | S1 | S2 | S3 }

Description: Outputs data with the specified data record regardless of the address range.

If there is an address that is larger than the specified data record, the appropriate data record is selected for the address.

When this option is omitted, various data records are output according to each address.

Remarks: This option is available only when **form=hexadecimal** or **stype** is specified.

ROm

ROM Support Function

Link/Library <Output>[Show entries for :][ROM to RAM mapped sections]

Format: ROm = <suboption>[,...]

<suboption>: <ROM section name>=<RAM section name>

Description: Reserves ROM and RAM areas in the initialized data area and relocates a defined symbol in the ROM section with the specified address in the RAM section.

Specifies a relocatable section including the initial value for the ROM section.

Specifies a nonexistent section or relocatable section whose size is 0 for the RAM section.

Examples: rom=D=R
start=D/100,R/8000

Reserves **R** section with the same size as **D** section and relocates defined symbols in **D** section with the **R** section addresses.

Remarks: When **form={object | relocate | library}** or **strip** is specified, this option is unavailable.

Output

Output File

Link/Library <Output> [Show entries for :][Output file path/ Messages] or [Divided output files]

Format: OUtput = <suboption>[,...]

<suboption>: <file name>[=<output range>]

<output range>: {<start address>-<end address> | <section name>[:...]}

Description: Specifies an output file name. When **form=absolute**, **hexadecimal**, **stype**, or **binary** is specified, two or more files can be specified. An address is specified in the hexadecimal notation. If the specified data starts with a letter from A to F, sections are searched first, and if no corresponding section is found, the data is interpreted as an address. Data starting with 0 are always interpreted as addresses.

When this option is omitted, the default is <first input file name>.<default extension>.

The default extensions are as follows:

form=absolute: abs	form=relocate: rel	form=object: obj
form=library: lib	form=hexadecimal: hex	form=stype: mot
form=binary: bin		

Examples: output=file1.abs=0-ffff, file2.abs=10000-1ffff

Outputs the range from 0 to 0xffff to **file1.abs** and the range from 0x10000 to 0x1ffff to **file2.abs**.

output=file1.abs=sec1:sec2, file2.abs=sec3

Outputs the **sec1** and **sec2** sections to **file1.abs** and the **sec3** section to **file2.abs**.

Remarks: When a file is output in section units while the CPU type is RX Family in big endian, the section size should be a multiple of 4.

MAp Output of External Symbol Allocation Information File

Link/Library <Output>[Generate external symbol-allocation information file]

Format: MAp [= <file name>]

Description: Outputs the external-symbol-allocation information file that is used by the compiler in optimizing access to external variables.

When <file name> is not specified, the file has the name specified by the **output** option or the name of the first input file, and the extension **bls**.

If the order of the declaration of variables in the external-symbol-allocation information file is not the same as the order of the declaration of variables found when the object was read after compilations, an error will be output.

Remarks: This option is valid only when **form**={**absolute** | **hexadecimal** | **stype** | **binary**} is specified.

This option is available when the CPU type is SuperH Family or RX Family.

SPace

Output to Unused Areas

Link/Library <Output>[Show entries for :][Specify value filled in unused area]
[Output padding data]

Format: SPace [= {<numerical value> | Random}]

Description: Fills the unused areas in the output ranges with random values or a user-specified hexadecimal value.

The following unused areas are filled with the value according to the output range specification in the **output** option:

When section names are specified for the output range:

The specified value is output to unused areas between the specified sections.

When an address range is specified for the output range:

The specified value is output to unused areas within the specified address range.

A 1-, 2-, or 4-byte value can be specified. The hexadecimal value specified to the **space** option determines the output data size. If a 3-byte value is specified, the upper digit is extended with 0 to use it as a 4-byte value. If an odd number of digits are specified, the upper digits are extended with 0 to use it as an even number of digits.

If the size of an unused area is not a multiple of the size of the specified value, the value is output as many times as possible, then a warning message is output.

Remarks: When no suboption is specified by this option, unused areas are not filled with values.

This option is available only when **form={binary | stype | hexadecimal}** is specified.

When no output range is specified by the **output** option, this option is unavailable.

Message, NOMessage

Information Message

Link/Library <Output>[Show entries for :] [Output file path/ Messages]
[Repressed information level messages :]

Format: Message

NOMessage [=<suboption>[,...]]

<suboption>: <error number>[-<error number>]

Description: Specifies whether information level messages are output.

When **message** is specified, information level messages are output.

When **nomessage** is specified, the output of information level messages are disabled. If an error number is specified, the output of the error message with the specified error number is disabled. A range of error message numbers to be disabled can be specified using a hyphen (-). If a warning or error level message number is specified, the message output is disabled assuming that **change_message** has changed the specified message to the information level.

When this option is omitted, the default is **nomessage**.

Examples: `nomessage=4,200-203,1300`

Messages of L0004, L0200 to L0203, and L1300 are disabled to be output.

MSg_unused

Notification of Unreferenced Symbol

Link/Library <Output>[Show entries for :] [Output Messages] [Notify unused symbol:]

Format: MSg_unused

Description: Notifies the user of the externally defined symbol which is not referenced during linkage through an output message.

Examples: `optlnk -msg_unused a.obj`

Remarks: When an absolute file is input, this option is invalid.

To output a message, the **message** option must also be specified.

The linkage editor may output a message for the function that was inline-expanded at compilation. To avoid this, add a **static** declaration for the function definition.

In any of the following cases, references are not correctly analyzed so that information shown by output messages will be incorrect.

- **goptimize** is not specified at assembly and there are branches to the same section within the same file (only when an H8, H8S, H8SX Family CPU is specified).
- There are references to constant symbols within the same file.
- There are branches to immediate subordinate functions when optimization is specified at compilation.
- The external variable access optimization is valid at compilation (only when an SuperH Family CPU is specified).
- An offset value is directly specified in a **#pragma tbr** in the C source program (only when the SH-2A or SH2A-FPU is specified as the CPU).
- Optimization is specified at linkage and constants or literals are unified.

DAta_stuff

Reduce empty areas of boundary alignment

Link/Library <Output>[Show entries for :] [Reduce empty areas of boundary alignment:]

Format: DAta_stuff

Description: At linkage, reduces empty areas of boundary alignment. This option affects constant, initialized and uninitialized data areas.

When this option is specified, empty areas generated as the boundary alignment of sections after compilation are filled at linkage. However, the order of data allocation is not changed.

When this option is not specified, linkage is based on the boundary alignment of sections after compilation.

Specifying this option fills the unnecessary empty areas generated by boundary alignment, reducing the size of the data sections as a whole.

Examples:	<pre><tp1.c> ----- long a; char b,c;</pre>	<pre><tp2.c> ----- char d; long e; char f;</pre>
-----------	--	--

Sizes of data sections after compilation (taking the output of the SuperH Family compiler as an example):

tp1.obj: 4 + 1 + 1 = 6 bytes
 tp2.obj: 1 + 3 [*] + 4 + 1 = 9 bytes

Sizes of data sections for **tp1.obj** and **tp2.obj** after linkage:

- 1) When **data_stuff** is not specified
 Object files are linked based on the boundary alignment of the sections (conventional process).
 6 bytes [tp1] + 2 bytes [*] + 9 bytes [tp2] = 17 bytes
- 2) When **data_stuff** is specified
 Linkage is performed with filling of the unnecessary empty spaces generated between sections by boundary alignment.
 (4 + 1 + 1) bytes + 1 byte + 1 byte [*] + 4 bytes + 1 byte = 13 bytes

Notes: 1. * indicates an empty area generated by boundary alignment.

2. The sizes of the data sections after compilation may differ from those in the above example according to the specification of other options, etc. at compilation.

Remarks: Correct operation is not guaranteed if this option is specified when an object file compiled with the **smap** option of the SuperH Family compiler is linked.

The function of this option is not applicable to object files generated by the assembler.

Specification of this option is invalid in any of the following cases:

- **form=library**, **object**, or **relocate** is specified
- An absolute load module is input
- **memory=low** is specified
- **nooptimize** is not specified

Optimization will not be applied in the linkage of a relocatable file that was generated with this option specified.

This option is unavailable when the CPU type is RX Family, M16C Series, or R8C Family.

BYte_count

Specification of Data Record Byte Count

Link/Library <Output>[Length of data record :]

Format: `BYte_count=<numerical value>`

Description: Specifies the maximum byte count for a data record when a file is to be created in the **Intel-Hex** format. Specify a one-byte hexadecimal value (01 to FF) for the byte count. When this option is not specified, the linkage editor assumes FF as the maximum byte count when creating an **Intel-Hex** file.

Examples: `byte_count=10`

Remarks: This option is invalid when the file to be created is not an **Intel-Hex**-type (**form=hex**) file.

CRC

CRC

Link/Library <Output> [Show entries for :] [Generate CRC code]

Format: CRC = <suboption>

<suboption>: <address where the result is output>=<target range>
 [/<polynomial expression>][:<endian>]

<address where the result is output>: <address>

<target range>: <start address>-<end address>[,...]

<polynomial expression>: { CCITT | 16 }

<endian>: {BIG | LITTLE}

Description: This option is used for cyclic redundancy checking (CRC) of values from the lowest to the highest address of each target range and outputs the calculation result to the specified address.

<endian> can be specified only when the CPU type is RX Family. When <endian> is specified, the calculation result is output to the specified address in the specified endian. When <endian> is not specified, the result is output to the specified address in the endian used in the absolute file.

CRC-CCITT or **CRC-16** is selectable as a polynomial expression (default: **CRC-CCITT**).

Polynomial expression:

CRC-CCITT

$X^{16}+X^{12}+X^5+1$

In bit expression: (10001000000100001)

CRC-16

$X^{16}+X^{15}+X^2+1$

In bit expression: (11000000000000101)

Example 1: `optlnk *.obj -form=stype -start=P1,P2/1000,P3/2000
-crc=2FFE=1000-2FFD -output=out.mot=1000-2FFF`

	After linkage	CRC	Setting for the output option	Output (out.mot)
0x1000	P1	P1	Target range (0x1000 to 0x2FFF)	P1
	P2	P2		P2
	Free	Calculated as 0xFF		
0x2000	P3	P3		P3
	Free	Calculated as 0xFF		
		Address where the result will be output		Result of CRC
0x2FFF				0x2FFE

crc option: `-crc=2FFE=1000-2FFD`

In this example, CRC will be calculated for the range from 0x1000 to 0x2FFD and the result will be output to address 0x2FFE.

When the **space** option has not been specified, **space=0xFF** is assumed for calculation of free areas within the target range.

output option: `-output=out.mot=1000-2FFF`

Since the **space** option has not been specified, the free areas are not output to the **out.mot** file. 0xFF is used in CRC for calculation of the free areas, but will not be filled into these areas.

- Notes:
1. The address where the result of CRC will be output cannot be included in the target range.
 2. The address where the result of CRC will be output must be included in the output range specified with the **output** option.

Example 2: `optlnk *.obj -form=stype -start=P1/1000,P2/1800,P3/2000
-space=7F -crc=2FFE=1000-17FF,2000-27FF
-output=out.mot=1000-2FFF`

	After linkage	CRC	Setting for the output option	Output (out.mot)	
0x1000	P1	P1	Target range (0x1000 to 0x2FFF)	P1	0x1000
	Free	Calculated as 0x7F		Filled with 0x7F	
0x1800	P2			P2	
	Free			Filled with 0x7F	
0x2000	P3	P3		P3	
		Calculated as 0x7F		Filled with 0x7F	
0x2800	Free			Filled with 0x7F	
0x2FFF		Address where the result will be output		Result of CRC	0x2FFE 0x2FFF

crc option: `-crc=2FFE=1000-2FFD,2000-27FF`

In this example, CRC will be calculated for the two ranges, 0x1000 to 0x17FF and 0x2000 to 0x27FF, and the result will be output to address 0x2FFE.

Two or more non-contiguous address ranges can be selected as the target range for CRC.

space option: `-space=7F`

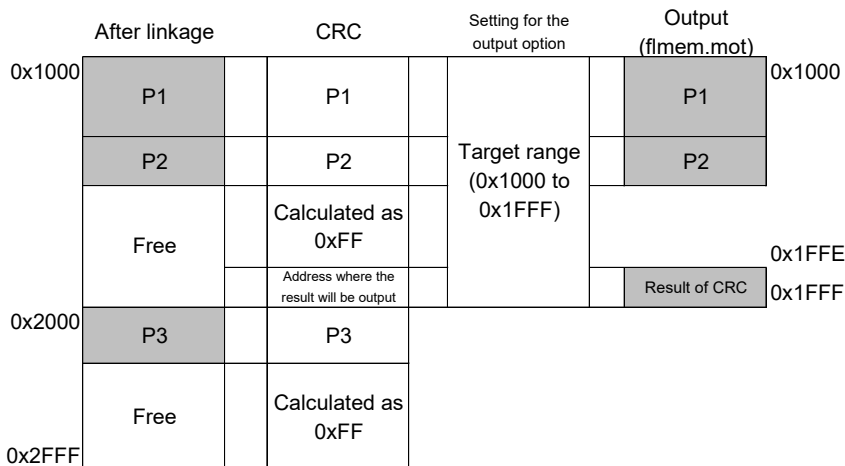
The value of the **space** option (0x7F) is used for CRC in free areas within the target range.

output option: `-output=out.mot=1000-2FFF`

Since the **space** option has been specified, the free areas are output to the **out.mot** file. 0x7F will be filled into the free areas.

- Notes:
1. The order that CRC is calculated for the specified address ranges is not the order that the ranges have been specified. CRC proceeds from the lowest to the highest address.
 2. Even if you wish to use the **crc** and **space** options at the same time, the **space** option cannot be set as **random** or a value of 2 bytes or more. Only 1-byte values are valid.

Example 3: `optlnk *.obj -form=stype -start=P1,P2/1000,P3/2000
-crc=1FFE=1000-1FFD,2000-2FFF
-output=flmem.mot=1000-1FFF`



crc option: `-crc=1FFE=1000-1FFD,2000-2FFF`

In this example, CRC will be calculated for the two ranges, 0x1000 to 0x1FFD and 0x2000 to 0x2FFF, and the result will be output to address 0x1FFE.

When the **space** option has not been specified, **space=0xFF** is assumed for calculation of free areas within the target range.

output option: `-output=flmem.mot=1000-1FFF`

Since the **space** option has not been specified, the free areas are not output to the **flmem.mot** file. 0xFF is used in CRC for calculation of the free areas, but will not be filled into these areas.

Remarks: This option is invalid when two or more absolute files have been selected.

This option is valid only when **form={hexadecimal | stype}**.

When the **space** option has not been specified and the target range includes free areas that will not be output, the linkage editor assumes in CRC that 0xFF has been set in the free areas.

An error occurs if the target range includes an overlay area.

Sample Code: The sample code shown below is provided to check the result of CRC figured out by the **crc** option. The sample code program should match the result of CRC by **optlnk**.

When the selected polynomial expression is **CRC-CCITT**:

```
typedef unsigned char uint8_t;
typedef unsigned short uint16_t;
typedef unsigned long uint32_t;

uint16_t CRC_CCITT(uint8_t *pData, uint32_t iSize)
{
    uint32_t ui32_i;
    uint8_t *pui8_Data;
    uint16_t ui16_CRC = 0xFFFFu;

    pui8_Data = (uint8_t *)pData;

    for(ui32_i = 0; ui32_i < iSize; ui32_i++)
    {
        ui16_CRC = (uint16_t)((ui16_CRC >> 8u) |
                               ((uint16_t)((uint32_t)ui16_CRC << 8u));
        ui16_CRC ^= pui8_Data[ui32_i];
        ui16_CRC ^= (uint16_t)((ui16_CRC & 0xFFu) >> 4u);
        ui16_CRC ^= (uint16_t)((ui16_CRC << 8u) << 4u);
        ui16_CRC ^= (uint16_t)((ui16_CRC & 0xFFu) << 4u) << 1u);
    }
    ui16_CRC = (uint16_t)( 0x0000FFFFul &
                          ((uint32_t)~(uint32_t)ui16_CRC) );
    return ui16_CRC;
}
```

When the selected polynomial expression is **CRC-16**:

```
#define POLYNOMIAL 0xa001 // Generated polynomial expression CRC-16

typedef unsigned char uint8_t;
typedef unsigned short uint16_t;
typedef unsigned long uint32_t;

uint16_t CRC16(uint8_t *pData, uint32_t iSize)
{
    uint16_t crcdData = (uint16_t)0;
    uint32_t data = 0;
    uint32_t i, cycLoop;

    for(i=0; i<iSize; i++){
        data = (uint32_t)pData[i];
        crcdData = crcdData ^ data;
        for (cycLoop = 0; cycLoop < 8; cycLoop++) {
            if (crcdData & 1) {
                crcdData = (crcdData >> 1) ^ POLYNOMIAL;
            } else {
                crcdData = crcdData >> 1;
            }
        }
    }
    return crcdData;
}
```

PADDING

Filling padding data at section end

Format: PADDING

Description: Fills in padding data at the end of a section so that the section size is a multiple of the boundary alignment of the section.

Examples: `-start=P,C/0 -padding`

When the boundary alignment of section **P** is 4 bytes, the size of section **P** is 0x06 bytes, the boundary alignment of section **C** is 1 byte, and the size of section **C** is 0x03 bytes, two bytes of padding data is filled in section **P** to make its size become 0x08 bytes and then linkage is performed.

`-start=P/0,C/7 -padding`

When the boundary alignment of section **P** is 4 bytes, the size of section **P** is 0x06 bytes, the boundary alignment of section **C** is 1 byte, and the size of section **C** is 0x03 bytes, if two bytes of padding data is filled in section **P** to make its size become 0x08 bytes and then linkage is performed, error L2321 will be output because section **P** overlaps with section **C**.

Remarks: The value of the created padding data is 0x00.

Since padding is not performed to an absolute address section, the size of an absolute address section should be adjusted by the user.

This option is valid when the CPU type is SuperH Family or RX Family.

VECTN	Address Setting for Specified Vector Number
	Link/Library <Output> [Show entries for:] [Address allocation on specific vector]
Format:	VECTN = <suboption>[,...]
	<suboption>: <vector number> = {<symbol> <address>}
Description:	Assigns the specified address to the specified vector number in the variable vector table section.
	When this option is specified, a variable vector table section is created and the specified address is set in the table even if there is no interrupt function in the source code.
	Specify a decimal value from 0 to 255 for <vector number>.
	Specify the external name of the target function for <symbol>.
	Specify the desired hexadecimal address for <address>.
Examples:	<pre>-vectn=30=_f1,31=0000F100 ; Specifies the _f1 address for vector ; number 30 and 0x0f100 for vector ; number 31</pre>
Remarks:	This option is valid when the CPU type is RX Family, M16C Series, or R8C Family.
	This option is ignored when the user creates a variable vector table section in the source program because the variable vector table is not automatically created in this case.

VECT

Address Setting for Unused Vector Area

Link/Library <Output> [Show entries for:] [Filling address on empty vector]

Format: VECT={<symbol>|<address>}

Description: Assigns the specified address to the vector number to which no address has been assigned in the variable vector table section.

When this option is specified, a variable vector table section is created by the linkage editor and the specified address is set in the table even if there is no interrupt function in the source code.

Specify the external name of the target function for <symbol>.

Specify the desired hexadecimal address for <address>.

Remarks: This option is valid when the CPU type is RX Family, M16C Series, or R8C Family.

This option is ignored when the user creates a variable vector table section in the source program because the variable vector table is not automatically created in this case.

When the {<symbol>|<address>} specification is started with 0, the whole specification is assumed as an address.

UTL**utl30** information output

Link/Library <Other> [Other option] [utl file output]

Format: UTL

Description: Generates an external file (**utl** file) to be input to the tool (**utl30**) included with the compiler package.

The generated file is assigned a name <output file name>.utl.

Examples: `tp.obj`
`utl`
`output=test.abs`

Outputs inspector information from **tp.obj** to **test.utl**.

Remarks: This option is valid only when the compiler for the M16C microcontrollers is used.

This option cannot be used when processing the **abs** files input to the linkage editor.

This option is invalid when **form={object | library}** is specified.

JUMP_ENTRIES_FOR_PIC

Jump table output

Link/Library <Output> [Jump table]

Format: JUMP_ENTRIES_FOR_PIC=<section name>[,...]

Description: Outputs an assembly-language source for a jump table to branch to external definition symbols in the specified section.

This option is used for the PIC function of the RX family compilers.

The file name is <output file>.jmp.

Examples: `jump_entries_for_pic=sct2,sct3`
`output=test.abs`

A jump table for branching to external definition symbols in the sections **sct2** and **sct3** is output to **test.jmp**.

[Example of a file output to **test.jmp**]

```
;OPTIMIZING LINKAGE EDITOR GENERATED FILE 2009.07.19
    .glob _func01
    .glob _func02
    .SECTION P, CODE
_func01:
    MOV.L #1000H, R14
    JMP   R14
_func02:
    MOV.L #2000H, R14
    JMP   R14
    .END
```

Remarks: This option is invalid when **form={object | relocate| library}** or **strip** is specified.

This option is invalid when the CPU type is not the RX series.

The generated jump table is output to the **P** section.

Only the program section can be specified for the type of section in the section name.

4.2.3 List Options

Table 4.5 List Category Options

Item	Command Line Format	Dialog Menu	Specification
List file	LIST [= <file name>]	Link/Library <List> [Generate list file]	Specifies the output of list file.
List contents	SHow [= <sub>[...]] <sub>: {SYmbol Reference SEction Xreference Total_size VECTOR ALL }	Link/Library <List> [Contents :]	Symbol information Number of references Section information Cross-reference information Total sizes of sections Vector Information All information

LIST

List File

Link/Library <List> [Generate list file]

Format: LIST [=<file name>]

Description: Specifies list file output and a list file name.

If no list file name is specified, a list file with the same name as the output file (or first output file) is created, with the extension **lbp** when **form=library** or **extract** is specified, or **map** in other cases.

SHow

List Contents

Link/Library <List> [Contents]

Format: SHow [=<sub>[,...]]
<sub>: { SYmbol | Reference | SEction | Xreference | Total_size | VECTOR |
ALL }

Description: Specifies output contents of a list.

Table 4.6 lists the suboptions.

For details of list examples, refer to section 7.3, Linkage List, and section 7.4, Library List in the user's manual.

Table 4.6 Suboptions of show Option

Output Format	Suboption Name	Description
form=library or extract is specified.	symbol	Outputs a symbol name list in a module (when extract is specified)
	reference	Not specifiable
	section	Outputs a section list in a module (when extract is specified)
	xreference	Not specifiable
	total_size	Not specifiable
	vector	Not specifiable
	all	Not specifiable (when extract is specified) Outputs a symbol name list and a section list in a module (when form=library)
Other than form=library and extract is not specified.	symbol	Outputs symbol address, size, type, and optimization contents.
	reference	Outputs the number of symbol references.
	section	Not specifiable
	xreference	Outputs the cross-reference information.
	total_size	Shows the total sizes of sections allocated to the ROM and RAM areas.
	vector	Outputs vector information.
	all	If form=rel , the linkage editor outputs the same information as when show=symbol , xreference , or total_size is specified. If form=rel and data_stuff have been specified, the linkage editor outputs the same information as when show=symbol or total_size is specified. If form=abs , the linkage editor outputs the same information as when show=symbol , reference , xreference , or total_size is specified. If form=hex , stype , or bin , the linkage editor outputs the same information as when show=symbol , reference , xreference , or total_size is specified. If form=obj , all is not specifiable.

Remarks: The following table shows whether suboptions will be valid or invalid by all possible combinations of options **form**, **show**, and/or **show=all**.

		Symbol	Reference	Section	Xreference	Vector	Total_size
form=abs	show	Valid	Valid	Invalid	Invalid	Invalid	Invalid
	show=all	Valid	Valid	Invalid	Valid	Valid	Valid
form=lib	show	Valid	Invalid	Valid	Invalid	Invalid	Invalid
	show=all	Valid	Invalid	Valid	Invalid	Invalid	Invalid
form=rel	show	Valid	Invalid	Invalid	Invalid	Invalid	Invalid
	show=all	Valid	Invalid	Invalid	Valid*	Invalid	Valid
form=obj	show	Valid	Valid	Invalid	Invalid	Invalid	Invalid
	show=all	Valid	Invalid	Invalid	Invalid	Invalid	Invalid
form=hex/bin/sty	show	Valid	Valid	Invalid	Invalid	Invalid	Invalid
	show=all	Valid	Valid	Invalid	Valid	Valid*	Valid*

Note: The option is invalid if an absolute-format file is input.

Note the following limitations on output of the cross-reference information.

- When the relocatable format is specified for the output file and the **data_stuff** option is specified, no cross-reference information is output.
- When an absolute-format file is input, the referrer address information is not output.
- When **-goptimize** is not specified at assembly, information about branches to the same section within the same file is not output (only when an H8, H8S, H8SX Family CPU is specified).
- Information about references to constant symbols within the same file is not output.
- When optimization is specified at compilation, information about branches to immediate subordinate functions is not output.
- When optimization of access to external variables is specified, information about references to variables other than base symbols is not output (only when an SuperH Family or RX Family CPU is specified).
- When an offset value is directly specified in a **#pragma tbr** in the C source program, information about that function is not output (only when the SH-2A or SH2A-FPU is specified as the CPU).

- When optimization is specified at linkage and constants or literals are unified, information about references to these constants or literals is not output.
- Both **show=total_size** and **total_size** output the same information.
- **show=vector** can be used when the CPU type is RX Family, M16C Series, or R8C Family.
- When **show=reference** is valid, the number of references of the variable specified by **#pragma address** is output as 0 (only when a SuperH Family or RX Family CPU is specified).

4.2.4 Optimize Options

Table 4.7 Optimize Category Options

Item	Command Line Format	Dialog Menu	Specification
Optimization	<code>OPTimize = <sub>[...]</code> <code><sub>: {String_unify</code> <code> SYmbol_delete</code> <code> Register</code> <code> SAME_code</code> <code> Branch</code> <code> Speed</code> <code> SAFe }</code> <code>NOOPTimize}</code>	Link/Library <Optimize> [Show entries for :] [Optimize items] [Optimize :]	Executes optimization. Unifies constants/string literals. Deletes unreferenced symbols. Provides optimization with register save/restore. Unifies same codes. Provides optimization for branches. Provides optimization for speed. Provides safe optimization. No optimization.
Same code size	<code>SAMESize = <size></code> (default: <code>sames=1e</code>)	Link/Library <Optimize> [Eliminated size :]	Specifies the minimum size to unify same codes.
Profile information	<code>PROfile = <file name></code>	Link/Library <Optimize> [Include profile :]	Specifies a profile information file. (Dynamic optimization is provided.)
Cache size	<code>CAchesize=<sub></code> <code><sub>: Size=<size> </code> <code>Align=<line size></code> (default: <code>ca=s=8,a=20</code>)	Link/Library <Optimize> [Cache size :]	Specifies a cache size. Specifies a cache line size. (for SuperH Family)
Optimization partially disabled	<code>SYmbol_forbid=</code> <code><symbol name>[,...]</code> <code>SAMECode_forbid=</code> <code><function name>[,...]</code> <code>Variable_forbid=</code> <code><symbol name>[,...]</code> <code>FUnction_forbid=</code> <code><function name>[,...]</code> <code>SEction_forbid = <sub>[,...]</code> <code><sub>: [<file name></code> <code><module name></code> <code>(<section name>[,...])</code> <code>Absolute_forbid=</code> <code><address>[+<size>][,...]</code>	Link/Library <Optimize> [Show entries for :] [Forbid item]	Specifies a symbol where unreferenced symbol deletion is disabled. Specifies a symbol where same code unification is disabled. Specifies a symbol where short absolute addressing mode is disabled. Specifies a symbol where indirect addressing mode is disabled. Specifies a section where optimization is disabled. Specifies an address range where optimization is disabled.

OPTimize, NOOPTimize

Optimization

Link/Library <Optimize> [Show entries for :][Optimize items][Optimize :]

Format: OPTimize [= <suboption>[,...]]

NOOPTimize

<suboption>: { STring_unify | SYmbol_delete | Register | SAMe_code | Branch
| SPeed | SAFe }

Description: Specifies whether the inter-module optimization is executed.

When **optimize** is specified, optimization is performed for the file specified with the **goptimize** option at compilation or assembly.

When **nooptimize** is specified, no optimization is executed for a module.

When this option is omitted, the default is **optimize**.

Table 4.8 shows the suboptions

Table 4.8 Suboptions of Optimize Option

Suboption	Description
No parameter	V.9.04 Release 01 or earlier This suboption is the same as the following specifications: optimize=string_unify, symbol_delete, register, same_code, branch V.9.04 Release 02 or later This suboption is the same as the following specifications: optimize=string_unify, symbol_delete, same_code, branch
string_unify	Unifies same-value constants having the const attribute. Constants having the const attribute are: <ul style="list-style-type: none"> • Variables defined as const in C/C++ program • Initial value of character string data • Literal constant
symbol_delete	Deletes variables/functions that are not referenced. Always be sure to specify #pragma entry at compilation or the entry option in the optimizing linkage editor.
register	Investigates function calls, relocates registers and deletes redundant register save or restore codes. Always be sure to specify #pragma entry at compilation or the entry option in the optimizing linkage editor.
same_code	Creates a subroutine for the same instruction sequence.

Suboption	Description
branch	Optimizes branch instruction size according to program allocation information. Even if this option is not specified, it is performed when any other optimization is executed.
speed	Executes optimizations other than those reducing object speed. V.9.04 Release 01 or earlier This suboption is the same as the following specifications: optimize=string_unify, symbol_delete, register, branch V.9.04 Release 02 or later This suboption is the same as the following specifications: optimize=string_unify, symbol_delete, branch
safe	Executes optimizations other than those limited by variable or function attributes. V.9.04 Release 01 or earlier This suboption is the same as the following specifications: optimize=string_unify, register, branch V.9.04 Release 02 or later This suboption is the same as the following specifications: optimize=string_unify, branch

Remarks: When **form**={**object** | **relocate** | **library**} or **strip** is specified, this option is unavailable.

When optimization of access to external variables is specified at compilation, optimization with unification of constants/string literals (**optimize=string_unify**) is invalid.

When the CPU is SH-2A or SH2A-FPU, the code size may increase due to the **optimize=register** function.

When a start function with **#pragma entry** or **entry** is not specified, **optimize=symbol_delete** is invalid.

SAMesize

Common Code Size

Link/Library <Optimize> [Eliminated size :]

Format: SAMESize = <size>

Description: Specifies the minimum code size for the optimization with the same-code unification (**optimize=same_code**). Specify a hexadecimal value from 8 to 7FFF.

When this option is omitted, the default is **samesize=1E**.

Remarks: When **optimize=same_code** is not specified, this option is unavailable.

PROfile

Profile Information

Link/Library <Optimize> [Include profile :]

Format: PROfile = <file name>

Description: Specifies a profile information file.

Specifiable profile information files are those output from the High-performance Embedded Workshop Ver. 2.0 or later.

When a profile information file is specified, inter-module optimization according to dynamic information can be performed.

Table 4.9 shows optimizations influenced by a profile information input.

Table 4.9 Relations Between Profile Information and Optimization

Suboption	Description	Program to be Optimized*1			
		SHC	SHA	H8C	H8A
variable_access	Allocates variables from those that are dynamically accessed more frequently.	×	×	○	○
function_call	Lowers the optimizing priority of functions that are dynamically accessed frequently.	×	×	○	○
branch	Allocates a function that is dynamically accessed frequently near the calling function. For the SH program, the optimization with allocation is performed depending on the cache size specified using the cachesize option.	○	△*2	○	△

- Notes: 1. SHC: C/C++ program for SuperH Family
SHA: Assembly program for SuperH Family
H8C: C/C++ program for H8, H8S, H8SX Family
H8A: Assembly program for H8, H8S, H8SX Family
2. Movement is provided not in the function unit, but in the input file unit.

Remarks: When the **optimize** option is not specified, this option is unavailable.

CAchesize

Cache Size

Link/Library <Optimize> [Cache size :]

Format: CAchesize = <suboption>

<suboption>: Size = <size> | Align = <line size>

Description: Specifies a cache size and cache line size.

When **profile** is specified, this option is used at the branch instruction optimization (**optimize=branch**).

Specify the size in Kbytes and specify the line size in bytes in the hexadecimal notation.

When this option is omitted, the default is **cachesize=size=8, align=20**.

Remarks: If **profile** is not specified, this option is unavailable.

SYMBOL_forbid, SAMECode_forbid, Variable_forbid,**FUNction_forbid, SEction_forbid, Absolute_forbid**

Optimization Partially Disabled

Link/Library <Optimize> [Show entries for :] [Forbid item]

Format: SYMBOL_forbid = <symbol name> [,...]

SAMECode_forbid = <function name> [,...]

Variable_forbid = <symbol name> [,...]

FUNction_forbid = <function name> [,...]

SEction_forbid = <sub>[,...]

<sub>: [<file name>|<module name>](<section name>[,...])

Absolute_forbid = <address> [+<size>] [,...]

Description: Disables optimization for the specified symbol, section, or address range. Specify an address or the size in the hexadecimal notation. For a C/C++ variable or C function name, add an underscore (_) at the head of the definition name in the program. For a C++ function, enclose the definition name in the program with double-quotes including the parameter strings. When the parameter is **void**, specify as "<function name>()".

Table 4.10 shows the suboptions.

Table 4.10 Suboptions of Optimization Partially Disabling Option

Suboption	Parameter	Description
symbol_forbid	Function name variable name	Disables optimization regarding unreferenced symbol deletion
samecode_forbid	Function name	Disables optimization regarding same-code unification
variable_forbid	Variable name	Disables optimization regarding short absolute addressing mode
function_forbid	Function name	Disables optimization regarding indirect addressing mode
section_forbid	Section name File name Module name	Disables optimization for the specified section. If an input file name or library module name is also specified, the optimization can be disabled for a specific file, not only the entire section.
absolute_forbid	Address [+ size]	Disables optimization regarding address + size specification

Examples:

```

symbol_forbid="f(int) " ; Does not delete the C++ function f(int)
                        ; even if it is not referenced.

section_forbid=(P1)    ; Disables any optimization for section
                        ; P1.

section_forbid=a.obj (P1,P2) ; Disables any optimization for sections
                        ; P1 and P2 in a.obj.
    
```

Remarks: If optimization is not applied at linkage, this option is ignored.

To disable optimization for an input file with its path name, type the path with the file name when specifying **section_forbid**.

4.2.5 Section Options

Table 4.11 Section Category Options

Item	Command Line Format	Dialog Menu	Specification
Section address	START = <sub>[...] <sub>: [(<section name> [: , } <section name>[...])] [...] / <address>	Link/Library <Section> [Show entries for :] [Section]	Specifies a section start address
Symbol address file	FSymbol = <section name>[...]	Link/Library <Section> [Show entries for :] [Symbol file]	Outputs externally defined symbol addresses to a definition file.
Section alignment specification	ALIGNED_SECTION = <section name>[...]	Link/Library <Section> [Show entries for :] [Section alignment]	Changes the section alignment value to 16 bytes.

START

Section Address

Link/Library <Section> [Show entries for :] [Section]

Format: START = <sub> [,...]

<sub>: [(<section name> [{ : | , } <section name> [,...]] D) [,...]
[/ <address>]

Description: Specifies the start address of the section. Specify an address as the hexadecimal.

The section name can be specified with wildcards “*”. Sections specified with wildcards are expanded according to the input order.

Two or more sections can be allocated to the same address (i.e., sections are overlaid) by separating them with a colon “:”.

Sections specified at a single address are allocated in the specification order.

Sections to be overlaid can be changed by enclosing them by parentheses “()”.

Objects in a single section are allocated in the specification order of the input file or the input library.

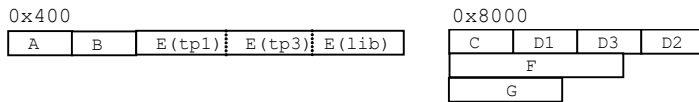
If no address is specified, the section is allocated at 0.

A section which is not specified with the **start** option is allocated after the last allocation address.

Examples: This example shows how sections are allocated when the objects are input in the following order (names enclosed by parentheses are sections in the objects).

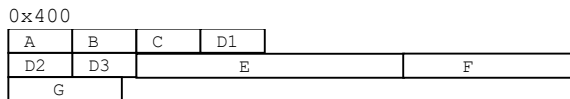
```
tp1.obj (A, D1, E) -> tp2.obj (B, D3, F) -> tp3.obj (C, D2, E, G)
-> lib.lib (E)
```

(1) -start=A, B, E/400, C, D*:F/G/8000



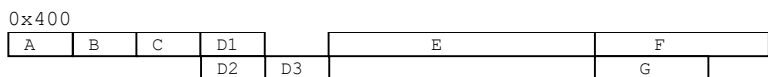
- Sections **C**, **F**, and **G** separated by colons are allocated to the same address.
- Sections specified with wildcards “*” (in this example, the sections whose names start with **D**) are allocated in the input order.
- Objects in the sections having the same name (**E** in this example) are allocated in the input order.
- An input library’s section having the same name (**E** in this example) as those of input objects is allocated after the input objects.

(2) -start=A, B, C, D1:D2, D3, E, F:G/400



- The sections that come immediately after the colons (**A**, **D2**, and **G** in this example) are selected as the start and allocated to the same address.

(3) -start=A, B, C, (D1:D2, D3), E, (F:G)/400



- When the sections to be allocated to the same address are enclosed by parentheses, the sections within parentheses are allocated to the address

immediately after the sections that come before the parentheses (**C** and **E** in this example).

- The section that comes after the parentheses (**E** in this example) is allocated after the last of the sections enclosed by the parentheses.

Remarks: When **form**={**object** | **relocate** | **library**} or **strip** is specified, this option is unavailable.

Parentheses cannot be nested.

One or more colons must be written within parentheses. Parentheses cannot be written without a colon.

Colons cannot be written outside of parentheses.

When this option is specified with parentheses, optimization with the linkage editor is disabled.

FSymbol	Symbol Address File
Link/Library <Section> [Show entries for :][Symbol file]	

Format: FSymbol = <section name> [,...]

Description: Outputs externally defined symbols in the specified section to a file in the assembler directive format.

The file name is <output file>.fsy.

Examples: fSymbol = sct2, sct3
 output=test.abs

Outputs externally defined symbols in sections **sct2** and **sct3** to **test.fsy**.

[Output example of **test.fsy**]

```
;OPTIMIZING LINKAGE EDITOR GENERATED FILE 1999.11.26
;fsymbol = sct2, sct3

;SECTION NAME = sct2
.export _f
_f: .equ h'00000000
.export _g
_g: .equ h'00000016
;SECTION NAME = sct3
.export _main
_main: .equ h'00000020
.end
```

Remarks: When **form={object | relocate | library}** or **strip** is specified, this option is unavailable.

This option is available when the CPU type is H8, H8S, H8SX Family, SuperH Family, or RX Family.

ALIGNED_SECTION

Changing Section Alignment to 16 bytes

Link/Library <Section> [Show entries for :][Section alignment]

Format: ALIGNED_SECTION = <section name>[,...]

Description: Changes the alignment value for the specified section to 16 bytes.

Remarks: When **form={object | relocate | library}**, **extract**, or **strip** is specified, this option is unavailable.

4.2.6 Verify Options

Table 4.12 Verify Category Options

Item	Command Line Format	Dialog Menu	Specification
Address check	CPU = { <cpu information file name> <memory type> = <address range>[,...] STRIDE} <memory type>: { ROm RAM XROm XRAM YROm YRAM } <address range>: <start address> -<end address>	Link/Library <Verify> [CPU information check :]	Specifies a specifiable allocation range for section addresses. The specified section will be divided.
Physical space overlap check	PS_check=<sub>[:<sub>...] <sub>: <LS>,<LS>[,...] <LS>: <start address> -<end address>	Link/Library <Verify> [Physical space overlap check :]	Specifies address ranges that may overlap each other in the physical space.
Not divide the specified section	CONTIGUOUS_SECTION = <section name>[,...]	Link/Library <Verify> [Not divide the specified section :]	The specified section will not be divided.

CPu

Address Check

Verify [CPU information check:]

Format: CPu={<cpu information file name>
 | <memory type> = <address range> [,...]
 | STRIDE}

<memory type>: { ROm | RAm | XROm | XRAm | YROm | YRAm | FIX}

<address range>: <start address> - <end address>

Description: When **cpu=stride** is not specified, a section larger than the specified range of addresses leads to an error.

When **cpu=stride** is specified, a section larger than the specified range of addresses is allocated to the next area of the same memory type or the section is divided.

[Example]

When the **stride** suboption is not specified:

```
start=D1, D2/100
```

```
cpu=ROM=100-1FF, RAM=200-2FF
```

The result is normal when **D1** and **D2** are respectively allocated within the ranges from 100 to 1FF and from 200 to 2FF. If they are not allocated within the ranges, an error will be output.

[Example]

When the **stride** suboption is specified:

```
start=D1, D2/100
```

```
cpu=ROM=100-1FF, RAM=200-2FF, ROM=300-3FF
```

```
cpu=stride
```

The result is normal when **D1** and **D2** are allocated within the ROM area (regardless of whether the section is divided). A linkage error occurs when they are not allocated within the ROM area even though the section is divided.

xrom and **xram** specify the X memory areas and **yrom** and **yram** specify the Y memory areas in the DSP.

Specify an address range in which a section can be allocated in hexadecimal notation. The memory type attribute is used for the inter-module optimization.

FIX for <memory type> is used to specify a memory area where the addresses are fixed (e.g. I/O area).

If the address range of <start>-<end> specified for **FIX** overlaps with that specified for another memory type, the setting for **FIX** is valid.

When <memory type> is **ROM** or **RAM** and the section size is larger than the specified memory range, sub-option **STRIDE** can be used to divide a section and allocate them to another area of the same memory type. Sections are divided in module units.

[Example]

```
cpu=ROM=0-FFFF, RAM=10000-1FFFF
```

Checks that section addresses are allocated within the range from 0 to FFFF or from 10000 to 1FFFF.

Object movement is not provided between different attributes with the inter-module optimization.

```
cpu=ROM=100-1FF, ROM=400-4FF, RAM=500-5FF
```

```
cpu=stride
```

When section addresses are not allocated within the range from 100 to 1FF, the linkage editor divides the sections in module units and allocates them to the range from 400 to 4FF.

Remarks:

When **form**={**object** | **relocate** | **library**} or **strip** is specified, this option is unavailable.

When **cpu=stride** and **memory=low** are specified, this option is unavailable.

Memory types **xrom**, **xram**, **yrom**, and **yram** are available only when the CPU is SHDSP, SH2DSP, SH3DSP or SH4ALDSP.

When **cpu=stride** and **optimize=register** are valid, error L2320 may be output. In such cases, disable **optimize=register**.

When section **B** is divided by **cpu=stride**, the size of section **CSBSEC** increases by 8 bytes × number of divisions because this amount of information is required for initialization.

PS_check

Physical Space Overlap Check

Verify [Physical space overlap check :]

Format: PS_check=<sub>[:<sub>...]

<sub>: <LS>,<LS>[,...]

<LS>: <start address>-<end address>

Description: Specifies objects that may overlap each other when they are allocated to the memory.

Use this option to detect SH3 or SH4 objects that will overlap each other when they are allocated to the actual memory even if their virtual addresses do not overlap.

If an overlap is detected after this option setting, an error will be output and the linkage operation will be terminated.

Specify address ranges (<LS> in the command line format) that may overlap each other in the memory.

To check multiple physical memory spaces, specify them by separation with a colon (:).

Examples: In the SH4, the 4-Gbyte address space is mapped to the 512-Mbyte (29-bit address) external memory area when the MMU is disabled (the upper three bits of address for the 4-Gbyte space are ignored).

For example, when the **U0** area (00000000 to 0x7fffffff) that can be used in user mode is mapped to the external memory (512 Mbytes), overlapped objects can be detected through the following setting.

```
-PS_check=00000000-1fffffff,20000000-3fffffff,  
40000000-5fffffff,60000000-7fffffff
```

This setting means that addresses 00000000, 20000000, 40000000, and 60000000 are allocated to the same location in the actual memory.

Remarks: This option is only valid for the SuperH Family CPUs.

This option is invalid if **object**, **relocate**, or **library** is specified for the **output** format (**form** option).

This option is invalid when an absolute file is input.

For the address space specifications of the CPU, refer to the hardware manual of the target CPU.

CONTIGUOUS_SECTION

Not divide the specific section

Link/Library <Verify> [Not divide the specified section :]

Format: CONTIGUOUS_SECTION=<section name>[,...]

Description: Allocates the specified section to another available area of the same memory type without dividing the section when **cpu=stride** is valid.

Examples: `start=P, PA, PB/100`
`cpu=ROM=100-1FF, ROM=300-3FF, ROM=500-5FF`
`cpu=stride`
`contiguous_section=PA`

Section **P** is allocated to address 100.

If section **PA** which is specified as **contiguous_section** is over address 1FF, section **PA** is allocated to address 300 without being divided.

If section **PB** which is not specified as **contiguous_section** is over address 3FF, section **PB** is divided and allocated to address 500.

Remarks: When **cpu=stride** is invalid, this option is unavailable.

4.2.7 Other Options

Table 4.13 Other Category Options

Item	Command Line Format	Dialog Menu	Specification
End code	S9	Link/Library <Other> [Miscellaneous options :] [Always output S9 record at the end]	Always outputs the S9 record.
Stack information file	STACK	Link/Library <Other> [Miscellaneous options :] [Stack information output]	Outputs a stack use information file.
Debugging information compression	Compress <u>NOCOMpress</u>	Link/Library <Other> [Miscellaneous options :] [Compress debug information]	Compresses debugging information Does not compress debugging information
Memory occupancy reduction	MEMory = [<u>High</u> Low]	Link/Library <Other> [Miscellaneous options :] [Low memory use during linkage]	Specifies the memory occupancy when an input file is loaded
Symbol name modification	REName = <sub>[,...] <sub>: {<file name> (<name>=<name>[,...]) <module name> (<name><name>[,...]) }	Link/Library <Other> [User defined options :]	Modifies a symbol name or section name.
Symbol name deletion	DELeTe = <sub>[,...] <sub>: {<module name> [<file name> (<name>[,...]) }	Link/Library <Other> [User defined options :]	Deletes a symbol name or module name.
Module replacement	REPlace = <sub>[,...] <sub>: <file> [(<module>[,...])]	Link/Library <Other> [User defined options :]	Replaces modules of the same name in a library file.
Module extraction	EXTRact = <module>[,...]	Link/Library <Other> [User defined options :]	Extracts the specified module in a library file.
Debugging information deletion	STRip	Link/Library <Other> [User defined options:]	Deletes debugging information in an absolute file or a library file.

Item	Command Line Format	Dialog Menu	Specification
Message level	CHange_message=<sub>[,...] <sub>: {Information Warning Error } [=<error number> [-<error number>] [...]]	Link/Library <Other> [User defined options:]	Modifies message levels.
Local symbol name hide	Hide	Link/Library <Other> [User defined options:]	Deletes local symbol name information
Showing total sizes of sections	Total_size	Link/Library <Other> [Miscellaneous options :] [Displays total section size]	This newly added option sends total sizes of sections after linkage to standard output.
Information file for the emulator	RTs_file	Link/Library <Other> [Miscellaneous options :] [Rts information output]	Outputs an information file for the emulator (for SuperH Family).

S9 End Code

Link/Library <Other>[Miscellaneous options :][Always output S9 record at the end]

Format: S9

Description: Outputs the **S9** record at the end even if the entry address exceeds 0x10000.

Remarks: When **form=stype** is not specified, this option is unavailable.

STACK

Stack Information File

Link/Library <Other>[Miscellaneous options :][Stack information output]

Format: STACK

Description: Outputs a stack consumption information file.

The file name is <output file name>.sni.

Remarks: When **form**={**object** | **relocate** | **library**} or **strip** is specified, this option is unavailable.**COmpress, NOCOmpress**

Debugging Information Compression

Link/Library <Other>[Miscellaneous options :][Compress debug information]

Format: COmpress

NOCOmpress

Description: Specifies whether debugging information is compressed.

When **compress** is specified, the debugging information is compressed.When **nocompress** is specified, the debugging information is not compressed.By compressing the debugging information, the debugger loading speed is improved. If the **nocompress** option is specified, the link time is reduced.If this option is omitted, the default is **nocompress**.Remarks: When **form**={**object** | **relocate** | **library** | **hexadecimal** | **stype** | **binary**} or **strip** is specified, the compress option is unavailable.

MEMory

Memory Occupancy Reduction

Link/Library <Other>[Miscellaneous options :][Low memory use during linkage]

Format: MEMory = [High | Low]

Description: Specifies the memory size occupied for linkage.

When **memory = high** is specified, the processing is the same as usual.

When **memory = low** is specified, the linkage editor loads the information necessary for linkage in smaller units to reduce the memory occupancy. This increases file accesses and processing becomes slower when the occupied memory size is less than the available memory capacity.

memory = low is effective when processing is slow because a large project is linked and the memory size occupied by the linkage editor exceeds the available memory in the machine used.

Remarks: When one of the following options is specified, the **memory=low** option is unavailable:

When **form=absolute, hexadecimal, stype, or binary** is specified:

compress, delete, rename, map, stack, cpu=stride, or list and show[={reference | xreference}] are specified in combination.

When **form=library** is specified:

delete, rename, extract, hide, or replace

When **form=object or relocate** is specified:

extract

When the microcontroller is of a type that is not a member of the NC family and **optimize** is specified.

Some combinations of this option and the input or output file format are unavailable. For details, refer to table 4.4 in section 4.2.2, Output Options.

REName

Symbol Name Modification

Link/Library <Other>[User defined options :]

Format: REName = <suboption> [,...]

```
<suboption>: {[<file>] (<name> = <name> [,...])
              | [<module>] (<name> = <name> [,...]) }
```

Description: Modifies a symbol name or a section name.

Symbol names or section names in a specific file or library in a module can be modified.

For a C/C++ variable name, add an underscore (`_`) at the head of the definition name in the program.

When a function name is modified, the operation is not guaranteed.

If the specified name matches both section and symbol names, the symbol name is modified.

If there are several files or modules of the same name, the priority depends on the input order.

Examples: `rename=(_sym1=data) ;` Modifies **_sym1** to **data**.

```
rename=lib1 (P=P1) ;
```

 Modifies the section **P** to **P1**
; in the library module **lib1**.
Remarks: When **extract** or **strip** is specified, this option is unavailable.

When **form=absolute** is specified, the section name of the input library cannot be modified.

DELeTe

Symbol Name Deletion

Link/Library <Other>[User defined options :]

Format: DELeTe = <suboption> [,...]

<suboption>: {[<file>] (<name>[,...]) | <module>}

Description: Deletes an external symbol name or library module.

Symbol names or modules in the specified file can be deleted.

For a C/C++ variable name or C function name, add an underscore (_) at the head of the definition name in the program. For a C++ function name, enclose the definition name in the program with double-quotes including the parameter strings. If the parameter is **void**, specify as "<function name>()". If there are several files or modules of the same name, the file that is input first is applied.

When a symbol is deleted using this option, the object is not deleted but the attribute is changed to the internal symbol.

Examples: `delete=(_sym1)` ; Deletes the symbol **_sym1** in all files.

`delete=file1.obj(_sym2)` ; Deletes the symbol **_sym2**
; in the file **file1.obj**.

Remarks: When **extract** or **strip** is specified, this option is unavailable.

When **form=library** has been specified, this option deletes modules.

When **form={absolute|relocate|hexadecimal|stype|binary}** has been specified, this option deletes external symbols.

REPlace

Module Replacement

Link/Library <Other>[User defined options :]

Format: REPlace = <suboption> [,...]

<suboption>: <file name> [(<module name> [,...]) }

Description: Replaces library modules.

Replaces the specified file or library module with the module of the same name in the library specified with the **library** option.Examples: `replace=file1.obj` ; Replaces the module **file1**
; with the module **file1.obj**.`replace=lib1.lib(md11)` ; Replaces the module **md11** with
; the module **md11** in the input library
; file **lib1.lib**.Remarks: When **form={object | relocate | absolute | hexadecimal | stype | binary}**,
extract, or **strip** is specified, this option is unavailable.

EXtract

Module Extraction

Link/Library <Other>[User defined options :]

Format: EXtract = <module name> [,...]

Description: Extracts library modules.

Extracts the specified library module from the library file specified using the **library** option.

Examples: `extract=file1` ; Extracts the module **file1**.

Remarks: When **form**={**absolute** | **hexadecimal** | **stype** | **binary**} or **strip** is specified, this option is unavailable.

When **form**=**library** has been specified, this option deletes modules.

When **form**={**absolute**|**relocate**|**hexadecimal**|**stype**|**binary**} has been specified, this option deletes external symbols.

STRip

Debugging Information Deletion

Link/Library <Other>[User defined options :]

Format: STRip

Description: Deletes debugging information in an absolute file or library file.

When the **strip** option is specified, one input file should correspond to one output file.

Examples: `input=file1.abs file2.abs file3.abs`
`strip`

Deletes debugging information of **file1.abs**, **file2.abs**, and **file3.abs**, and outputs this information to **file1.abk**, **file2.abk**, and **file3.abk**, respectively. Files before debugging information is deleted are backed up in **file1.abk**, **file2.abk**, and **file3.abk**.

Remarks: When **form**={**object** | **relocate** | **hexadecimal** | **stype** | **binary**} is specified, this option is unavailable.

CHange_message

Message Level

Link/Library <Other>[User defined options :]

Format: CHange_message = <suboption> [,...]
 <suboption>: <error level> [= <error number> [-<error number>] [,...]
 <error level>: {Information | Warning | Error}

Description: Modifies the level of information, warning, and error messages.
 Specifies the execution continuation or abort at the message output.

Examples: `change_message=warning=2310`
 Modifies L2310 to the warning level and specifies execution continuation at L2310 output.

`change_message=error`
 Modifies all information and warning messages to error level messages.
 When a message is output, the execution is aborted.

Hide

Local Symbol Name Hide

Link/Library <Other>[User defined options :]

Format: Hide

Description: Deletes local symbol name information from the output file. Since all the name information regarding local symbols is deleted, local symbol names cannot be checked even if the file is opened with a binary editor. This option does not affect the operation of the generated file.

Use this option to keep the local symbol names secret.

The following types of symbol names are hidden:

C source: Variable or function names specified with the **static** qualifiers

C source: Label names for the **goto** statements

Assembly source: Symbol names of which external definition (reference) symbols are not declared

Note: The entry function name is not hidden.

Examples: The following is a C source example in which this option is valid:

```
int g1;
int g2=1;
const int g3=3;
static int s1;          /*<- The static variable name will be hidden.
static int s2=1;       /*<- The static variable name will be hidden.
static const int s3=2; /*<- The static variable name will be hidden.

static int sub1()      /*<- The static function name will be hidden.
{
    static int s1;     /*<- The static variable name will be hidden.
    int l1;

    s1 = l1; l1 = s1;
    return(l1);
}

int main()
{
    sub1();
    if (g1==1)
        goto L1;
    g2=2;
L1:          /*<- The label name of the goto statement
            // will be hidden.

    return(0);
}
```

Remarks: This option is available only when the output file format is specified as **absolute**, **relocate**, or **library**.

When the input file was compiled or assembled with the **goptimize** option specified, this option is unavailable if the output file format is specified as **relocate** or **library**.

To use this option with the external variable access optimization, do not use this option for the first linkage, and use it only for the second linkage.

The symbol names in the debugging information are not deleted by this option.

Total_size

Showing total sizes of sections

Link/Library <Other> [Miscellaneous options :] [Displays total section size]

Format: Total_size

Description: Sends total sizes of sections after linkage to standard output. The sections are categorized as follows, with the overall size of each being output.

- Executable program sections
- Non-program sections allocated to the ROM area
- Sections allocated to the RAM area

This option makes it easy to see the total sizes of sections allocated to the ROM and RAM areas.

Remarks: The **show=total_size** option must be used if total sizes of sections are to be output in the linkage listing.

When the ROM-support function (**rom** option) has been specified for a section, the section will be used by both the source (ROM) and destination (RAM) of the transfer. The sizes of sections of this type will be added to the total sizes of sections in both ROM and RAM.

RTs_file

Information File for the Emulator

Link/Library <Other> [Miscellaneous options :] [Rts information output]

Format: RTs_file

Description: This option creates a return address information file (**.rts** file) for the emulator. For usage of this option, refer to the user's manual for the emulator in use. This option is not available in some types of emulators.

The name of the return address information file is **<load module name>.rts**. If the file to be output is **test.abs** as specified with the **output** option, for example, its file will be created as **test.rts**. The return address information file is created under the same directory where the load module has been created.

Remarks: This option is invalid when **form={object | relocate | library}** has been specified.

This option is invalid when an absolute file is selected as an input file.

For usage of this option, refer to the user's manual for the emulator in use. This option is not available in some types of emulators.

This option can be used when the CPU type is SuperH Family.

4.2.8 Subcommand File Options

Table 4.14 Subcommand Tab Option

Item	Command Line Format	Dialog Menu	Specification
Subcommand file	SUbcommand = <file name>	Link/Library <Subcommand file> [Use external subcommand file]	Specifies options with a subcommand file

Subcommand	Subcommand File
------------	-----------------

Link/Library <Subcommand file> [Use external subcommand file]

Format: SUBcommand = <file name>

Description: Specifies options with a subcommand file.

The format of the subcommand file is as follows:

<option> { = | Δ } [<suboption> [,...]] [Δ&] [;<comment>]

The option and suboption are separated by an “=” sign or a space.

For the **input** option, suboptions are separated by a space.

One option is specified per line in the subcommand file.

If a subcommand description exceeds one line, the description can be allowed to overflow to the next line by using an ampersand (&).

The **subcommand** option cannot be specified in the subcommand file.

Examples: Command line specification:

```
optlnk file1.obj -sub=test.sub file4.obj
```

Subcommand specification:

```
input file2.obj file3.obj ; This is a comment.  
library lib1.lib, & ; Specifies line continued.  
lib2.lib
```

Option contents specified with a subcommand file are expanded to the location at which the subcommand is specified on the command line and are executed.

The order of file input is **file1.obj**, **file2.obj**, **file3.obj**, and **file4.obj**.

4.2.9 CPU Option

Table 4.15 CPU Tab Option

Item	Command Line Format	Dialog Menu	Specification
SBR address specification	SBr = { <SBR address> User }	CPU [Specify SBR address :]	Specifies the start address of the 8-bit absolute area (for H8SX Family).

SBr	SBR Address Specification
	CPU [Specify SBR address :]

Format: SBr = { <address> | User }

Description: Specifies the **SBR** address.

When the **SBR** address is specified in this option, optimization using the **abs8** area is available. When **user** is specified in this option, optimization for the **abs8** area is disabled.

Remarks: This option is available only when the CPU is H8SX Family.

If more than one **SBR** address is specified within the source or by tool options, the optimizing linkage editor assumes that **user** is specified regardless of this option setting.

4.2.10 Options Other Than Above

Table 4.16 Options Other Than Above

Item	Command Line Format	Dialog Menu	Specification
Copyright	<u>LOgo</u> NOLOgo	— (NOLOgo is always valid)	Output Not output
Continuation	END	—	Executes option strings already input, inputs continuing option strings and continues processing.
Termination	EXIt	—	Specifies the termination of option input.

LOgo, NOLOgo

Copyright

None (nologo is always available.)

Format: LOgo

NOLOgo

Description: Specifies whether the copyright is output.

When the **logo** option is specified, the copyright is displayed.

When the **nologo** option is specified, the copyright display is disabled.

When this option is omitted, the default is **logo**.

END

Execution Continued

None

Format: **END**

Description: Executes option strings specified before **END**. After the linkage processing is terminated, option strings that are specified after **END** are input and the linkage processing is continued.

This option cannot be specified on the command line.

Examples: =a.obj,b.obj ; Processing (1)
 start=P,C,D/100,B/8000 ; Processing (2)
 output=a.abs ; Processing (3)
 end
 =a.abs ; Processing (4)
 form=stype ; Processing (5)
 output=a.mot ; Processing (6)

Executes the processing from (1) to (3) and outputs **a.abs**. Then executes the processing from (4) to (6) and outputs **a.mot**.

EXIt

Termination Processing

None

Format: EXIt

Description: Specifies the end of the option specifications.

This option cannot be specified on the command line.

Examples: Command line specification:

```
optlnk -sub=test.sub -nodebug
```

test.sub:

```
input=a.obj,b.obj          ; Processing (1)
start=P,C,D/100,B/8000     ; Processing (2)
output=a.abs               ; Processing (3)
exit
```

Executes the processing from (1) to (3) and outputs **a.abs**.

The **nodebug** option specified on the command line after **exit** is executed is ignored.

Section 5 Standard Library Generator Operating Method

5.1 Option Specifications

The format of the command line is as follows:

```
lbgsh [ $\Delta$ <option string>...]  
      <option string>:-<option>[=<suboption>[,...]]
```

5.2 Option Descriptions

Options and suboptions of the standard library generator are based on the compiler options. The following section describes the difference between the options and suboptions of the standard library generator and those of the compiler. For details on compiler options, refer to section 2, Compiler Options.

In the command line format, uppercase letters indicate abbreviations. The format of the dialog menus that correspond to the integrated development environment is as follows: Category name [Item].

5.2.1 Additional Options

Table 5.1 shows additional options.

Table 5.1 Additional Options

Item	Command Line Format	Dialog Menu	Specification
Header file	Head = <sub>[,...] <sub>:{ <u>ALL</u> RUNTIME CTYPE MATH MATHF STDARG STDIO STDLIB STRING IOS NEW COMPLEX CPPSTRING }	Library [Category:]	Specifies a configuration file. All library functions Runtime routine ctype.h + runtime routine ctype.h + runtime routine math.h + runtime routine mathf.h + runtime routine stdarg.h + runtime routine stdio.h + runtime routine stdlib.h + runtime routine string.h + runtime routine ios + runtime routine new + runtime routine complex + runtime routine string + runtime routine
Output file	OUTPut = <file name>	Object [Output file:]	Specifies an output library file name.
Simple I/O function	NOFLoat	Object [Simple I/O function:]	Creates simple I/O function.
Reentrant library	REent	Object [Generate reentrant library:]	Creates reentrant library.

Head

Library [Category:]

- Command Line Format

Head = <sub>[,...]

```
<sub>:{ ALL
      | RUNTIME
      | CTYPE
      | MATH
      | MATHF
      | STDARG
      | STDIO
      | STDLIB
      | STRING
      | IOS
      | NEW
      | COMPLEX
      | CPPSTRING      }
```

- Description

Specifies a configuration file with a header file name. For relationships between header files and library functions, refer to section 10.4, C/C++ Library. The runtime routine is always configured. The default of this option is **head=all**.

- Example

```
lbgsh -output=sh2.lib -head=mathf -cpu=sh2
```

Compiles library functions defined by mathf.h and runtime routine with option: -cpu=sh2, and outputs library file sh2.lib.

OUTPut

Object [Output file:]

- Command Line Format
OUTPut = <File name>
- Description
Specifies an output file name. The default of this option is **output=stdlib.lib**.
- Example

```
lbgsh -output=sh2.lib -optimize -speed -goptimize -cpu=sh2
```

Compiles all standard library source files with options: -optimize -speed -goptimize -cpu=sh2, and outputs library file sh2.lib.

NOFLoat

Object[Simple I/O function:]

- Command Line Format
NOFLoat
- Description
Selects the creation of simple I/O functions that do not support the conversion of floating point numbers (%f, %e, %E, %g, %G). When inputting or outputting files that do not require the conversion of floating point numbers, ROM can be saved.
Target functions: fprintf, fscanf, printf, scanf, sprintf, sscanf, vfprintf, vprintf, and vsprintf
- Remarks
When a floating-point number is specified in I/O functions, linkages of library that are created by this option will not operate correctly on the floating-point number thus specified.

REent

Object[Generate reentrant library:]

- Command Line Format
REent
- Description
Creates reentrant functions. Note that the **rand** and **srand** functions are not reentrant functions.

- Remarks

When reentrant functions are linked, use `#define` statements to define macro names (**`#define _REENTRANT`**) or use the **`define`** option to define **`_REENTRANT`** at compilation before including standard include files in the program.

5.2.2 Options Not Available for the Standard Library Generator

Table 5.2 shows options that cannot be specified for the standard library generator. If any of the options listed in table 5.2 are specified, these specifications are ignored.

Table 5.2 Options Not Available for Standard Library Generator

Item	Option	Compiler Interpretation	Description
Include file directory	include	None	—
Inter-file inline expansion directory specification	file_inline_path	None	—
Macro name definition	define	None	—
Message output control	message nomessage	nomessage	No output
Preprocessor inline output	preprocessor	None	—
Restriction for output at preprocessor expansion	noline	None	—
Object type	code	code = machinecode	Outputs machine code program
Debugging information	debug nodebug	nodebug	No output
Object file output	objectfile	None	—
Template instance generation	template	None	No template function used
Listing file	listfile nolistfile	nolistfile	No output
Listing format	show	None	—
Inter-file inline expansion	file_inline	None	—

Table 5.2 Options Not Available for Standard Library Generator (cont)

Item	Option	Compiler Interpretation	Description
Comment nesting	comment	None	No comment nesting function used
MAC register	macsave	macsave = 1	Contents of MACH and MACL registers are guaranteed.
Message level	change_message	None	—
Selecting C or C++ language	lang	None	Determined by an extension
Disable of Copyright output	logo nologo	nologo	Copyright output disabled
Character code select in euc string literals	sjis latin1	None	No character code used
Japanese character conversion within object code	outcode	None	No character code used
TBR relative function call	tbr	None	—
Disposition of variables in \$G0/\$G1	stuff_gbr	None	—
Preventing expansion of C++ inline functions	cpp_noinline	None	—
Optimization considering alias type of object indicated by pointer		alias=noansi	Optimization in consideration of types of objects indicated by pointers in compliance with the ANSI standard is not performed

5.2.3 Notes on Specifying Options

When options are specified, follow the rules below:

- (1) Specify the same options as in compiling for options **cpu**, **division**, **endian**, **fpu**, **round**, **denormalize**, **pic**, **double=float**, **rtti**, and **pack**.
- (2) When `#pragma global_register` is used, specify a header file that includes the `#pragma global_register` declaration with the **preinclude** option. When the integrated development environment is used, specify it with Other[User defined options:].

Section 6 Operating CallWalker

6.1 Overview

The CallWalker displays the stack amount by reading the stack information file (*.sni) output by the optimizing linkage editor or the profile information file (*.pro) output by the simulator debugger.

For the stack amount of the assembly program (assembled by the assembler of V6 or earlier) that cannot be output in the stack information file, the information can be added or modified by using the edit function. In addition, the stack amount of whole systems can be calculated.

The information on the edited stack amount can be saved and read as the call information file (*.cal).

6.2 Starting the CallWalker

To start the CallWalker, select [Run...] from the start menu of Windows® and specify Call.exe for execution.

When the Renesas High-Performance Embedded Workshop is used, select [Program] from the start menu of Windows®, select the Renesas High-Performance Embedded Workshop menu, and then select Call Walker.

After the Renesas High-Performance Embedded Workshop is started, the CallWalker can also be started from the [Tools] menu.

For details on operation, refer to the help of the CallWalker.

Section 7 Environment Variables

7.1 Environment Variable List

Environment variables are listed in table 7.1.

Table 7.1 Environment Variables

Environment Variable	Description
path	Specifies a storage directory for the execution file. Specification format: C> path = <execution file path name>; [<previous path name>;...]
SHC_LIB	Specifies a directory at which compiler load modules exist. This environment variable must be specified for compilation from the command prompt. Specification format: C> set SHC_LIB = <execution file path name>

Table 7.1 Environment Variables (cont)

Environment Variable	Description
SHCPU	<p>Specifies the CPU type by the cpu option of the compiler or assembler using environment variables. The following is specified.</p> <p><CPU></p> <p>SH1</p> <p>SH2</p> <p>SH2E</p> <p>SH2A</p> <p>SH2AFPU</p> <p>SH2DSP</p> <p>SH3</p> <p>SH3DSP</p> <p>SH4</p> <p>SH4A</p> <p>SH4ALDSP</p> <p>When the specification of CPU by the SHCPU environment variable and the cpu options differ, a warning message is displayed and the cpu option has priority over the SHCPU specification.</p> <p>When SHDSP is specified for the compiler, SH2DSP is assumed.</p> <p>Specification format: C> set SHCPU = <CPU></p>

Table 7.1 Environment Variables (cont)

Environment Variable	Description
SHC_INC*	<p>Specifies a directory at which a system include file of the compiler exists. A system include file is searched for at a directory specified by the include option, SHC_INC specified directory, and system directory (SHC_LIB) in this order. User include files are searched for at the current directory, a directory specified by the include option, SHC_INC specified directory, and system directory (SHC_LIB) in this order.</p> <p>If this option is not specified, no value is set.</p> <p>Specification format: C> set SHC_INC = <include path name> [<include path name>; ...]</p>
SHC_TMP	<p>Specifies a directory for a temporary file generated by the compiler. This environment variable must be specified for compilation from the command prompt.</p> <p>Specification format: C> set SHC_TMP = <temporary file path name></p>

Table 7.1 Environment Variables (cont)

Environment Variable	Description
HLNK_LIBRARY1 HLNK_LIBRARY2 HLNK_LIBRARY3	<p>Specifies a default library name for the optimizing linkage editor. Libraries which are specified by a library option are linked first. Then, if there is an unresolved symbol, the default libraries are searched in the order 1, 2, 3.</p> <p>Specification format: C> set HLNK_LIBRARY1 = <library name 1> C> set HLNK_LIBRARY2 = <library name 2> C> set HLNK_LIBRARY3 = <library name 3></p>
HLNK_TMP	<p>Specifies a directory in which the optimizing linkage editor creates temporary files. If HLNK_TMP is not specified, the temporary files are created in the current directory.</p> <p>Specification format: C> set HLNK_TMP = <temporary file path name></p>
HLNK_DIR*	<p>Specifies an input file storage directory for the optimizing linkage editor. The order of searching for files specified by the input or library option is the current directory then the directory specified as HLNK_DIR.</p> <p>However, when a wild card is used in the file specification, only the current directory is searched.</p> <p>Specification format: C> set HLNK_DIR = <input file path name> [;<input file path name >;...]</p>

Note: More than one directory can be specified by using semicolons (;) or commas (,) to demarcate the directory names.

7.2 Compiler Implicit Declaration

The following implicit **#define** declarations are made by the compiler according to the option specification and the version.

Table 7.2 Compiler Implicit Declaration

Option	Implicit Declaration
cpu=sh1	#define _SH1
cpu=sh2	#define _SH2
cpu=sh2e	#define _SH2E
cpu=sh2a	#define _SH2A
cpu=sh2afpu	#define _SH2AFPU
cpu=sh2dsp	#define _SH2DSP
cpu=sh3	#define _SH3
cpu=sh3dsp	#define _SH3DSP
cpu=sh4	#define _SH4
cpu=sh4a	#define _SH4A
cpu=sh4aldsp	#define _SH4ALDSP
pic=1	#define _PIC
endian=big	#define _BIG
endian=little	#define _LIT
double=float	#define _FLT, #define __FLT__
fpu=single	#define _FPS
fpu=double	#define _FPD
denormalize=on	#define _DON
round=nearest	#define _RON
dspc	#define _DSPC
fixed_const	#define _FXD
—	#define __HITACHI_VERSION__ *1
—	#define __HITACHI__ *2
—	#define _SH*2
—	#define __RENASAS_VERSION__ *1
—	#define __RENASAS__ *2

Notes: 1. The value of `__HITACHI_VERSION__` and `__RENESAS_VERSION__` is referenced as follows:

C source program: `__HITACHI_VERSION__==aabb`

aa: version

bb: revision

Example definition in the compiler:

```
#define __HITACHI_VERSION__ 0x0701 //V.7.1.00
```

```
#define __HITACHI_VERSION__ 0x0900 //V.9.00.00
```

```
#define __RENESAS_VERSION__ 0x0900 //V.9.00.00
```

2. Always defined.

Section 8 File Specifications

8.1 Naming Files

A standard file extension is automatically added to the name of a compiled file when omitted. The standard file extensions used by the integrated development environment are shown in table 8.1.

Table 8.1 Standard File Extensions Used by the Integrated Development Environment

No.	File Extension	Description
1	c	Source program file written in C
2	cpp, cc, cp	Source program file written in C++
3	h	Include file
4	lst	C source program listing file
5	lpp	C++ source program listing file
6	p	C source program preprocessor expansion file
7	pp	C++ source program preprocessor expansion file
8	src	Assembly source program file
9	exp	Assembly program preprocessor expansion file
10	lis	Assembly program listing file
11	obj	Relocatable object program file
12	rel	Relocatable load module file
13	abs	Absolute load module file
14	map	Linkage map listing file
15	lib	Library file
16	lbp	Library listing file
17	mot	S-type format file
18	hex	HEX format file
19	bin	Binary file
20	fsy	Symbol address file for optimizing linkage editor output
21	sni	Stack information file
22	pro	Profile information file
23	dbg	DWARF2-format debugging information file
24	rti	Object file including definition that was specified by a file with extension td
25	cal	Information file to be called
26	bls	Information file for external symbol allocation

Filenames beginning with **rti_** are reserved for the system; do not use those files.

Table 8.2 lists the extensions for files that are output under the `tpldir` folder generated by each project.

Table 8.2 tpldir Folder Output File

No.	File Extension	Description
1	td	Tentative-defined variable information file
2	ti	Template information file
3	pi	Parameter information file
4	ii	Instance information file

For details on naming files, refer to the user's manual of the host computer because naming rules vary according to each host computer.

8.2 Compiler Listings

This section covers the contents and format of the compiler formats.

8.2.1 Structure of Compiler Listings

Table 8.3 shows the structure and contents of compiler listings.

Table 8.3 Structure and Contents of Compiler Listings

Creating List	Contents	Suboption *1	Default
Source listing information	Source program listing *2	show=source show=nosource	No output
	Source program listing after include file expansion *3	show=include show=noinclude	No output
	Source program listing after macro expansion *3	show=expansion show=noexpansion	No output
Object information	Machine code used in object programs and the assembly code	show=object show=noobject	Output
Statistics information	Total number of errors, number of source program lines, size of each section, and number of symbols	show=statistics show=nostatistics	Output
Command specification information	Displays file names and options specified by the command		Output

Notes: 1. All options are valid when **listfile** option is specified.

2. Source program listings are included in the object information when **show=object** suboption is specified.

3. The source program listing after include file expansion and macro expansion is valid only when **show=source** is specified.

8.2.2 Source Listing

The source listing may be output in two ways. When **show=noinclude, noexpansion** is specified, the unpreprocessed source program is output. When **show=include, expansion** is specified, the preprocessed source program is output. Figures 8.1 and 8.2 show these output formats, respectively. In addition, figure 8.2 shows the differences between them with bold characters.

```

***** SOURCE LISTING *****

FILE NAME: m0260.c

Seq      File      Line      0----+----1----+----2----+----3----+----4----+----5----
  1      m0260.c      1          #include "header.h"
  4      m0260.c      2
  5      m0260.c      3          int sum2(void)
  6      m0260.c      4          {   int j;
  7      m0260.c      5
  8      m0260.c      6          #ifdef SMALL
  9      m0260.c      7              j=SML_INT;
 10      m0260.c      8          #else
 11      m0260.c      9              j=LRG_INT;
 12      m0260.c     10          #endif
 13      m0260.c     11
 14      m0260.c     12          return j;/* continue123456789012345678901234567
(1)      (2)      (3)          +2345678901234567890 */
              (7)
 15      m0260.c     13          }
    
```

Figure 8.1 Source Listing Output for show = noinclude, noexpansion

```

***** SOURCE LISTING *****

FILE NAME: m0260.c

Seq      File  Line  0-----1-----2-----3-----4-----5---
  1  m0260.c   1      #include "header.h"
  2  header.h   1      #define SML_INT      1
  3  header.h   2      #define LRG_INT      100      (4)
  4  m0260.c   2
  5  m0260.c   3      int sum2(void)
  6  m0260.c   4      {  int j;
  7  m0260.c   5
  8  m0260.c   6      #ifndef SMALL
  9  m0260.c   7  X (5)          j=SML_INT;
10  m0260.c   8      #else
11  m0260.c   9  E (6)          j=100;
12  m0260.c  10      #endif
13  m0260.c  11
14  m0260.c  12          return j;/* continue123456789012345678901234567
(1)  (2)  (3)          ±2345678901234564890 */
                        (7)
15  m0260.c  13      }

```

Figure 8.2 Source Listing Output for show=include, expansion

Description:

- (1) Listing line number
- (2) Source program file name or include file name
- (3) Line number in source program or include file
- (4) Source program lines resulting from an include file expansion when **show=include** is specified.
- (5) Source program lines that are not to be compiled due to conditional compile directives such as **#ifdef** and **#elif** being marked with an X when **show=expansion** is specified.
- (6) Source program lines containing a macro expansion **#define** directives being marked with an E when **show=expansion** is specified.
- (7) If a source program line is longer than the maximum listing line, the continuation symbol (+) is used to indicate that the source program line is extended over two or more listing lines.

8.2.3 Object Listing

Figure 8.3 shows an example of object listing.

```

***** OBJECT LISTING *****

FILE NAME: m0251.c

   SCT   OFFSET   CODE   C LABEL   INSTRUCTION OPERAND   COMMENT
   (1)   (2)     (3)                   (4)                   (5)

           m0251.c   1   extern int multipli(int);
           m0251.c   2
           m0251.c   3   int multipli(int x)
P 00000000           _multipli:           ;function: multipli
                                           ;frame size=16 (6)

00000000  4F22           STS.L   PR,R15
00000002  7FF4           ADD    #-12,R15
00000004  1F42           MOV.L  R4,@(8,R15)
           m0251.c   4   {
           m0251.c   5       int i;
           m0251.c   6       int j;
           m0251.c   7
           m0251.c   8       j=1;
00000006  E201           MOV    #1,R2
00000008  2F22           MOV.L  R2,@R15
           m0251.c   9   for(i=1;i<=x;i++){
0000000A  E301           MOV    #1,R3
0000000C  1F31           MOV.L  R3,@(4,R15)
0000000E  A009           BRA    L213
00000010  0009           NOP
00000012           L214:
           m0251.c  10           j*=i;
00000012  50F1           MOV.L  @(4,R15),R0
00000014  61F2           MOV    @R15,R1
00000016  D30A           MOV.L  L216+2,R3           ;_ _multi
00000018  430B           JSR    @R3
.
.

```

Figure 8.3 Object Listing Output for show = source, object

Description:

- (1) Section name (P, C, D, B, C\$INIT, and C\$VTBL) of each section
- (2) Offset address relative to the beginning of each section
- (3) Contents of the offset address of each section
- (4) Assembly code corresponding to machine language
- (5) Comments corresponding to the program
- (6) Stack frame size in bytes

8.2.4 Statistics Information

Figure 8.4 shows an example of statistics information.

```

***** STATISTICS INFORMATION *****

***** ERROR INFORMATION ***** (1)

NUMBER OF ERRORS:           0
NUMBER OF WARNINGS:        0
NUMBER OF INFORMATIONS:     0

***** SOURCE LINE INFORMATION ***** (2)

COMPILED SOURCE LINE:       13

***** SECTION SIZE INFORMATION ***** (3)

PROGRAM   SECTION (P) :      0x000044 Byte(s)
CONSTANT  SECTION (C) :      0x000000 Byte(s)
DATA      SECTION (D) :      0x000000 Byte(s)
BSS       SECTION (B) :      0x000000 Byte(s)

TOTAL PROGRAM SECTION: 00000044 Byte(s)
TOTAL CONSTANT SECTION: 00000000 Byte(s)
TOTAL DATA SECTION: 00000000 Byte(s)
TOTAL BSS SECTION: 00000000 Byte(s)

TOTAL PROGRAM SIZE: 0x000044 Byte(s)

***** LABEL INFORMATION ***** (4)

NUMBER OF EXTERNAL REFERENCE SYMBOLS:  1
NUMBER OF EXTERNAL DEFINITION SYMBOLS:  1
NUMBER OF INTERNAL/EXTERNAL SYMBOLS:    6
    
```

Figure 8.4 Statistics Information

Description:

- (1) Total number of messages by the level
- (2) Number of compiled lines from the source file
- (3) Size of each section and total size of sections
- (4) Number of external reference symbols, number of external definition symbols, and total number of internal and external labels

Note: NUMBER OF INFORMATIONS in messages by the level ((1) above) is not output when **message** option is not specified. Section size information (3) and label information (4) are not output if the **noobject** option has been specified or if an error-level error or a fatal-level error has occurred. In addition, section size information (3) is output (indicated as "1") or not output (indicated as "0") according to its specification when **code=asmcode** option is specified.

8.2.5 Command Line Specification

The file names and options specified on the command line when the compiler is invoked are displayed. Figure 8.5 shows an example of command line specification information.

```
*** COMMAND PARAMETER ***  
  
-listfile test.c
```

Figure 8.5 Command Line Specification

8.3 Assembly Listings

This section covers the contents and format of the assembly listing.

8.3.1 Structure of Assembly Listing

Table 8.4 shows the structure and contents of the assembly listing.

Table 8.4 Structure and Contents of Assembly Listing

Creating List	Contents	Option*	Default
Source list information	Specifies the source program information	source	Output
Cross reference list information	Specifies the source-program symbol information	cross_reference	Output
Section information list	Specifies the source-program section information	section	Output

Note: All the options above are enabled when **list** option is specified.

8.3.2 Source List Information

The source list information is output. Figure 8.6 shows an example of the source list information.

```

PROGRAM NAME =                "SAMPLE"                (7)
 1                          1  .HEADING ""SAMPLE""
 2                          2  POINT .ASSIGNA 16
 3                          3  Parm1 .REG (R0)
 4                          4  Parm2 .REG (R1)
 5                          5  WORK1 .REG (R2)
 6                          6  WORK2 .REG (R3)
 7                          7  WORK3 .REG (R4)
 8                          8  WORK4 .REG (R5)
:
20 00000000                9 I1 FIX_MUL:
21 00000000 2107           10 I1   DIV0S  Parm1, Parm2
22 00000002 0229           11 I1   MOVT  WORK1
23 00000004 4011           12 I1   CMP/PZ Parm1
24 00000006 8900           13 I1   BT    MUL01
25 00000008 600B           14 I1   NEG   Parm1, Parm1
(1) (2) (3) (4) (5) (6)
:
231 ***** BEGIN-POOL *****
232 00000180 00018000      DATA FOR SOURCE-LINE 17
233 00000184 00024000      DATA FOR SOURCE-LINE 18
234 00000188 00030000      DATA FOR SOURCE-LINE 19
235 0000018C 00050000      DATA FOR SOURCE-LINE 20
236 ***** END-POOL *****
237                          35          .END
****TOTAL ERRORS            0
****TOTAL WARNINGS         0
(9)

```

Figure 8.6 Source Program Listing

Description:

- (1) Line numbers (in decimal)
- (2) The value of the location counter (in hexadecimal)
- (3) The object code (in hexadecimal). The size of the reserved area in bytes is listed for areas reserved with the .RES, .SRES, .SRESC, .SRESZ, and .FRES.
- (4) Source line numbers (in decimal)
- (5) Expansion type. Whether the statement is expanded by file inclusion, conditional assembly function, or macro function is listed.
 - In: File inclusion (n indicates the nest level).
 - C: Satisfied conditional assembly, performed iterated expansion, or satisfied conditional iterated expansion
 - M: Macro expansion
- (6) The source statements
- (7) The header setup with the .HEADING assembler directive.
- (8) The literal pool
- (9) The total number of errors and warnings. Error messages are listed on the line following the source statement that caused the error.

8.3.3 Cross Reference Listing

The cross reference information is output. Figure 8.7 shows an example of the cross reference information listing.

*** CROSS REFERENCE LIST											
NAME	SECTION	ATTR	VALUE	SEQUENCE							
FIX_DIV	SAMPLE		00000088	91*	223						
FIX_MUL	SAMPLE		00000000	19*	218						
MUL01	SAMPLE		0000000A	23	25*						
MUL02	SAMPLE		00000010	26	28*						
MUL03	SAMPLE		00000082	87	89*						
Parm1		REG		3*	20	22	24	24			
					28	29	29	31	32		
					32	35	36	36	38		
					40	45	49	55	57		
					59	61	63	65	67		
					69	71	73	75	77		
Parm2		REG		4*	20	25	27	27			
					28	31	33	33	35		
					38	41	43	44	46		
					48	54	56	58	60		
					62	64	66	68	70		

Figure 8.7 Cross Reference Listing

Description:

- (1) The symbol name
- (2) The name of the section that includes the symbol (first eight characters)
- (3) The symbol attribute
 - EXPT: Export symbol
 - IMPT: Import symbol
 - SCT: Section name
 - REG: Symbol defined with the .REG assembler directive
 - FREG: Symbol defined with the .FREG assembler directive
 - ASGN: Symbol defined with the .ASSIGN assembler directive
 - EQU: Symbol defined with the .EQU assembler directive
 - MDEF: Symbol defined two or more times
 - UDEF: Undefined symbol

No symbol attribute (blank): A symbol other than those listed above

- (4) The value of symbol (in hexadecimal)
- (5) The list line numbers (in decimal) of the source statements where the symbol is defined or referenced. The line number marked with an asterisk is the line where the symbol is defined.

8.3.4 Section Information Listing

The section information is output. Figure 8.8 shows an example of the section information output.

*** SECTION DATA LIST			
SECTION	ATTRIBUTE	SIZE	START
<u>SAMPLE</u>	<u>REL-CODE</u>	<u>000000190</u>	<u> </u>
(1)	(2)	(3)	(4)

Figure 8.8 Section Information Listing

Description:

- (1) The section name
- (2) The section type
 - REL: Relative address section
 - ABS: Absolute address section
 - CODE: Code section
 - DATA: Data section
 - STACK: Stack section
 - DUMMY: Dummy section
- (3) The section size (in hexadecimal, byte units)
- (4) The start address of absolute address sections

8.4 Linkage List

This section covers the contents and format of the linkage list output by the optimizing linkage editor.

8.4.1 Structure of Linkage List

Table 8.5 shows the structure and contents of the linkage list.

Table 8.5 Structure and Contents of Linkage List

No.	Output Information	Contents	When show Option* is Specified	When show Option is not Specified
1	Option information	Option strings specified by a command line or subcommand	None	Output
2	Error information	Error messages	None	Output
3	Linkage map information	Section name, start/end addresses, size, and type	None	Output
4	Symbol information	Static definition symbol name, address, size, and type in the order of address When show=reference is specified: Symbol reference count and optimization information in addition to the above information	show =symbol show =reference	Not output Not output
5	Symbol deletion optimization information	Symbols deleted by optimization	show =symbol	Not output
6	Cross-reference information	Symbol reference information	show =xreference	Not output
7	Total section size	Total sizes of RAM, ROM, and program sections	show=total_size	Not output
8	Vector information	Vector numbers and address information	show=vector	Not output
9	CRC information	CRC calculation result and output addresses	None	Always output when the CRC option is specified

Note: * The **show** option is valid when the **list** option is specified.

8.4.2 Option Information

The option strings specified by a command line or a subcommand file are output. Figure 8.9 shows an example of option information output when **optlnk -sub=test.sub -list -show** is specified.

```
(test.sub contents)
INPUT test.obj

*** Options ***

-sub=test.sub
INPUT test.obj (2)
-list
-show } (1)
```

Figure 8.9 Example of Option Information Output (Linkage List)

- (1) Outputs option strings specified by a command line or a subcommand in the specified order.
- (2) Subcommand in the **test.sub** subcommand file

8.4.3 Error Information

Error messages are output. Figure 8.10 shows an example of error information output.

```
*** Error Information ***

** L2310 (E) Undefined external symbol "strcmp" referred to in "test.obj" } (1)
```

Figure 8.10 Example of Error Information Output (Linkage List)

- (1) Outputs an error message.

8.4.4 Linkage Map Information

The start and end addresses, size, and type of each section are output in the order of address. Figure 8.11 shows an example of linkage map information output.

```
*** Mapping List ***
```

<u>SECTION</u> (1)	<u>START</u> (2)	<u>END</u> (3)	<u>SIZE</u> (4)	<u>ALIGN</u> (5)
P	00001000	00001000	1	1
C	00001004	00001007	4	4
D_2	00001008	000014dd	4d6	2
B_2	000014de	000050b3	3bd6	2

Figure 8.11 Example of Linkage Map Information Output (Linkage List)

- (1) Section name
- (2) Start address
- (3) End address
- (4) Section size
- (5) Section boundary alignment value

8.4.5 Symbol Information

When **show=symbol** is specified, the addresses, sizes, and types of externally defined symbols or static internally defined symbols are output in the order of address. When **show=reference** is specified, the symbol reference counts and optimization information are also output. Figure 8.12 shows an example of symbol information output.

```

*** Symbol List ***

SECTION=(1)
FILE=(2)      START      END      SIZE
                (3)      (4)      (5)
  SYMBOL      ADDR      SIZE      INFO      COUNTS  OPT
  (6)         (7)      (8)      (9)      (10)   (11)

SECTION=P
FILE=test.obj
  00000000      00000428      428
  _main
  00000000      2      func ,g      0
  _malloc
  00000000      32      func ,l      0
FILE=mvn3
  00000428      00000490      68
  $MVN#3
  00000428      0      none ,g      0

```

Figure 8.12 Example of Symbol Information Output (Linkage List)

- (1) Section name
- (2) File name
- (3) Start address of a section included in the file indicated by (2) above
- (4) End address of a section included in the file indicated by (2) above
- (5) Section size of a section included in the file indicated by (2) above
- (6) Symbol name
- (7) Symbol address
- (8) Symbol size
- (9) Symbol type as shown below

Data type:	func	Function name
	data	Variable name
	entry	Entry function name
	none	Undefined (label, assembler symbol)

Declaration type: g External definition
 l Internal definition

(10) Symbol reference count only when **show=reference** is specified. * is output when **show=reference** is not specified.

(11) Optimization information as shown below.

ch Symbol modified by optimization
cr Symbol created by optimization
mv Symbol moved by optimization

8.4.6 Symbol Deletion Optimization Information

The size and type of symbols deleted by symbol deletion optimization (**optimize=symbol_delete**) are output. Figure 8.13 shows an example of symbol deletion optimization information output.

```

*** Delete Symbols ***

  SYMBOL                               SIZE      INFO
  (1)                                (2)      (3)
  _Version                             4      data ,g
    
```

Figure 8.13 Example of Symbol Deletion Optimization Information Output (Linkage List)

- (1) Deleted symbol name
- (2) Deleted symbol size
- (3) Deleted symbol type as shown below

Data type: func Function name
 data Variable name

Declaration type: g External definition
 l Internal definition

8.4.7 Cross-Reference Information

The symbol reference information (cross-reference information) is output if `show=xreference` is specified. Figure 8.14 shows an example of cross-reference information output.

```

*** Cross Reference List ***

No      Unit Name  Global.Symbol  Location  External Information
(1)     (2)          (3)           (4)      (5)
0001    a
        SECTION=P  _func
                                00000100
                                _func1
                                00000116
                                _main
                                0000012c
                                _g
                                00000136
        SECTION=B
                                _a
                                00000190    0001 (00000140:P)
                                                0002 (00000178:P)
                                                0003 (0000018c:P)
0002    b
        SECTION=P
                                _func01
                                00000154    0001 (00000148:P)
                                _func02
                                00000166    0001 (00000150:P)
0003    c
        SECTION=P
                                _func03
                                00000184

```

Figure 8.14 Example of Cross-Reference Information Output (Linkage List)

- (1) Unit number, which is an identification number in object units
- (2) Object name, which specifies the input order at linkage
- (3) Symbol name output in ascending order of allocation addresses for every section
- (4) Symbol allocation address, which is a relative value from the beginning of the section when **form=relocate** is specified
- (5) Address of an external symbol that has been referenced

Output format: <Unit number> (<address or offset in section>:<section name>)

8.4.8 Total Section Size

The total sizes of ROM, RAM, and program sections are output. Figure 8.15 shows an example of total section size output.

```

*** Total Section Size ***

RAMDATA SECTION :      00000660 Byte(s)
(1)
ROMDATA SECTION  :      00000174 Byte(s)
(2)
PROGRAM SECTION  :      000016d6 Byte(s)
(3)
    
```

Figure 8.15 Example of Total Section Size Output (Linkage List)

- (1) Total size of RAM data sections
- (2) Total size of ROM data sections
- (3) Total size of program sections

8.4.9 Vector Information

The contents of the variable vector table are output if show=vector is specified. Figure 8.16 shows an example of vector information output.

```

*** Variable Vector Table List ***

NO.      SYMBOL/ADDRESS
(1)      (2)
  0      $fdummy
  1      $fa
  2      00ff8800
  3      $fdummy
      :
      <Omitted>
    
```

Figure 8.16 Example of Vector Output (Linkage List)

- (1) Vector number
- (2) Symbol. When no symbol is defined for the vector number, the address is output.

8.4.10 CRC Information

The CRC calculation result and output address are output when the CRC option is specified.

```
*** CRC Code ***  
  
CODE      : cb0b  
(1)  
ADDRESS   : 00007ffe  
(2)
```

Figure 8.17 Example of CRC Information Output (Linkage List)

- (1) CRC calculation result
- (2) Address where the CRC calculation result is output

8.5 Library Listings

This section covers the contents and format of the library listing output by the optimizing linkage editor.

8.5.1 Structure of Library Listing

Table 8.6 shows the structure and contents of the library listing.

Table 8.6 Structure and Contents of Library Listing

Creating List	Contents	Suboption*	Default
Option information	Displays option strings specified by a command line or subcommand	—	Output
Error information	Displays error messages	—	Output
Library information	Displays library information	—	Output
Information of module, section, and symbol within library	Displays module within the library	—	Output
	When show=symbol is specified, displays a list of symbol names in a module within the library	show=symbol	Not output
	When show=section is specified, displays lists of section names and symbol names in a module within the library	show=section	Not output

Note: The suboptions above are enabled only when **list** option is specified.

8.5.2 Option Information

Option information displays option strings specified by a command line or a subcommand file. Option information is output as shown in figure 8.17 when `optlnk -sub = test.sub -list -show` is specified.

```
(test.sub contents)

form    library
in      adhry.obj
output  test.lib

*** Options ***

-sub = test.sub
form    library
in      adhry.obj
output  test.lib
-list
-show

      ) (2)
      ) (1)
```

Figure 8.17 Option Information Output Example (Library Listing)

Description:

- (1) Outputs option strings specified by a command line or a subcommand in the specified order.
- (2) Subcommand in the test.sub subcommand file

8.5.3 Error Information

Error information outputs an error message as shown in figure 8.18.

```
*** Error information ***  
** L1200 (W) Backed up file "main.lib" into "main.lbk" (1)
```

Figure 8.18 Error Information Output Example (Library Listing)

Description:

(1) Outputs an error message.

8.5.4 Library Information

Library information outputs library type in the format shown in figure 8.19.

```
*** Library Information ***  
  
LIBRARY NAME = test.lib (1)  
CPU = SuperH (2)  
ENDIAN = Big (3)  
ATTRIBUTE = system (4)  
NUMBER OF MODULE = 1 (5)
```

Figure 8.19 Library Information Output Example (Library Listing)

Description:

- (1) Library name
- (2) CPU name
- (3) Endian type
- (4) Library file attribute either system library or user library
- (5) Number of modules within the library

8.5.5 Module, Section, and Symbol Information within Library

This information lists modules within the library.

When **show=symbol** is specified, symbol names in a module within the library are listed. When **show=section** is specified, section names and symbol names in a module within the library are listed.

Figure 8.20 shows an output example of module, section and symbol information within a library.

```

*** Library List ***

MODULE      LAST UPDATE
(1)         (2)
SECTION
(3)
SYMBOL
(4)
adhry
          29-Feb-2000 12:34:56
P
  _main
  _Proc0
  _Proc1
C
D
  _Version
B
  _IntGlob
  _CharGlob

```

Figure 8.20 Module, Section, and Symbol Information Output Example (Library Listing)

Description:

- (1) Module name
- (2) Module definition date
If the module is updated, the latest module update date is displayed.
- (3) Section name within a module
- (4) Symbol within a section

Section 9 Programming

9.1 Program Structure

9.1.1 Sections

Each of the regions for execution instructions and data of the object programs output by the compiler or assembler comprises a section. A section is the smallest unit for data placement in memory. Sections have the following properties.

- Section attributes
 - code Stores execution instructions
 - data Stores data
 - stack Stack area
- Format type
 - Relative-address format: A section that can be relocated by the optimizing linkage editor.
 - Absolute-address format: A section of which the address has been determined; it cannot be relocated by the optimizing linkage editor.
- Initial values
 - Specifies whether there are initial values at the start of program execution. Data which has initial values and data which does not have initial values cannot be included in the same section. If there is even one initial value, the area without initial values is initialized to zero.
- Write operations
 - Specifies whether write operations are or are not possible during program execution.
- Boundary alignment
 - Corrections to addresses assigned to sections. The optimizing linkage editor corrects addresses so that they are multiples of the boundary alignment.

9.1.2 C/C++ Program Sections

The correspondence between memory areas and sections for C/C++ programs and the standard library is described in table 9.1.

Table 9.1 Summary of Memory Area Types and Their Properties

Name	Section		Format Type	Initial Values		Description
	Name	Attribute		Write Operations	Align-ment	
Program area	P*1	code	Relative	Yes No	4*2 bytes	Stores machine code
Constant area	C*1*5	data	Relative	Yes No	4 bytes	Stores const-type data
Initialized data area	D*1*5	data	Relative	Yes No	4 bytes	Stores data with initial values
Uninitialized data area	B*1*5	data	Relative	Yes Yes	4 bytes	Stores data without initial values
X memory constant area	\$XC	data	Relative	Yes No	4 bytes	Stores const-type data in X memory
Y memory constant area	\$YC	data	Relative	Yes No	4 bytes	Stores const-type data in Y memory
X memory initialized data area	\$XD	data	Relative	Yes Yes	4 bytes	Stores data with initial values in X memory
Y memory initialized data area	\$YD	data	Relative	Yes Yes	4 bytes	Stores data with initial values in Y memory
X memory uninitialized data area	\$XB	data	Relative	No Yes	4 bytes	Stores data without initial values in X memory

Table 9.1 Summary of Memory Area Types and Their Properties (cont)

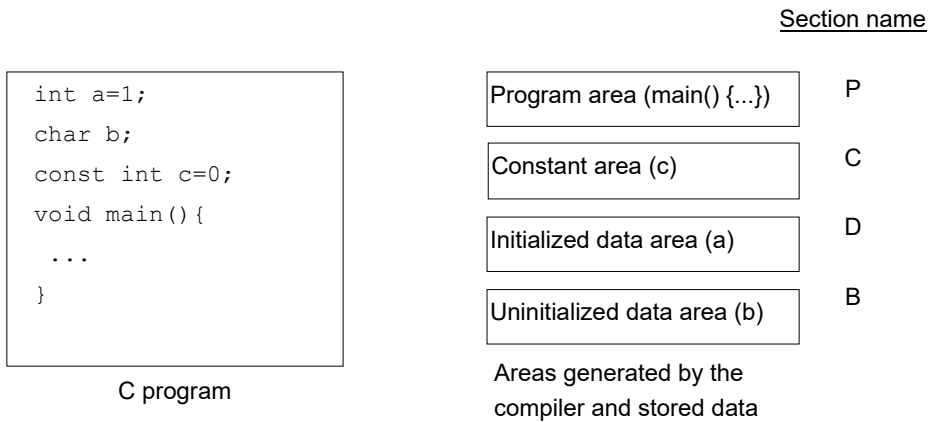
Name	Section		Format Type	Initial Values		Description
	Name	Attribute		Write Operations	Align-ment	
Y memory uninitialized data area	\$YB	data	Relative	No Yes	4 bytes	Stores data without initial values in Y memory
GBR section	\$G0*6	data	Relative	Yes Yes	4 bytes	Stores data with initial values specified by #pragma gbr_base . If data does not have initial values, 0 is stored.
GBR section	\$G1*6	data	Relative	Yes Yes	4 bytes	Stores data with initial values specified by #pragma gbr_base1 . If data does not have initial values, 0 is stored.
C++ initial processing/postprocessing data area	C\$INIT	data	Relative	Yes No	4 bytes	Stores addresses of constructors and destructors called for global class objects
C++ virtual function table area	C\$VTBL	data	Relative	Yes No	4 bytes	Stores data for calling the virtual function when a virtual function exists in the class declaration
Stack area	S	stack	Relative	No Yes	4 bytes	Area necessary for program execution (see section 9.2.1 (2), Dynamic Memory Allocation)
Heap area	—	—	Relative	No Yes	—	Area used by library functions malloc, realloc, calloc, and new (see section 9.2.1 (2), Dynamic Memory Allocation)

Table 9.1 Summary of Memory Area Types and Their Properties (cont)

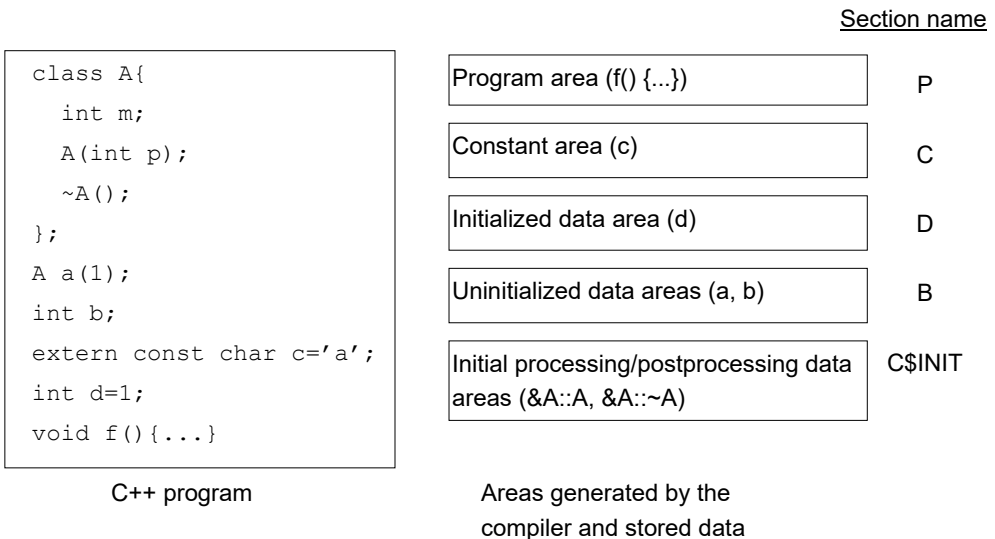
Name	Section		Format Type	Initial Values		Description
	Name	Attribute		Write Operations	Align-ment	
TBR table area	\$TBR	data	Relative	Yes No	4 bytes	Stores data to call functions using TBR relative addresses.
Absolute address variable area	\$ADDRESS \$<section> <address>*3	data	Absolute	Yes/No*4 Yes/No*4	—	Stores variables specified by #pragma address.

- Notes
1. Section names can be switched in the **section** option or extension **#pragma section**.
 2. Becomes 16 bytes when the **align16** option is specified, or 32 bytes when the **align32** option is specified.
 3. <section> is a C, D, or B section name, and <address> is an absolute address.
 4. The initial value and write operation depend on the attribute of the <section>.
 5. The stuff option divides sections up so that alignment is on one-, two-, or four-byte boundaries. Refer to the description of the stuff option in section 2.2.2, Object Options for details on the individual sections.
 6. The stuff_gbr option divides sections up so that alignment is on one-, two-, or four-byte boundaries. Refer to the description of the stuff_gbr option in section 2.2.2, Object Options for details on the individual sections.

Example 1: A program example is used to demonstrate the correspondence between a C program and the compiler-generated sections.



Example 2: A program example is used to demonstrate the correspondence between a C++ program and the compiler-generated sections.



9.1.3 Assembly Program Sections

In assembly programs, `.SECTION` is used to begin sections and declare attributes and format types. The format for declaration of `.SECTION` is given below. For details, refer to section 11.4, Assembler Directives.

```
.SECTION <section name>[, <section attribute>[, <format type>]]
```

`<format type>`: In the case of a relative address section, `ALIGN=< boundary alignment>`

In the case of an absolute address section, `LOCATE=<address value>`

Example: An example of an assembly program section declaration appears below.

```

        .CPU          SH2
        .OUTPUT       DBG
SIZE:   .EQU          8

        .SECTION     A, CODE, ALIGN=4                ; (1)
START:
        MOV.L        LITERAL, R0
        MOV.L        LITERAL+4, R1
        MOV.L        #SIZE, R2

LOOP:
        CMP.PL       R2
        BF           EXIT
        MOV.B        @R0+, R3
        MOV.B        R3, @R1
        ADD          #-1, R2
        ADD          #1, R1
        BRA          LOOP
        NOP

EXIT:
        SLEEP
        NOP

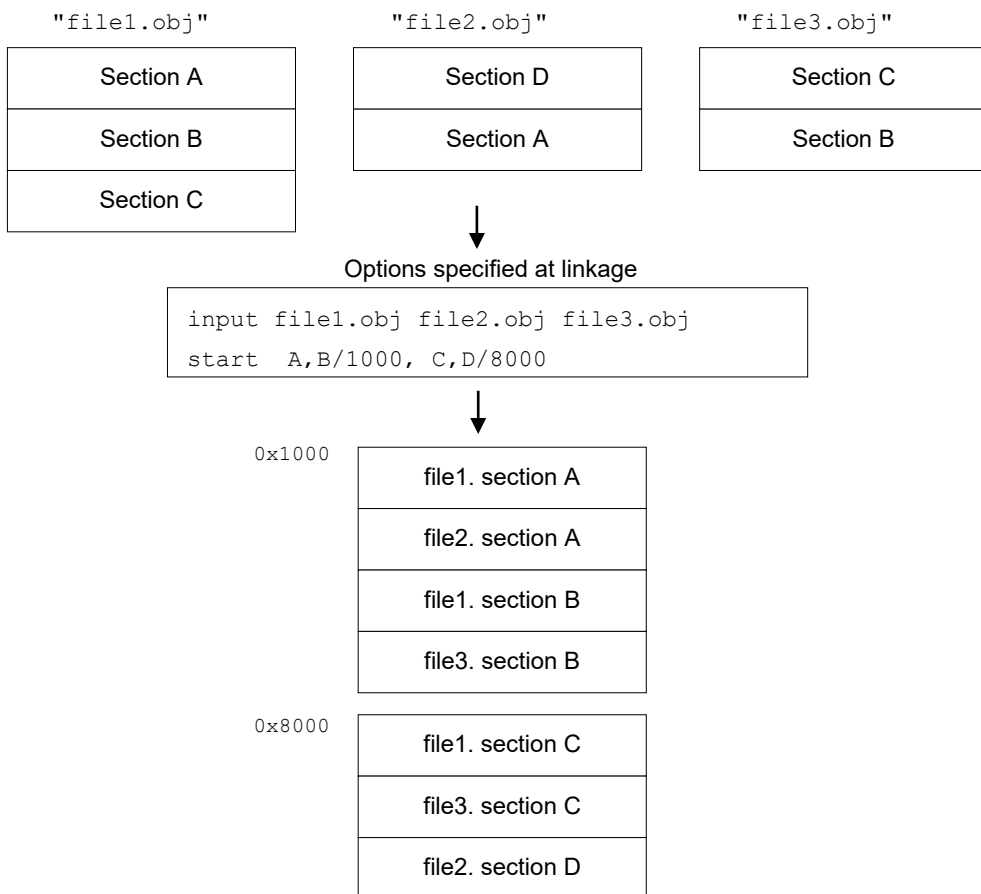
LITERAL:
        .DATA.L      CONST
        .DATA.L      DATA
;
        .SECTION     B, DATA, LOCATE=H'00002000    ; (2)
CONST:
        .DATA.B      H'01, H'02, H'03, H'04, H'05, H'06, H'07, H'08
;
        .SECTION     C, STACK, ALIGN=4             ; (3)
DATA:
        .RES.B       8
        .END
    
```

- (1) Declares a code section with section name A, boundary alignment 4, and relative address format.
- (2) Declares a data section with section name B, allocated address H'2000, and absolute address format.
- (3) Declares a stack section with section name C, boundary alignment 4, and relative address format.

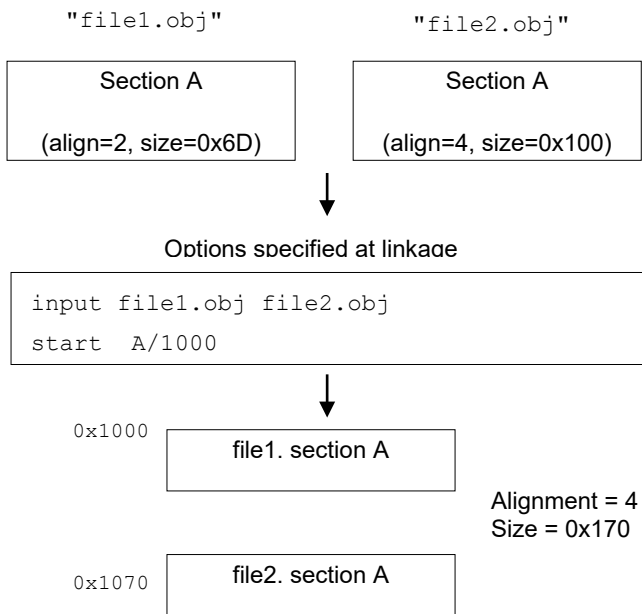
9.1.4 Linking Sections

The optimizing linkage editor links the same sections within input object programs, and allocates addresses specified by the **start** option.

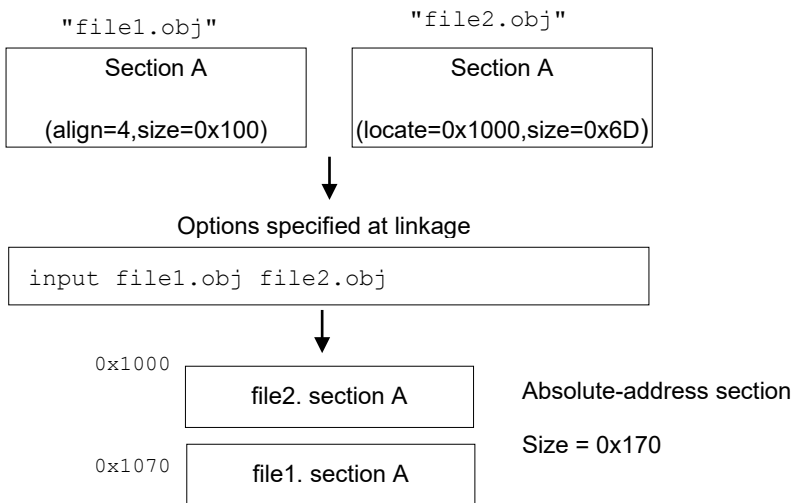
- (1) The same section names in different files are allocated continuously in the order of file input.



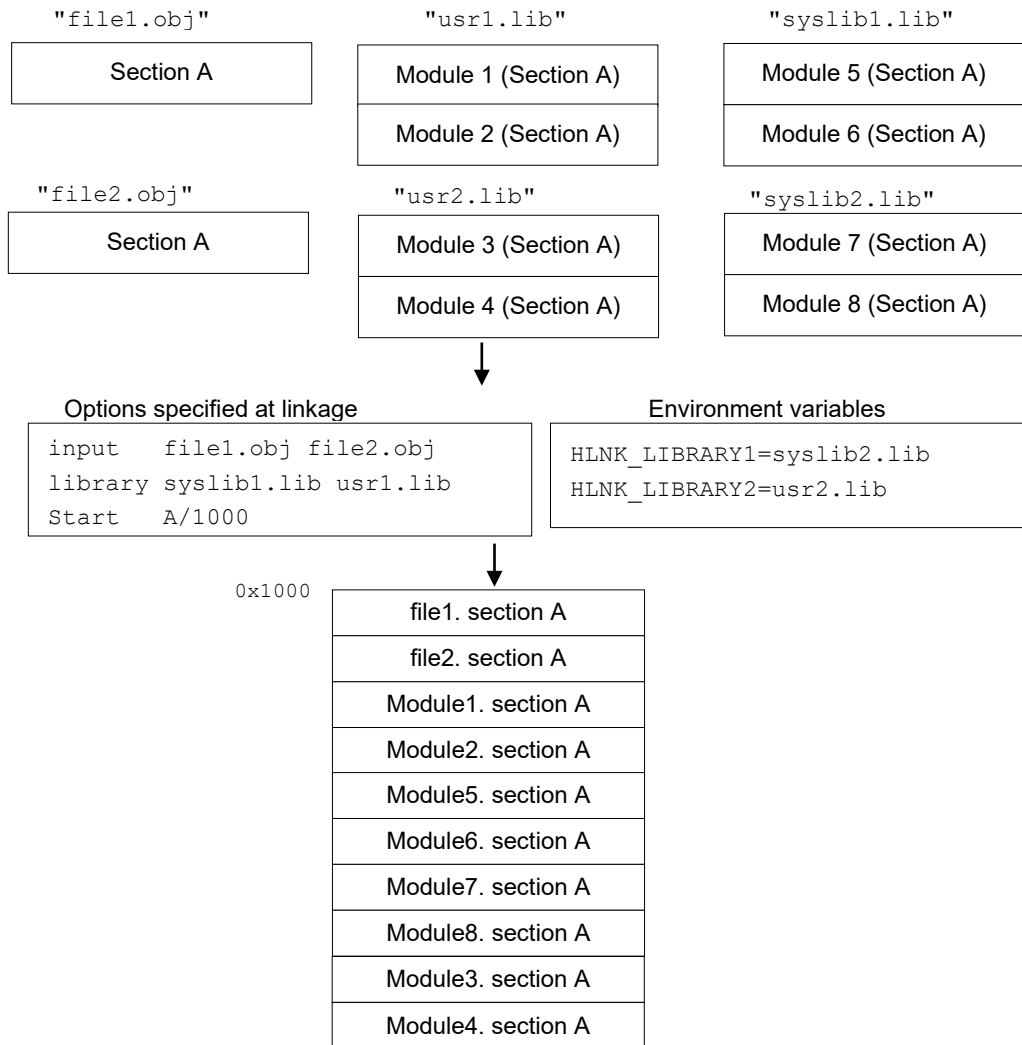
- (2) Sections with the same name but different boundary alignments are linked after alignment.
 Section alignment uses the larger of the section alignments.



- (3) When sections with the same name include both absolute-address and relative-address formats, relative-address objects are linked following absolute-address objects. Even when relocatable file output is specified (**form=relocate**), the section in question becomes an absolute-address section.



- (4) Rules for the order of linking objects within the same section name are as follows.
- Order specified by the **input** option or input files on the command line
 - Order specified for the user library by the **library** option and order of input of modules within the library
 - Order specified for the system library by the **library** option and order of input of modules within the library
 - Order specified for libraries by environment variables (HLNK_LIBRARY1 to HLNK_LIBRARY3) and order of input of modules within the library



9.2 Creation of Initial Setting Programs

Here methods of installing embedded programs for systems employing the SuperH RISC engine microcomputers are explained.

To install an embedded a program in a system, the following preparations are necessary.

- Memory allocation
Each section, the stack area, and the heap area must be allocated to system ROM and RAM.
- Settings for the program execution environment
Processing to set the program execution environment includes register initialization, memory initialization, and program startup.

In addition, when using I/O and other C/C++ library functions, the library must be initialized during preparation of the execution environment. In particular, when using I/O (stdio.h, ios, streambuf, istream, ostream) and memory allocation (stdlib.h, new), low-level I/O routines and memory allocation routines must be prepared.

When using C library functions for program termination (exit, atexit, abort functions), these functions must be prepared separately according to the user system.

In section 9.2.1, the method used to determine addresses for program memory is explained, and actual examples are used to describe the method for specifying options in the optimizing linkage editor for determining addresses.

In section 9.2.2, execution environment settings are explained, and an actual example of a program to set the execution environment is described.

Library function initialization processing, preparation of low-level interface routines, and examples of preparation of functions for termination processing are also explained.

9.2.1 Memory Allocation

To install an object program generated by the compiler on a system, determine the size of each memory area, and allocate the areas appropriately to the memory addresses.

Some memory areas, such as the area used to store machine code and the area used to store data declared using external definitions or static data members, are allocated statically. Other memory areas, such as the stack area, are allocated dynamically.

This section describes how to allocate each area in memory.

(1) Static Memory Allocation

(a) Contents of static memory

Sections other than the stack area and heap area are allocated statically.

Each of the sections in a C/C++ program (program area, constant area, initialized data area, uninitialized data area, C++ initial processing/postprocessing data area, and C++ virtual function table area) is allocated statically.

(b) Calculation of size

The size of static memory is the sum of the sizes of the object programs generated by the compiler and assembler and the sizes of the library functions used by the C/C++ program.

After linking object programs, the sizes of each section, including libraries, are output to the linkage map information within the linkage listing, and so the size of static memory can be determined.

Figure 9.1 shows an example of linkage map information within the linkage listing.

* * * Mapping list * * *				
<u>SECTION</u>	<u>START</u>	<u>END</u>	<u>SIZE</u>	<u>ALIGN</u>
(1)	(2)	(3)	(4)	(5)
P	00000000	000004d6	4d6	2
C	000004d6	00000533	5d	2
D	00000534	0000053c	8	2
B	0000053c	00004112	3bd6	2

Figure 9.1 Example of Linkage Map Information within the Linkage Listing

Section sizes of compilation units and assembly units are output to the compile list statistics information and assembly list section information. An example of compile list statistics information is shown in figure 9.2, and an example of assembly list section information is shown in figure 9.3.

```

***** SECTION SIZE INFORMATION *****
PROGRAM SECTION (P)           :0x00004A Byte(s)
CONSTANT SECTION (C)         :0x000018 Byte(s)
DATA SECTION (D)             :0x000004 Byte(s)
BSS SECTION (B)              :0x000004 Byte(s)

TOTAL PROGRAM SECTION :    0000004A Byte(s)
TOTAL CONSTANT SECTION :    00000018 Byte(s)
TOTAL DATA SECTION   :    00000004 Byte(s)
TOTAL BSS SECTION     :    00000004 Byte(s)

TOTAL PROGRAM SIZE: 0x00006A Byte(s)
    
```

Figure 9.2 Example of Compile List Statistics Information

```

*** SECTION DATA LIST

SECTION                ATTRIBUTE      SIZE           START
P                      REL-CODE     000000604
D                      REL-DATA     000000008
C                      REL-DATA     00000005D
B                      REL-DATA     000003BD6
    
```

Figure 9.3 Example of Assembly List Section Information

When not using a standard library, the total of section sizes for files is the size of the static area.

If a standard library is used, add the memory area used by the library functions to the memory area size of each section. Among the standard libraries provided by the compiler are, in addition to C library functions stipulated by the C language specifications and C++ class libraries for embedding, routines to perform arithmetic calculations (runtime routines) used for program execution. Accordingly, the standard library may be necessary even if library functions are not used in the C/C++ source program.

The runtime routines used by the C/C++ programs are output as external reference symbols in the assembly programs generated by the compiler (**code=asmcode**). The user can see the runtime routine names used in the C/C++ programs through the external reference symbols. Specific examples are presented below.

- C/C++ program

```
f( int a, int b)
{
    a /= b;
    return a;
}
```

- Assembly program output by the C compiler

```
.IMPORT      __divls      ;(External reference declaration of runtime routine)
.EXPORT      _f
.SECTION     P, CODE, ALIGN=4
_f:
                                ;function: f
                                ;frame size=4

    STS.L   PR, @-R15
    MOV     R5, R0
    MOV.L   L218, R3              ; __divls
    JSR     @R3
    MOV     R4, R1
    LDS.L   @R15+, PR
    RTS
    NOP
L218:
    .DATA.L   __divls
    .END
```

(c) ROM, RAM allocation

When preparing a program for systems with ROM, whether sections are allocated to RAM or to ROM is determined by whether there are initial values and whether write operations are enabled.

When preparing the sections of a C/C++ program for systems with ROM, sections are allocated to ROM or to RAM as follows.

- Program area (section P) ROM
- Constant areas (sections C, \$G0, \$G1*³) ROM
- Uninitialized data areas (sections B, \$G0, \$G1*³) RAM
- Initialized data areas (sections D, \$G0, \$G1*³) ROM, RAM (see (d) below)
- Initial processing/postprocessing data area*¹(section C\$INIT) ROM
- Virtual function table area*² (section C\$VTBL) ROM

- Notes:
1. Generated by the compiler when a C++ program has a global class object.
 2. Generated by the compiler when a C++ program has a virtual function declaration
 3. \$G0 and \$G1 can be assigned to only one of the above areas.

(d) Allocation of initialized data areas

Sections which have initial values and can be altered on program execution, such as initialized data areas, are placed in ROM at linkage and copied to RAM at the start of program execution. Hence the **rom** option of the optimizing linkage editor must be used to reserve the same memory area both in ROM and in RAM. For an example of this, refer to "(e) Example of memory allocation and address specification at linkage" below. Initial settings for sections to be copied from ROM to RAM are explained in section 9.2.2 (2), Initialization (PowerON_Reset).

(e) Example of memory allocation and address specification at linkage

When creating an absolute load module, addresses of allocated areas are specified for each section using an optimizing linkage editor option or a subcommand. Below, examples of static memory allocation and address specification at linkage are explained.

Figure 9.4 shows an example of allocation of static memory areas.

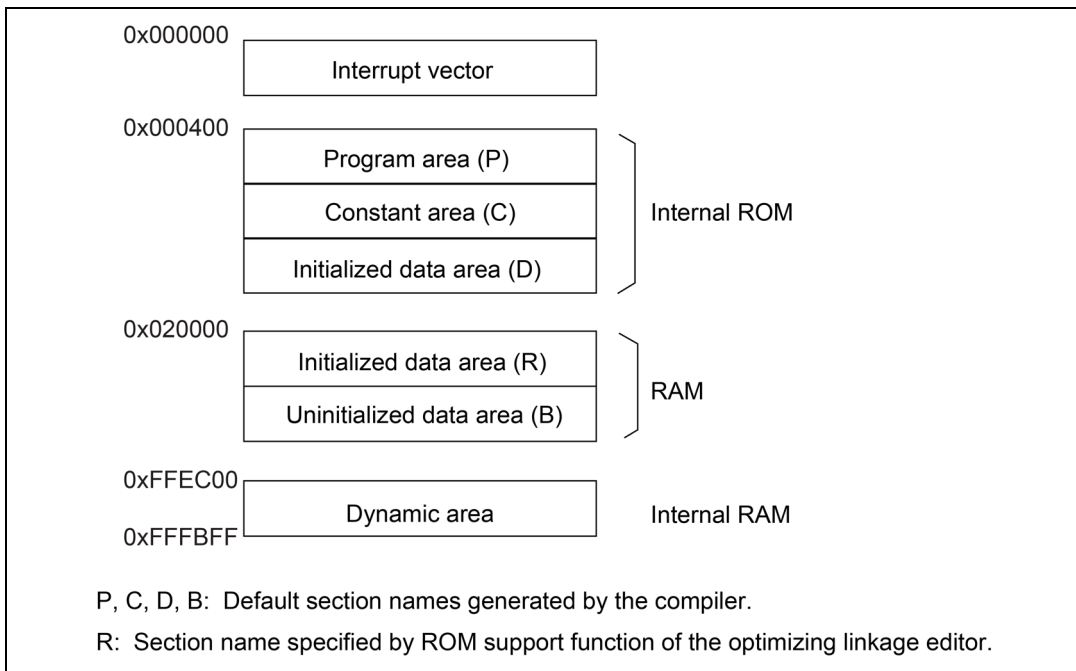


Figure 9.4 Example of Static Memory Allocation

When allocating memory as shown in figure 9.4, the following subcommands are specified at linkage.

```
ROMAD=R          . . . [1]
STARTAP, C, D/400, R, B/20000  . . . [2]
```

Explanation [1] Space for section R, of a size equal to section D, is allocated in the output load module. When symbols allocated to section D are referenced, relocation is performed as if the addresses are in section R. Section D and section R are the names of initialized data sections written to ROM and to RAM, respectively.

Explanation [2] Sections P, C, and D are allocated to continuous areas of memory in internal ROM starting from address 0x400. Sections R and B are allocated to continuous memory areas starting from RAM address 0x20000.

(2) Dynamic Memory Allocation

(a) Contents of dynamic memory

The following two types of dynamic memory areas are used in C/C++ programs:

- Stack area
- Heap area (for memory allocation of library functions)

(b) Calculation of stack area size

The maximum stack area size used by C/C++ programs and standard libraries can be calculated by specifying the **stack** option of the optimizing linkage editor to output a stack information file, and using the callwalker. For details of use of the callwalker, see section 6, Operating CallWalker.

The stack area used by an assembly program (assembled by the assembler of V6 or earlier) cannot be calculated by the callwalker. Instead, the stack usage of an assembly program should be computed by the method outlined below for calculating the stack usage of a C/C++ program, and the result should be added to the stack usage calculated by the callwalker.

- Stack Usage Calculation of the C/C++ Program

The stack area used in C/C++ programs is allocated each time a function is called and is deallocated each time a function is returned. The total stack area size is calculated based on the stack size used by each function and the nesting of function calls.

- Stack Area Used by Each Function

The object list (frame size) output by the compiler determines the stack size used by each function. The following example shows the object list, stack allocation, and stack size calculation method.

Example:

The following shows the object list and stack size calculation in a C program.
 The same calculation method is also applicable to C++ programs.

```
extern int h(char, int *, double );
int h(char a, register int *b, double c)
{
    char *d;

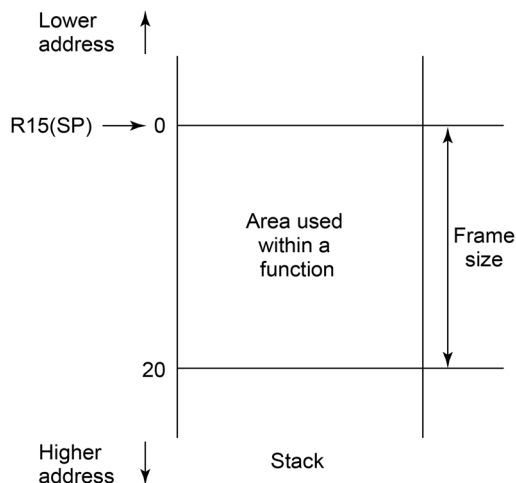
    d= &a;
    h(*d,b,c);
    {
        register int i;

        i= *d;
        return i;
    }
}
```

***** OBJECT LISTING *****

FILE NAME: m0251.c

SCT	OFFSET	CODE	C LABEL	INSTRUCTION	OPERAND	COMMENT
P	00000000		_h:			;function: h ;frame size=20
	00000000	2FE6		MOV.L	R14,@-R15	
	00000002	4F22		STS.L	PR,@-R15	
		:				



The size of the stack area used by a function is equal to the frame size. Therefore, in the above example, the stack size used by function `h` is 20 bytes which is shown as `frame size=20` in COMMENT of the object listing.

For details on the parameter allocated to the parameter area on the stack, refer to section 9.3.2 (4), Setting and Referencing Parameters and Return Values.

- Stack size calculation

The following example shows a stack size calculation depending on the function call nesting.

Example:

Figure 9.5 shows the function call nestings and stack size for each function.

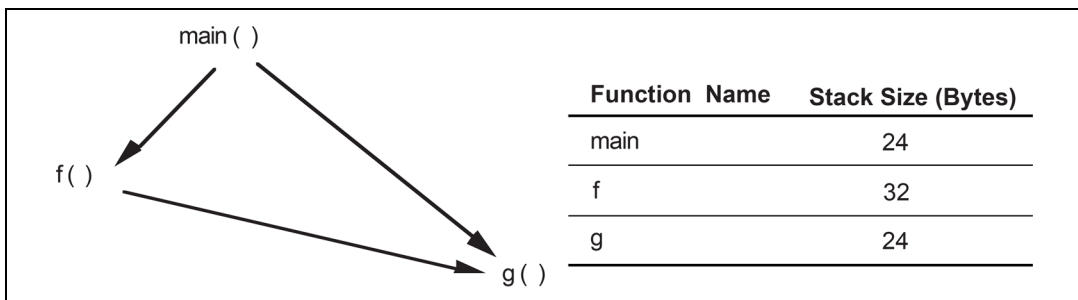


Figure 9.5 Nested Function Calls and Stack Size

If function g is called via function f, the stack area size is calculated according to the formula listed in table 9.2.

Table 9.2 Stack Size Calculation Example

Call Route	Sum of Stack Size (Bytes)
main (24) → f (32) → g (24)	80
main (24) → g (24)	48

As can be seen from table 9.2, the maximum size of stack area required for the longest function calling route should be determined (80 bytes in this example) and at least this size of memory should be allocated.

Note: If recursive calls are used in the C/C++ source program, first determine the stack area required for a recursive call, and then multiply the size with the maximum level of recursive calls.

(c) Heap Area

The total heap area required is equal to the sum of the areas to be allocated by memory management library functions (calloc, malloc, realloc, or new) in the C/C++ program. Four bytes must be added for one call because a 4-byte management area is used every time a memory management library function allocates an area.

The compiler controls heap area in units of the user-specified memory size (`_sbrk_size`). For the `_sbrk_size` specification, refer to section 9.2.2 (4), C/C++ library function initial settings (`_INITLIB`). The area size allocated for the heap area (HEAPSIZE) is calculated by the following formula:

$$\text{HEAPSIZE} = \text{_sbrk_size} \times n \quad (n \geq 1)$$

(Area size allocated by the memory management library) + control area size ≤ HEAPSIZE

An I/O library function uses memory management library functions for internal processing.

The size of the area allocated in an I/O is determined by the following formula:

$$516 \text{ bytes} \times (\text{maximum number of simultaneously opened files})$$

Note: Areas released by the free or delete function, which is a memory management library function, can be reused. However, since these areas are often fragmented (separated from one another), a request to allocate a new area may be rejected even if the net size of the free areas is sufficient. To prevent this, take note of the following:

1. If possible, allocate the largest area first after program execution is started.
2. If possible, make the data area size to be reused constant.

- Rules for Allocating Dynamic Area

The dynamic area is allocated to RAM.

The stack area is determined by specifying the highest address of the stack to the vector table, and refer to it as SP (stack pointer). Since the interrupt operation of the SH-3, SH3-DSP, SH-4, SH-4A, and SH4AL-DSP differs from that of the SH-1, SH-2, SH-2E, SH-2A, SH2A-FPU, and SH2-DSP, interrupt handlers are necessary.

The heap area is determined by the initial settings of the low-level interface routine (sbrk).

For details on stack and heap areas, refer to section 9.2.2 (1), Vector table setting (VEC_TBL), and section 9.2.2 (6), Low-level interface routines, respectively.

9.2.2 Execution Environment Settings

Here, processing to prepare the environment for program execution is described. However, the environment for program execution will differ among user systems, and so a program to set the execution environment must be created according to the specifications of the user system.

Figure 9.6 shows an example of the structure of such a program.

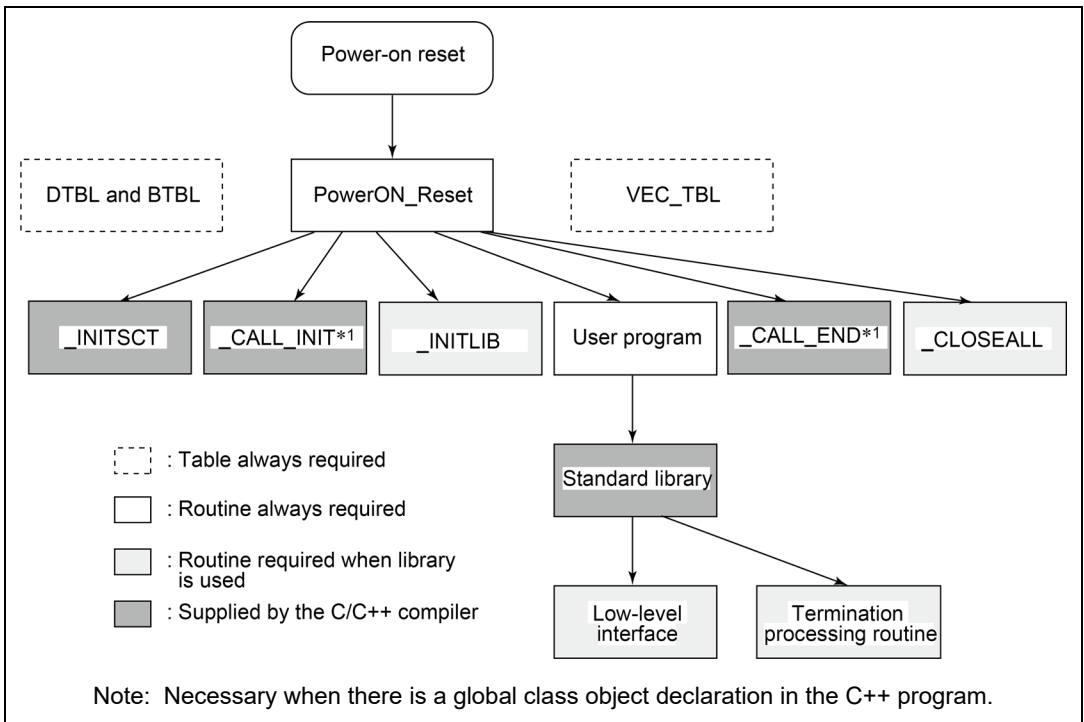


Figure 9.6 Example of Program Structure

The components are explained below.

- **Vector Table Setting (VEC_TBL)**
Sets the vector table to initiate the register initialization program (PowerON_Reset) and set the stack pointer (SP) at power-on reset. Since the interrupt operation of the SH-3, SH3-DSP, SH-4, SH-4A, and SH4AL-DSP differs from that of the SH-1, SH-2, SH-2E, SH-2A, SH2A-FPU, and SH2-DSP, interrupt handlers are necessary.
- **Initialization (PowerON_Reset)**
Initializes registers and sequentially calls the initialization routines.
- **Section Initialization Tables (DTBL, BTBL)**
Uses the section address operator to set the starting and ending addresses for the section used in the section initialization routine.
- **Initializing Sections (_INITSCT)*1**
Initializes to zero any static variable area (uninitialized data area) for which no initial values are set. Also copies initial values of initialized data areas from ROM to RAM.

- Global Class Object Initial Processing (`_CALL_INIT`)*1*2
Calls a constructor of a class object that is declared as global.
- Global Class Object Postprocessing (`_CALL_END`)*1*2
Calls a destructor of a global class object after the main function is executed.
- Initializing C/C++ Library Functions (`_INITLIB`)
Initializes library functions required to be initialized; especially, prepares standard I/O functions.
- Closing Files (`_CLOSEALL`)
Closes all open files.
- Low-Level Interface Routines
Routines providing an interface between the user system and library functions which are necessary when standard I/O (`stdio.h`, `ios`, `streambuf`, `istream`, and `ostream`) and memory management libraries (`stdlib.h` and `new`) are used.
- Termination Processing Routine (`exit`, `atexit`, and `abort`)*3
Processing for terminating the program.

Notes: 1. Provided as a standard library.

2. Required when there is a declaration of a global class object in a C++ program.

3. When using the C library function `exit`, `atexit`, or `abort` to terminate a program, these functions must be created as appropriate to the user system.

When using the C++ program or C library macro `assert`, the `abort` function must always be created.

Implementation of the above routines is described below.

(1) Vector table setting (`VEC_TBL`)

To call register initialization function `PowerON_Reset` at power-on reset, specify the starting address of function `PowerON_Reset` at address 0 in the vector table. Also to specify the SP, specify the highest address of the stack to address H'4. Since the interrupt operation of the SH-3, SH3-DSP, SH-4, SH-4A, and SH4AL-DSP differs from that of the SH-1, SH-2, SH-2E, SH-2A, SH2A-FPU, and SH2-DSP, interrupt handlers are necessary. When the user system implements interrupt handling, interrupt vector settings are also performed by this routine. The coding example of `VEC_TBL` is shown below.

Example 1 Vector Table for SH-1, SH-2, SH-2E, SH-2A, SH2A-FPU, and SH2-DSP:

```
#pragma interrupt (IRQ0)

extern void Manual_Reset_PC(void);
extern void Manual_Reset_SP(void);

extern void IRQ0(void);

#pragma section VEECTBL /* Outputs the RESET_Vectors to the CVEECTBL section */
/* by #pragma section declaration */
/* Allocates the CVEECTBL section to address 0x0 */
/* by the start option at linkage */
void (*const RESET_Vectors[]) (void)={
    (void*) PowerON_Reset_PC,
    _secdend("S"),
    (void*) Manual_Reset_PC,
    _secdend("S")
};

#pragma section VEECT2 /* Outputs the vec_table2 to the CVEECT2 section */
/* by #pragma section declaration */
/* Allocates the CVEECT2 section to the specified */
/* address by the starting address at linkage */

void (*const vec_table2[]) (void)={IRQ0};
```

Example 2 Interrupt Handler when Bank 0 is Used in the Program (SH7708):

```
;;;;;;
;                                     env.inc                                     ;
;;;;;;

EXPEVT:
    .EQU    H'FFFFFFD4

INTEVT:
    .EQU    H'FFFFFFD8

;;;;;;
;                                     vect.inc                                     ;
;;;;;;

SR_Init:
    .EQU    B'0000000000000000000000000011110000

;<<VECTOR DATA START (POWER ON RESET)>>
;H'000 Power On Reset
    .GLOBAL    PowerON_Reset
;<<VECTOR DATA END (POWER ON RESET)>>
;<<VECTOR DATA START (MANUAL RESET)>>
;H'020 Manual Reset
    .GLOBAL    Manual_Reset
;<<VECTOR DATA END (MANUAL RESET)>>
;H'040 TLB miss/invalid (load)
    .GLOBAL    INT_TLBMiss_Load
;H'060 TLB miss/invalid (store)
```

```
.GLOBAL     INT_TLBMiss_Store
;H'080 Initial page write
.GLOBAL     INT_TLBInitial_Page
;H'0A0 TLB protect (load)
.GLOBAL     INT_TLBProtect_Load
;H'0C0 TLB protect (store)
.GLOBAL     INT_TLBProtect_Store
;H'0E0 Address error (load)
.GLOBAL     INT_Address_load
;H'100 Address error (store)
.GLOBAL     INT_Address_store
;H'120 Reserved
.GLOBAL     INT_Reserved1
;H'140 Reserved
.GLOBAL     INT_Reserved2
;H'160 TRAPA
.GLOBAL     INT_TRAPA
;H'180 Illegal code
.GLOBAL     INT_Illegal_code
;H'1A0 Illegal slot
.GLOBAL     INT_Illegal_slot
;H'1C0 NMI
.GLOBAL     INT_NMI
;H'1E0 User breakpoint trap
.GLOBAL     INT_User_Break
;H'200 External hardware interrupt
.GLOBAL     INT_Extern_0000
;H'220 External hardware interrupt
.GLOBAL     INT_Extern_0001
;H'240 External hardware interrupt
.GLOBAL     _INT_Extern_0010
;H'260 External hardware interrupt
.GLOBAL     _INT_Extern_0011
;H'280 External hardware interrupt
.GLOBAL     _INT_Extern_0100
;H'2A0 External hardware interrupt
.GLOBAL     _INT_Extern_0101
;H'2C0 External hardware interrupt
.GLOBAL     _INT_Extern_0110
;H'2E0 External hardware interrupt
.GLOBAL     _INT_Extern_0111
;H'300 External hardware interrupt
.GLOBAL     _INT_Extern_1000
;H'320 External hardware interrupt
.GLOBAL     _INT_Extern_1001
;H'340 External hardware interrupt
.GLOBAL     _INT_Extern_1010
;H'360 External hardware interrupt
.GLOBAL     _INT_Extern_1011
;H'380 External hardware interrupt
.GLOBAL     _INT_Extern_1100
;H'3A0 External hardware interrupt
```



```

        .GLOBAL      _INT_Extern_1101
;H'3C0 External hardware interrupt
        .GLOBAL      _INT_Extern_1110
;H'3E0 External hardware interrupt
        .GLOBAL      _INT_Extern_1111
;H'400 TMU0 TUNIO
        .GLOBAL      _INT_Timer_Under_0
;H'420 TMU1 TUNII
        .GLOBAL      _INT_Timer_Under_1
;H'440 TMU2 TUNI2
        .GLOBAL      _INT_Timer_Under_2
;H'460 TMU2 TICPI2
        .GLOBAL      _INT_Input_Capture
;H'480 RTC ATI
        .GLOBAL      _INT_RTC_ATI
;H'4A0 RTC PRI
        .GLOBAL      _INT_RTC_PRI
;H'4C0 RTC CUI
        .GLOBAL      _INT_RTC_CUI
;H'4E0 SCI ERI
        .GLOBAL      _INT_SCI_ERI
;H'500 SCI RXI
        .GLOBAL      _INT_SCI_RXI
;H'520 SCI TXI
        .GLOBAL      _INT_SCI_TXI
;H'540 SCI TEI
        .GLOBAL      _INT_SCI_TEI
;H'560 WDT ITI
        .GLOBAL      _INT_WDT
;H'580 REF RCMI
        .GLOBAL      _INT_REF_RCMI
;H'5A0 REF ROVI
        .GLOBAL      _INT_REF_ROVI

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;
;                               vhandler.src
;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

        .INCLUDE      "env.inc"
        .INCLUDE      "vect.inc"

IMASKclr:
        .EQU          H'FFFFFF0F
RBBLclr:
        .EQU          H'FFFFFFFF
MDRBBLset:
        .EQU          H'70000000

        .IMPORT RESET_Vectors
        .IMPORT INT_Vectors
        .IMPORT INT_MASK
    
```

```

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                               macro definition                               ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
        .MACRO  PUSH_EXP_BASE_REG
STC.L   SSR,@-R15           ; save SSR
STC.L   SPC,@-R15         ; save SPC
STC.L   PR,@-R15          ; save CONTEXT REGISTERS
STC.L   R7_BANK,@-R15
STC.L   R6_BANK,@-R15
STC.L   R5_BANK,@-R15
STC.L   R4_BANK,@-R15
STC.L   R3_BANK,@-R15
STC.L   R2_BANK,@-R15
STC.L   R1_BANK,@-R15
STC.L   R0_BANK,@-R15
        .ENDM

;

        .MACRO  POP_EXP_BASE_REG
LDC.L   @R15+,R0_BANK     ; RECOVER REGISTERS
LDC.L   @R15+,R1_BANK
LDC.L   @R15+,R2_BANK
LDC.L   @R15+,R3_BANK
LDC.L   @R15+,R4_BANK
LDC.L   @R15+,R5_BANK
LDC.L   @R15+,R6_BANK
LDC.L   @R15+,R7_BANK
LDS.L   @R15+,PR
LDC.L   @R15+,SPC
LDC.L   @R15+,SSR
        .ENDM

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                               reset                                       ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
        .SECTION      RSTHandler,CODE
_ResetHandler:
MOV.L   #EXPEVT,R0
MOV.L   @R0,R0
SHLR2   R0
SHLR    R0
MOV.L   #_RESET_Vectors,r1
ADD     R1,R0
MOV.L   @R0,R0
JMP     @R0
NOP

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                               exceptional interrupt                         ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
        .SECTION      INTHandler,CODE
        .EXPORT INTHandlerPRG
INTHandlerPRG:

```

```
__ExpHandler:
    PUSH_EXP_BASE_REG
;
    MOV.L    #EXPEVT,R0          ; set event address
    MOV.L    @R0,R1             ; set exception code
    MOV.L    #_INT_Vectors,R0   ; set vector table address
    ADD     #- (H'40),R1        ; exception code - H'40
    SHLR2   R1
    SHLR    R1
    MOV.L    @(R0,R1),R3        ; set interrupt function addr
;
    MOV.L    #_INT_MASK,R0      ; interrupt mask table addr
    SHLR2   R1
    MOV.B    @(R0,R1),R1        ; interrupt mask
    EXTU.B  R1,R1
;
    STC     SR,R0               ; save SR
    MOV.L    #(RBBLclr&IMASKclr),R2
;
    AND     R2,R0               ; RB,BL,mask clear data
    OR      R1,R0               ; clear mask data
    OR      R1,R0               ; set interrupt mask
    LDC     R0,SSR              ; set current status
;
    LDC.L   R3,SPC
    MOV.L    #__int_term,R0     ; set interrupt terminate
    LDS     R0,PR
;
    RTE
    NOP
;
    .POOL
;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                          Interrupt terminate                          ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
    .ALIGN 4
__int_term:
    MOV.L    #MDRBBLset,R0     ; set MD,BL,RB
    LDC.L   R0,SR
;
    POP_EXP_BASE_REG
;
    RTE                      ; return
    NOP
;
    .POOL
;
```

Section 9 Programming

```

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                               TLB miss interrupt                               ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
        .ORG      H'300
__TLBmissHandler:
        PUSH_EXP_BASE_REG
;
        MOV.L    #EXPEVT,R0          ; set event address
        MOV.L    @R0,R1              ; set exception code
        MOV.L    #_INT_Vectors,R0   ; set vector table address
        ADD     #-(H'40),R1         ; exception code - H'40
        SHLR2   R1
        SHLR    R1
        MOV.L    @(R0,R1),R3        ; set interrupt function addr
;
        MOV.L    #_INT_MASK,R0      ; interrupt mask table addr
        SHLR2   R1
        MOV.B    @(R0,R1),R1        ; interrupt mask
        EXTU.B  R1,R1
;
        STC     SR,R0               ; save SR
        MOV.L    #(RBBLclr&IMASKclr),R2
;
        AND     R2,R0               ; RB,BL,mask clear data
        OR      R1,R0               ; clear mask data
        LDC     R0,SSR              ; set interrupt mask
;
        LDC.L   R3,SPC
        MOV.L    #__int_term,R0     ; set interrupt terminate
        LDS     R0,PR
;
        RTE
        NOP
;
        .POOL
;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                               IRQ                                           ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
        .ORG      H'500
__IRQHandler:
        PUSH_EXP_BASE_REG
;
        MOV.L    #INTEVT,R0         ; set event address
        MOV.L    @R0,R1              ; set exception code
        MOV.L    #_INT_Vectors,R0   ; set vector table address
        ADD     #-(H'40),R1         ; exception code - H'40
        SHLR2   R1
        SHLR    R1
        MOV.L    @(R0,R1),R3        ; set interrupt function addr
;

```

```

MOV.L  #_INT_MASK,R0          ; interrupt mask table addr
SHLR2  R1
MOV.B  @(R0,R1),R1           ; interrupt mask
EXTU.B R1,R1
;
STC    SR,R0                 ; save SR
MOV.L  #(RBBLclr&IMASKclr),R2 ; RB,BL,mask clear data
AND    R2,R0                 ; clear mask data
OR     R1,R0                 ; set interrupt mask
LDC    R0,SSR                ; set current status
;
LDC.L  R3,SPC
MOV.L  #__int_term,R0        ; set interrupt terminate
LDS    R0,PR
;
RTE
NOP
;
.POOL
.END

```

Note: Do not link the function for which #pragma interrupt has been specified.

(2) Initialization (PowerON_Reset)

When library functions are used, this function sequentially calls the initialization routine `_INITLIB` and file closing routine `_CLOSEALL`. The coding example of `PowerON_Reset` is shown below. Since the interrupt operation of the SH-3, SH3-DSP, SH-4, SH-4A, and SH4AL-DSP differs from that of the SH-1, SH-2, SH-2E, SH-2A, SH2A-FPU, and SH2-DSP, interrupt handlers are necessary.

Example:

```
#include <_h_c_lib.h>
#include <machine.h>

#pragma entry PowerON_Reset_PC
#pragma stacksize 0x100

#define SR_Init 0x000000F0
    /* The initial value is 0x400000F0 when cpu=sh3, cpu=sh3dsp, cpu=sh4, cpu=sh4a, or
       cpu=sh4aldsp is specified */
#define FPSCR_Init 0x00040001*1
    /* Only when cpu=sh2afpu, cpu=sh4, or cpu=sh4a is specified */
#define INT_OFFSET 0x10

extern unsigned int INT_Vectors;
extern void PowerON_Reset_PC();
extern void main();
#ifdef __cplusplus
extern "C" {
#endif
extern void _INIT_IOLIB();
extern void _INIT_OTHERLIB();
extern void _CLOSEALL();
#ifdef __cplusplus
}
#endif
```

```
void PowerON_Reset_PC() {
    set_vbr((void *) (INT_Vectors - INT_OFFSET));
    set_fpscr(FPSCR_Init);
    /* Set this value only when cpu=sh2afpu, cpu=sh4, or cpu=sh4a is specified */
    _INITSCT();
    _INIT_IOLIB();
    _INIT_OTHERLIB();
#ifdef __cplusplus
    _CALL_INIT();
#endif
    set_cr(SR_Init);
    main();
#ifdef __cplusplus
    _CALL_END();
#endif
    _CLOSEALL();
    sleep();
}
```

Note *1: Change the initial value for FPSCR in accord with option settings as described below. Refer to the hardware manual for details.

- When `-fpu=double` is specified, set the PR bit in FPSCR to 1. Otherwise, set this bit to 0.
- When `-round=nearest` is specified, set the RM bit in FPSCR to 00. Otherwise, set this bit to 01.
- When `-cpu=sh4` or `-cpu=sh4a` is specified along with `-denormalize=on`, set the DN bit in FPSCR to 0. Otherwise, set this bit to 1.

(3) Tables for section initialization (DTBL, BTBL)

The section initialization routine (`_INITSCT`) initializes any uninitialized data sections to zero, and copies initialization data in ROM for initialized data sections to RAM. Here the start and end addresses of sections which use the `_INITSCT` function are set in the table for section initialization using the section address operator.

Section names in the section initialization table are declared, using `C$BSEC` for uninitialized data areas, and `C$DSEC` for initialized data areas.

A coding example is shown below.

```
#pragma section $DSEC //Section name must be C$DSEC.
static const struct {
    void *rom_s; //Starting address member of the initialized data
                //section in ROM
    void *rom_e; //End address member of the initialized data
                //section in ROM
    void *ram_s; //Starting address member of the initialized data
                //section in RAM
} DTBL[] = { __sectop("D"), __secend("D"), __sectop("R")};

#pragma section $BSEC //Section name must be C$BSEC.
static const struct {
    void *b_s; //Starting address member of the uninitialized data
              //section
    void *b_e; //End address member of the uninitialized data
              //section
} BTBL[] = { __sectop("B"), __secend("B")};
```

(4) C/C++ library function initial settings (_INITLIB)

Here, the method for setting initial values for C/C++ library functions is explained.

In order to set only those values which are necessary for the functions that are actually to be used, please refer to the following guidelines.

- When using the <stdio.h>, <ios>, <streambuf>, <istream>, or <ostream> functions or the assert macro, the standard I/O initial setting (_INIT_IOLIB) is necessary.
- When an initial setting is required in the prepared low-level interface routines, the initial setting (_INIT_LOWLEVEL) in accordance with the specifications of the low-level interface routines is necessary.
- When using the rand function or the strtok function, initial settings other than those for standard I/O (_INIT_OTHERLIB) are necessary.

An example of a program to perform initial library settings is shown below. FILE-type data is shown in figure 9.7.


```

#include <stdio.h>
#include <stdlib.h>
#define IOSTREAM 3
const size_t _sbrk_size = 520; // Specifies the minimum unit of the size to define
                                // for the heap area (default: 1024)
const int _nfiles = IOSTREAM; // Specifies the number of I/O files (default: 20)
struct _iobuf _iob[IOSTREAM];
unsigned char _sml_buf[IOSTREAM];
extern char *_slp_ptr;

#ifdef __cplusplus
extern "C" {
#endif
void _INITLIB (void)
{
    _INIT_LOWLEVEL(); // Set initial setting for low-level interface routines
    _INIT_IOLIB(); // Set initial setting for I/O library
    _INIT_OTHERLIB(); // Set initial setting for rand function, strtok function
}

void _INIT_LOWLEVEL (void)
{
    // Set necessary initial setting for low-level library
}

void _INIT_IOLIB(void)
{
    FILE *fp;
    for( fp = _iob; fp < _iob + _nfiles; fp++ ) // Set initial setting for FILE
                                                // type data
    {
        fp->_bufptr = NULL;
        fp->_bufcnt = 0;
        fp->_buflen = 0;
        fp->_bufbase = NULL;
        fp->_ioflag1 = 0;
        fp->_ioflag2 = 0;
        fp->_iofd = 0;
    }
    if(freopen("stdin"1, "r", stdin)== NULL) // Open standard input file
        stdin->_ioflag1 = 0xff; // Forbid file access if open fails
    stdin->_ioflag1 |= _IOUNBUF; // Disable data buffering2
    if(freopen("stdout"1, "w", stdout)== NULL) // Open standard output file
        stdout->_ioflag1 = 0xff; // Forbid file access if open fails
    stdout->_ioflag1 |= _IOUNBUF; // Disable data buffering2
    if(freopen("stderr"1, "w", stderr)== NULL) // Open standard error file
        stderr->_ioflag1 = 0xff; // Forbid file access if open fails
    stderr->_ioflag1 |= _IOUNBUF; // Disable data buffering2
}

void _INIT_OTHERLIB(void)
{
    srand(1); // Set initial setting if using rand function
    _slp_ptr=NULL; // Set initial setting if using strtok function
}
#ifdef __cplusplus
}
#endif

```

- Notes:
1. Specify the filename for the standard I/O file. This name is used in the low-level interface routine "open".
 2. In the case of a console or other interactive device, a flag is set to prevent the use of buffering.

```

/* File-type data declaration in C language */

struct _iobuf{
    unsigned char *_bufptr;    /* Pointer to buffer */
    long          _bufcnt;    /* Buffer counter */
    unsigned char *_bufbase;  /* Base pointer to buffer */
    long          _buflen;    /* Buffer length */
    char          _ioflag1;   /* I/O flag */
    char          _ioflag2;   /* I/O flag */
    char          _iofd;      /* I/O flag */
}iob[_nfiles];

```

Figure 9.7 FILE-Type Data

(5) Closing files (_CLOSEALL)

Normally, output to files is held in a buffer area in memory, and when the buffer becomes full data is actually written to an external memory device. Hence if a file is not closed properly, it is possible that data output to a file may not actually be written to the external memory device. In the case of a program intended for embedding in equipment, normally the program is not terminated. However, if the main function is terminated due to a program error or for some other reason, open files must all be closed.

This processing closes any files that are open at the time of termination of the main function.

An example of a program to close all open files is shown below.

```
#include <stdio.h>

#ifdef __cplusplus
extern "C"
#endif
void _CLOSEALL(void)
{
    int i;

    for( i=0; i < _nfiles; i++ )

        // Check to see whether the file is open or not
        if( _iob[i]._ioflag1 & (_IOREAD | _IOWRITE | _IORW ) )
            fclose( &_iob[i] );        // Close the file
}
```

(6) Low-level interface routines

When using standard I/O or memory management library functions in a C/C++ program, low-level interface routines must be prepared. Table 9.3 lists the low-level interface routines used by C library functions.

Table 9.3 List of Low-Level Interface Routines

Name	Description
open	Opens file
close	Closes file
read	Reads from file
write	Writes to file
lseek	Sets the read/write position in a file
sbrk	Allocates area in memory
sbrk__X	Allocates area in X memory
sbrk__Y	Allocates area in Y memory
errno_addr*	Acquires errno address
wait_sem*	Defines semaphore
signal_sem*	Releases semaphore

Note: These routines are necessary when the reentrant library is used.

Initialization necessary for low-level interface routines must be performed on program startup. This initialization should be performed using the `_INIT_LOWLEVEL` function described in section 9.2.2 (4), C/C++ library function initial settings (`_INITLIB`).

Below, after explaining the basic approach to low-level I/O, the specifications for each interface routine are described.

Note: The function names `open`, `close`, `read`, `write`, `lseek`, `sbrk`, `sbrk__X`, `sbrk__Y`, `errno_addr`, `wait_sem`, and `signal_sem` are reserved for low-level interface routines. They should not be used in user programs.

(a) Approach to I/O

In the standard I/O library, files are managed by means of FILE-type data; but in low-level interface routines, positive integers are assigned in a one-to-one correspondence with actual files for management. These integers are called file numbers.

In the open routine, a file number is provided for a specified filename. The open routine must set the following information such that this number can be used for file input and output.

- The device type of the file (console, printer, disk file, etc.) (In the cases of special devices such as consoles or printers, special filenames must be set by the system and identified in the open routine.)
- When using file buffering, information such as the buffer position and size
- In the case of a disk file, the byte offset from the start of the file to the position for reading or writing

Based on the information set using the open routine, all subsequent I/O (read and write routines) and read/write positioning (lseek routine) is performed.

When output buffering is being used, the close routine should be executed to write the contents of the buffer to the actual file, so that the data area set by the open routine can be reused.

(b) Specifications of low-level interface routines

In this section, specifications for low-level interface routines are described. For each routine, the interface for calling the routine, its operation, and information for using the routine are described.

The interface for the routines is indicated using the following format. Low-level interface routines should always be given a prototype declaration. Add "extern C" to declare in the C++ program.

(Routine name)

Description	(A summary of the routine operations is given)	
Return value	Normal: (The meaning of the return value on normal termination is explained)	
	Error: (The return value when an error occurs is given)	
Parameters	(Name)	(Meaning)
	(The name of the parameter appearing in the interface)	(The meaning of the value passed as a parameter)

int open (char *name, int mode, int flg)

Description Prepares for operations on the file corresponding to the filename of the first parameter. In the open routine, the file type (console, printer, disk file, etc.) must be determined in order to enable writing or reading at a later time. The file type must be referenced using the file number returned by the open routine each time reading or writing is to be performed.

The second parameter, mode, specifies processing to be performed when the file is opened. The meanings of each of the bits of this parameter are as follows.

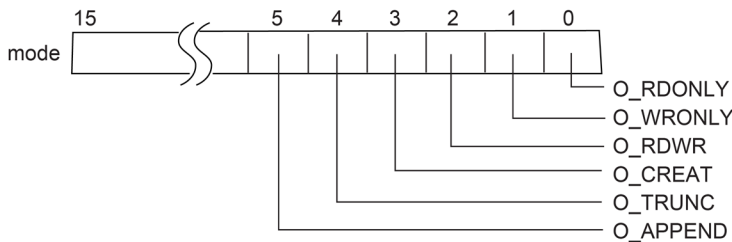


Table 9.4 Explanation of Bits in Parameter "mode" of open Routine

Bit	Description
O_RDONLY (bit 0)	When this bit is 1, the file is opened in read-only mode
O_WRONLY (bit 1)	When this bit is 1, the file is opened in write-only mode
O_RDWR (bit 2)	When this bit is 1, the file is opened for both reading and writing
O_CREAT (bit 3)	When this bit is 1, if a file with the filename given does not exist, it is created
O_TRUNC (bit 4)	When this bit is 1, if a file with the filename given exists, the file contents are deleted and the file size is set to 0
O_APPEND (bit 5)	Sets the position within the file for the next read/write operation When 0: Set to read/write from the beginning of file When 1: Set to read/write from file end

When there is a contradiction between the file processing specified by mode and the properties of the actual file, error processing should be performed. When the file is opened normally, the file number (0 to 127) should be returned which should be used in subsequent read, write, lseek, and close routines. The correspondence between file numbers and the actual files must be managed by low-level interface routines. If the open operation fails, -1 should be returned.

Return value	Normal:	The file number for the successfully opened file
	Error:	-1
Parameters	name	Filename of the file
	mode	Specifies the type of processing when the file is opened
	flg	Specifies processing when the file is opened (always 0777)

int close (int fileno)

Description	The file number obtained using the open routine is passed as an parameter. The file management information area set using the open routine should be released to enable reuse. Also, when output file buffering is performed in low-level interface routines, the buffer contents should be written to the actual file. When the file is closed successfully, 0 is returned; if the close operation fails, -1 is returned.	
Return value	Normal:	0
	Error:	-1
Parameter	fileno	File number of the file to be closed

int read (int fileno, char *buf, unsigned int count)

Description	Data is read from the file specified by the first parameter (fileno) to the area in memory specified by the second parameter (buf). The number of bytes of data to be read is specified by the third parameter (count). When the end of the file is reached, only a number of bytes fewer than or equal to count bytes can be read. The position for file reading/writing advances by the number of bytes read. When reading is performed successfully, the actual number of bytes read is returned; if the read operation fails, -1 is returned.	
Return value	Normal:	Actual number of bytes read
	Error:	-1
Parameters	fileno	File number of the file to be read
	buf	Memory area to store read data
	count	Number of bytes to read

int write (int fileno, char *buf, unsigned int count)

Description	<p>Writes data to the file indicated by the first parameter (fileno) from the memory area indicated by the second parameter (buf). The number of bytes to be written is indicated by the third parameter (count).</p> <p>If the device (disk, etc.) of the file to be written is full, only a number of bytes fewer than or equal to count bytes can be written. It is recommended that, if the number of bytes actually written is zero a certain number of times in succession, the disk should be judged to be full and an error (-1) should be returned.</p> <p>The position for file reading/writing advances by the number of bytes written. If writing is successful, the actual number of bytes written should be returned; if the write operation fails, -1 should be returned.</p> <p>When the value of parameter count is 0, the return value must also be 0.</p>						
Return value	<table> <tr> <td>Normal:</td> <td>Actual number of bytes written</td> </tr> <tr> <td>Error:</td> <td>-1</td> </tr> </table>	Normal:	Actual number of bytes written	Error:	-1		
Normal:	Actual number of bytes written						
Error:	-1						
Parameters	<table> <tr> <td>fileno</td> <td>File number to which data is to be written</td> </tr> <tr> <td>buf</td> <td>Memory area containing data for writing</td> </tr> <tr> <td>count</td> <td>Number of bytes to write</td> </tr> </table>	fileno	File number to which data is to be written	buf	Memory area containing data for writing	count	Number of bytes to write
fileno	File number to which data is to be written						
buf	Memory area containing data for writing						
count	Number of bytes to write						

int lseek (int fileno, long offset, int base)

Description Sets the position within the file, in byte units, for reading from and writing to the file.

The position within a new file should be calculated and set using the following methods, depending on the third parameter (base).

(1) When base is 0: Set the position at offset bytes from the file beginning

(2) When base is 1: Set the position at the current position plus offset bytes

(3) When base is 2: Set the position at the file size plus offset bytes

When the file is a console, printer, or other interactive device, when the new offset is negative, or when in cases (1) and (2) the file size is exceeded, an error occurs.

When the file position is set correctly, the new position for reading/writing should be returned as an offset from the file beginning; when the operation is not successful, -1 should be returned.

Return value Normal: The new position for file reading/writing, as an offset in bytes from the file beginning

Error: -1

Parameters

fileno	File number
offset	Position for reading/writing, as an offset (in bytes)
base	Starting-point of the offset

char *sbrk (int size)

Description	The size of the memory area to be allocated is passed as a parameter.	
	When calling the sbrk routine several times, memory areas should be allocated in succession starting from lower addresses. If the memory area for allocation is insufficient, an error should occur. When allocation is successful, the address of the beginning of the allocated memory area should be returned; if unsuccessful, (char *) -1 should be returned.	
Return value	Normal:	Starting address of allocated memory
	Error:	(char *) -1
Parameter	size	Size of area to be allocated

char __X *sbrk __X (int size)

Description	The size of the X memory area to be allocated is passed as a parameter.	
	When calling the sbrk __X routine several times in a row, memory areas should be allocated in succession starting from lower addresses. If the memory area for allocation is insufficient, an error should occur. When allocation is successful, the address of the beginning of the allocated memory area should be returned; if unsuccessful, (char __X *) -1 should be returned.	
Return value	Normal:	Starting address of allocated memory
	Error:	(char __X *) -1
Parameter	size	Size of area to be allocated

char __Y *sbrk__Y (int size)

Description	The size of the Y memory area to be allocated is passed as a parameter. When calling the sbrk__Y routine several times in a row, memory areas should be allocated in succession starting from lower addresses. If the memory area for allocation is insufficient, an error should occur. When allocation is successful, the address of the beginning of the allocated memory area should be returned; if unsuccessful, (char __Y *) -1 should be returned.	
Return value	Normal:	Starting address of allocated memory
	Error:	(char __Y *) -1
Parameter	size	Size of area to be allocated

int *errno_addr (void)

Description	Returns the address of the error number of the current task. This routine is necessary when using a standard library, which was created by the standard library generator with the reent option specified.
Return value	Address of the error number of the current task

int wait_sem (int semnum)

Description Defines the semaphore specified by semnum.

When the semaphore has been defined normally, 1 must be returned.
Otherwise, 0 must be returned.

This routine is necessary when using a standard library, which was created by the standard library generator with the **reent** option specified.

Return value Normal: 1
 Error: 0

Parameter semnum Semaphore ID

int signal_sem (int semnum)

Description Releases the semaphore specified by **semnum**.

When the semaphore has been released normally, 1 must be returned.
Otherwise, 0 must be returned.

This routine is necessary when using a standard library, which was created by the standard library generator with the **reent** option specified.

Return value Normal: 1
 Error: 0

Parameter semnum Semaphore ID

(c) Example of coding the low-level interface routines

```

/*****
/*
/*          lowsrc.c:
/*-----*/
/*      SuperH RISC engine Series Simulator/Debugger Interface Routine
/*      Only standard I/O (stdin,stdout,stderr) are supported
/*****
#include <string.h>

/* File Number */
#define STDIN 0          /* Standard input (Console) */
#define STDOUT 1       /* Standard output (Console) */
#define STDERR 2       /* Standard error output (Console) */

#define FLMIN 0         /* Minimum file number */
#define FLMAX 3         /* Maximum number of files */

/* File flags */
#define O_RDONLY 0x0001 /* Read only */
#define O_WRONLY 0x0002 /* Write only */
#define O_RDWR 0x0004  /* Read/Write */

/* Special character code */
#define CR 0x0d         /* Carriage return */
#define LF 0x0a         /* Line feed */

/* Area size managed by sbrk */
#define HEAPSIZ 1024

/*****
/*          Reference function declaration:
/*
/*      Assembly program reference which inputs/outputs characters to
/*      console using simulator/debugger
/*****
extern void charput(char); /* One character input processing */
extern char charget(void); /* One character output processing */

/*****
/*          Static variable definition:
/*
/*      Definition of static variables used in low-level interface routine
/*****
char flmod[FLMAX]; /* Mode setting location of open file */

union HEAP_TYPE{
    long dummy; /* Dummy for four-byte alignment */
    char heap[HEAPSIZ]; /* Declaration of area managed by sbrk */
};

static union HEAP_TYPE heap_area;
static __X union HEAP_TYPE heap_area __X;
static __Y union HEAP_TYPE heap_area __Y;
static char *brk=(char*)&heap_area; /* End address allocated by sbrk */
static __X char *brk __X=(char __X*)&heap_area __X;
/* End address allocated by sbrk __X */
static __Y char *brk __Y=(char __Y*)&heap_area __Y;
/* End address allocated by sbrk __Y */

```

```

/*****
/*                               open: Open file                               */
/*                               Return value: File Number (Normal)           */
/*                               -1 (Error)                                   */
/*****
int open(char *name, /* File name */
          int mode) /* File mode */
{
    /* Check mode according to the file name, and return the file number */

    if (strcmp(name,"stdin")==0) { /* Standard input file */
        if ((mode&O_RDONLY)==0) {
            return (-1);
        }
        flmod[STDIN]=mode;
        return (STDIN);
    }

    else if (strcmp(name,"stdout")==0) { /* Standard output file */
        if ((mode&O_WRONLY)==0) {
            return (-1);
        }
        flmod[STDOUT]=mode;
        return (STDOUT);
    }

    else if (strcmp(name,"stderr")==0){ /* Standard error output file */
        if ((mode&O_WRONLY)==0) {
            return (-1);
        }
        flmod[STDERR]=mode;
        return (STDERR);
    }

    else {
        return (-1); /* Error */
    }
}

/*****
/*                               close: Close file                               */
/*                               Return value      0 (Normal)                   */
/*                               -1 (Error)                                   */
/*****
int close(int fileno) /* File number */
{
    if (fileno<FLMIN || FLMAX<fileno) { /* Check file number range */
        return -1;
    }

    flmod[fileno]=0; /* Reset file mode */

    return 0;
}

```

```

/*****
/*                               read: Read data                               */
/*                               Return value: Read character count (Normal) */
/*                               -1                                           (Error) */
/*****
int read(int fileno, /* File number */
        char *buf, /* Transfer destination buffer address */
        unsigned int count) /* Read character count */
{
    unsigned int i;

    /* Check mode according to file name, input one character each, */
    /* and store the characters to buffer */

    if (flmod[fileno]&O_RDONLY || flmod[fileno]&O_RDWR) {
        for (i=count;i>0;i--) {
            *buf=charget();
            if (*buf==CR) { /* Replace line feed character */
                *buf=LF;
            }
            buf++;
        }
        return count;
    }

    else {
        return -1;
    }
}

/*****
/*                               write: Write data                               */
/*                               Return value: Written data count (Normal) */
/*                               -1                                           (Error) */
/*****
int write(int fileno, /* File number */
        char *buf, /* Transfer source buffer address */
        unsigned int count) /* Written character count */
{
    unsigned int i;
    char c;

    /* Check mode according to file name and output one character at a time */

    if (flmod[fileno]&O_WRONLY || flmod[fileno]&O_RDWR) {
        for (i=count; i>0; i--) {
            c=*buf++;
            charput(c);
        }
        return count;
    }

    else {
        return -1;
    }
}

```

```

/*****
/*          lseek: Set file read/write position          */
/*      Return value: Offset from the beginning of file to be read/written (Normal) */
/*          -1 (Error)                                */
/*          (Console I/O does not support lseek)      */
/*****
long lseek(int fileno, /* File number */
           long offset, /* Read/write start position */
           int base) /* Start of offset */
{
    return -1;
}

/*****
/*          sbrk: Memory area allocation                */
/*      Return value: Start address of allocated area (Normal) */
/*          -1 (Error)                                */
/*****
char *sbrk(unsigned long size) /* Size of area to be allocated */
{
    char *p;

    /* Check empty area */

    if (brk+size>heap_area.heap+HEAPSIZE) {
        return (char *)-1;
    }

    p=brk; /* Allocate area */
    brk+=size; /* Update end address */
    return p;
}

/*****
/*          sbrk_X: Memory area allocation             */
/*      Return value: Start address of allocated area (Normal) */
/*          -1 (Error)                                */
/*****
char _X *sbrk_X(unsigned long size) /* Size of area to be allocated */
{
    _X char *p;

    /* Check empty area */

    if (brk_X+size>heap_area_X.heap+HEAPSIZE) {
        return (char _X *)-1;
    }

    p=brk_X; /* Allocate area */
    brk_X+=size; /* Update end address */
    return p;
}

```



```

/*****
/*          sbrk__Y: Memory area allocation          */
/*          Return value: Start address of allocated area (Normal) */
/*          -1 (Error)                                */
*****/
char __Y *sbrk__Y(unsigned long size)
/* Size of area to be allocated */
{
    __Y char *p;

    /* Check empty area */

    if (brk__Y+size>heap_area__Y.heap+HEAPSIZE) {
        return (char __Y *)-1;
    }

    p=brk__Y; /* Allocate area */
    brk__Y+=size; /* Update end address */
    return p;
}

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                               lowlvl.src                               ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; SuperH RISC engine Series Simulator/Debugger Interface Routine      ;
;                               Input/Output one character              ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
    .EXPORT    _charput
    .EXPORT    _charget
SIM_IO:
    .EQU       H'0000 ; Specify TRAP_ADDRESS

    .SECTION   P, CODE, ALIGN=4

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                               _charput: One character output          ;
;                               C program interface: charput(char)      ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

_charput:
    MOV.L     O_PAR,R0          ; Set buffer address
    MOV.B     R4,@R0           ; Set parameter to buffer
    MOV.L     #O_PAR,R1        ; Set parameter block address
    MOV.L     #H'01220000,R0   ; Set function code (PUTC)
    MOV.W     #SIM_IO,R2       ; Set system call address
    JSR      @R2
    NOP
    RTS
    NOP

    .ALIGN 4
O_PAR:          ;Parameter block area
    .DATA.L  OUT_BUF

```

```

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;
;           _charget: One character input           ;
;           C program interface: char charget(void) ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

        .ALIGN 4
_charget:
MOV.L   #I_PAR,R1      ; Set parameter block address
MOV.L   #H'01210000,R0 ; Set function code (GETC)
MOV.W   #SIM_IO,R2     ; Set system call address
JSR     @R2
NOP
MOV.L   I_PAR,R0       ; Set buffer address
MOV.B   @R0,R0         ; Set the input data as the return value
RTS
NOP

        .ALIGN      4
I_PAR:  .DATA.L     IN_BUF

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;
;           Definition of I/O buffer                ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

        .SECTION   B,DATA,ALIGN=4

OUT_BUF:
        .RES.L 1   ; Output buffer
IN_BUF:
        .RES.L 1   ; Input buffer

        .END

```

(d) Example of low-level interface routine for reentrant library

The following shows an example of a low-level interface routine for a reentrant library. This routine is necessary when using a standard library, which was created by the standard library generator with the **reent** option specified.

When an error is returned from the **wait_sem** function or **signal_sem** function, set **errno** as follows to return from the library function.

Bit Function	errno	Description
wait_sem	EMALRESM	Failed to allocate semaphore resources for malloc
	ETOKRESM	Failed to allocate semaphore resources for strtok
	EIOBRESM	Failed to allocate semaphore resources for _job
signal_sem	EMALFRSM	Failed to release semaphore resources for malloc
	ETOKFRSM	Failed to release semaphore resources for strtok
	EIOBFRSM	Failed to release semaphore resources for _job

When an interrupt with a priority level higher than the current level is generated after semaphores have been defined, dead locks will occur if semaphores are defined again. Therefore, be careful for processes that share resources because they might be nested by interrupts.

```
#define MALLOC_SEM      1      /* Semaphore No. for malloc */
#define STRTOK_SEM     2      /* Semaphore No. for strtok */
#define FILE_TBL_SEM  3      /* Semaphore No. for fopen */
#define MALLOC_SEM_ _X 4      /* Semaphore No. for malloc_ _X */
#define MALLOC_SEM_ _Y 5      /* Semaphore No. for malloc_ _Y */
#define IOB_SEM        6      /* Semaphore No. for _iob */
#define SEMSIZE        26     /* IOB_SEM + nfiles (when _nfiles = 20) */
#define TRUE           1
#define FALSE          0
#define OK              1
#define NG              0
```

```
extern int *errno_addr(void);
extern int wait_sem(int);
extern int signal_sem(int);
```

```
int sem_errno;
int force_fail_signal_sem = FALSE;
static int semaphore[SEMSIZE];
```

```
/*
 *          errno_addr: Acquisition of errno address          *
 *          Return value: errno address                       *
 */
```

```
int *errno_addr(void)
{
    /* Return the errno address of the current task */
    return (&sem_errno);
}
```

```
/*
 *          wait_sem: Defines the specified numbers of semaphores          *
 *          Return value: OK(=1) (Normal)                               *
 *          NG(=0) (Error)                                              *
 */
```

```
int wait_sem(int semnum) /* Semaphore ID */
{
    if((0 <= semnum) && (semnum < SEMSIZE)) {
        if(semaphore[semnum] == FALSE) {
            semaphore[semnum] = TRUE;
            return(OK);
        }
    }
    return(NG);
}

/*****
/*      signal_sem: Releases the specified numbers of semaphores      */
/*              Return value: OK(=1) (Normal)                          */
/*              NG(=0) (Error)                                         */
*****/
int signal_sem(int semnum) /* Semaphore ID */
{
    if(!force_fail_signal_sem) {
        if((0 <= semnum) && (semnum < SEMSIZE)) {
            if(semaphore[semnum] == TRUE ) {
                semaphore[semnum] = FALSE;
                return(OK);
            }
        }
    }
    return(NG);
}
```

(7) Termination processing routine

- (a) Example of preparation of a routine for termination processing registration and execution (atexit)

The method for preparation of the library function atexit to register termination processing is described.

The atexit function registers, in a table for termination processing, a function address passed as a parameter. If the number of functions registered exceeds the limit (in this case, the number that can be registered is assumed to be 32), or if an attempt is made to register the same function twice, NULL is returned. Otherwise, a value other than NULL (in this case, the address of the registered function) is returned.

A program example is shown below.

Example:

```
#include <stdlib.h>
typedef void *atexit_t ;

int _atexit_count=0 ;

atexit_t (*_atexit_buf[32])(void) ;

#ifdef __cplusplus
extern "C"
#endif
atexit_t atexit(atexit_t (*f)(void))
{
    int i;

    for(i=0; i<_atexit_count ; i++)        // Check whether it is already registered
        if(_atexit_buf[i]==f)
            return NULL ;
    if(_atexit_count==32) // Check the limit value of number of registration
        return NULL ;
    else {
        _atexit_buf[_atexit_count++]=f;    // Register the function address
        return f;
    }
}
```

(b) Example of preparation of a routine for program termination (exit)

The method for preparation of an exit library function for program termination is described. Program termination processing will differ among user systems; refer to the program example below when preparing a termination procedure according to the specifications of the user system.

The exit function performs termination processing for a program according to the termination code for the program passed as a parameter, and returns to the environment in which the program was started. Here, the termination code is set to an external variable, and execution returned to the environment saved by the `setjmp` function immediately before the main function was called. In order to return to the environment prior to program execution, the following `callmain` function should be created, and instead of calling the function `main` from the `PowerON_Reset` initial setting function, the `callmain` function should be called.

A program example is shown below.

```

#include <setjmp.h>
#include <stddef.h>

typedef void * atexit_t ;
extern int _atexit_count ;
extern atexit_t (*_atexit_buf[32])(void) ;
#ifdef __cplusplus
extern "C"
#endif
void _CLOSEALL(void);
int main(void);
extern jmp_buf _init_env ;
int _exit_code ;

#ifdef __cplusplus
extern "C"
#endif
void exit(int code)
{
    int i;
    _exit_code=code ; // Set the return code in _exit_code
    for(i=_atexit_count-1; i>=0; i--) // Execute in sequence the functions
        (*_atexit_buf[i]) (); // registered by the atexit function
    _CLOSEALL(); // Close all open functions
    longjmp(_init_env, 1) ; // Return to the environment saved by setjmp
}

#ifdef __cplusplus
extern "C"
#endif
void callmain(void)
{
    // Save the current environment using setjmp and call the main function
    if(!setjmp(_init_env))
        _exit_code=main(); // On returning from the exit function,
                          // terminate processing
}

```


(c) Example of creation of an abnormal termination (abort) routine

On abnormal termination, processing for abnormal termination must be executed in accordance with the specifications of the user system.

In a C++ program, the abort function will also be called in the following cases:

- When exception processing was unable to operate correctly.
- When a pure virtual function is called.
- When `dynamic_cast` has failed.
- When `typeid` has failed.
- When information could not be acquired when a class array was deleted.
- When the definition of the destructor call for objects of a given class causes a contradiction.

Below is shown an example of a program which outputs a message to the standard output device, then closes all files and begins an infinite loop to wait for reset.

```
#include <stdio.h>
#ifdef __cplusplus
extern "C"
#endif
void _CLOSEALL(void);
#ifdef __cplusplus
extern "C"
#endif
void abort(void)
{
    printf("program is abort !!\n");           //Output message
    _CLOSEALL();                             //Close all files
    while(1) ;                               //Begin infinite loop
}
```

9.3 Linking C/C++ Programs and Assembly Programs

Here the following matters to be born in mind when linking C/C++ programs and assembly programs are discussed.

- Method for mutual referencing of external names
- Interface for function calls

9.3.1 Method for Mutual Referencing of External Names

External names which have been declared in a C/C++ program can be referenced and updated in both directions between the C/C++ program and an assembly program. The compiler treats the following items as external names.

- Global variables which are not declared as static storage classes (C/C++ programs)
- Variable names declared as extern storage classes (C/C++ programs)
- Function names not declared as static memory classes (C programs)
- Non-member, non-inline function names not specified as static memory classes (C++ programs)
- Non-inline member function names (C++ programs)
- Static data member names (C++ programs)

(1) Method for referencing assembly program external names in C/C++ programs

In assembly programs, `.EXPORT` is used to declare external symbol names (preceded by an underscore (`_`)).

In C/C++ programs, symbol names (not preceded by an underscore) are declared using the `extern` keyword.

Assembly program (definition)

```
.EXPORT  _a, _b
.SECTION D, DATA, ALIGN=4
_a: .DATA.L 1
_b: .DATA.L 1
.END
```

C/C++ program (reference)

```
extern int a,b;

void f()
{
    a+=b;
}
```

(2) Method for referencing C/C++ program external names (variables and C functions) from assembly programs

A C/C++ program can define external variable names (without an underscore (_)).

In an assembly program, .IMPORT is used to declare an external name (preceded by an underscore).

C/C++ program (definition)

```
int a;
```

Assembly program (reference)

```
.IMPORT    _a
.SECTION  P, CODE, ALIGN=4
MOV.L    A_a, R1
MOV.L    @R1, R0
ADD      #1, R0
RTS
MOV.L    R0, @R1
.ALIGN   4
A_a:    .DATA.L    _a
.END
```

(3) Method for referencing C++ program external names (functions) from assembly programs

By declaring functions to be referenced from an assembly program using the extern "C" keyword, the function can be referenced using the same rules as in (2) above. However, functions declared using extern "C" cannot be overloaded.

C++ program (callee)

```
extern "C"
void sub()
{
    .
    .
}
```

Assembly program (caller)

```

        .IMPORT    _sub
        .SECTION  P, CODE, ALIGN=4
        .
        .

        STS.L     PR, @-R15
        MOV.L     R1, @ (1, R15)
        MOV       R3, R12
        MOV.L     A_sub, R0
        JSR      @R0
        NOP
        LDS.L     @R15+, PR
        .
        .
A_sub:  .DATA.L   _sub
        .END

```

9.3.2 Function Calling Interface

When either a C/C++ program or an assembly program calls the other, the assembly programs must be written using rules involving the following:

1. Stack pointer
2. Allocating and deallocating stack frames
3. Registers
4. Setting and referencing parameters and return values

(1) Stack Pointer

Valid data must not be stored in a stack area with an address lower than the stack pointer (in the direction of address H'0), since the data may be destroyed by an interrupt process.

(2) Allocating and Deallocating Stack Frames

In a function call (immediately after the JSR or the BSR instruction has been executed), the stack pointer indicates the lowest address of the stack used by the calling function. Allocating and setting data at addresses greater than this address must be done by the caller.

After the callee deallocates the area it has set with data, control returns to the caller usually with the RTS instruction. The caller then deallocates the area having a higher address (the return value address and the parameter area).

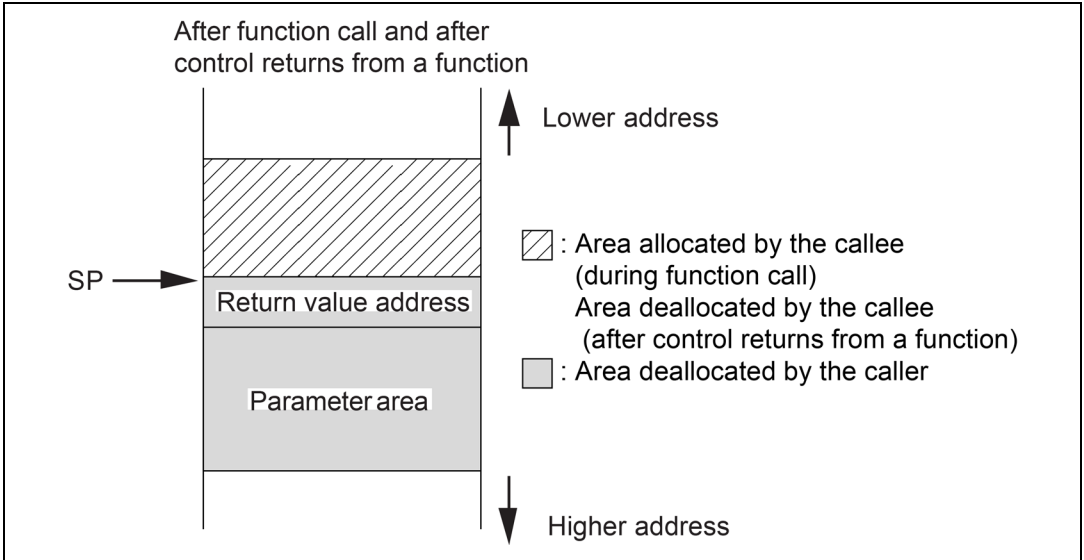


Figure 9.8 Allocation and Deallocation of a Stack Frame

(3) Registers

Some registers may change during a function call, while some may not. Table 9.5 shows the rules to save and restore registers.

Table 9.5 Rules to Save and Restore Registers

Item	Registers Used in a Function	Notes on Programming
Registers not guaranteed	R0 to R7, FR0 to FR11* ¹ , DR0 to DR10* ² , FPUL* ^{1*2} , FPSCR* ^{1*2*4} , A0* ³ , A0G* ³ , A1* ³ , A1G* ³ , M0* ³ , M1* ³ , X0* ³ , X1* ³ , Y0* ³ , Y1* ³ , DSR* ³ , MOD* ³ , RS* ³ , and RE* ³	If registers used in a function contain valid data when a program calls the function, the caller must save the data onto the stack or into the register before calling the function. The callee function can use the registers without saving the contained data. However, when fpscr=safe is specified, the contents of FPSCR are guaranteed.
Registers guaranteed	R8 to R15, MACH, MACL, PR, FR12 to FR15* ¹ , and DR12 to DR14* ²	The data in registers used in functions is saved onto the stack at function entry, and restored from the stack at function exit. Note that data in the MACH and MACL registers are not guaranteed if macsave=0 is specified. When gbr=auto is specified, the contents of GBR are guaranteed.

- Notes:
1. Single-precision floating point registers for SH-2E, SH2A-FPU, SH-4, and SH-4A.
 2. Double-precision floating point registers for SH2A-FPU, SH-4, and SH-4A.
 3. DSP registers for SH2-DSP, SH3-DSP, and SH4AL-DSP.
 4. The precision modes at the start of functions are as follows.
 - When the **fpu=double** option is used, the mode is double-precision.
 - When the **fpu=single** option is used or when the **fpu** option is not used, the mode is single-precision. In the case of interrupt functions, the precision mode might need to be set since they might actually be called in double-precision mode. For details, see section 9.4.1 (6) Interrupt Functions When the CPU Type Is SH2A-FPU, SH4, or SH4A.

The following examples show the rules on registers.

- A subroutine in an assembly program is called by a C/C++ program

Assembly program (callee)

```

        .EXPORT    _sub
        .SECTION  P, CODE, ALIGN=4
_sub:   MOV.L     R14, @-R15
        MOV.L     R13, @-R15
        ADD      #-8, R15

        .
        .

        ADD      #8, R15
        MOV.L    @R15+, R13
        RTS
        MOV.L    @R15+, R14
        .END
    
```

Saves the registers used in the function.

Processing of the function
(The contents of R0 to R7 registers are not guaranteed, so the registers can be used without saving the contents in the function.)

Restores the saved registers.

C/C++ program (caller)

```

#ifdef __cplusplus
extern "C"
#endif
void sub();

void f()
{
    sub();
}
    
```

- A function in a C/C++ program is called by an assembly program
C/C++ program (callee)

```
void sub()
{
    .
    .
}
```

Assembly program (caller)

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

    STS.L   PR, @-R15

    MOV.L   R1, @(1, R15)
    MOV     R3, R12

    MOV.L   A_sub, R0
    JSR     @R0
    NOP
    LDS.L   @R15+, PR
    .
    .
A_sub:    .DATA.L   _sub
        .END
```

- } The called function name prefixed with () is declared by the .IMPORT (C).
The external name generated from the function declaration or definition by the compiler is declared by the .IMPORT (C++).
- } Stores the PR register (return address storage register) when calling the function.
- } If registers R0 to R7 contain valid data, the data is pushed onto the stack or stored in unused registers.
- } Calls function sub.
- } Restores the PR register.
- Address data of function sub.

Note: The compiler uses a rule to convert the external name created by the function name or static data member. When you need to know the external name created by the compiler, refer to the external name created by the compiler using **code=asmcode** or the **listfile** option. Defining a C++ function with extern "C" specified applies the same generation rules as C functions to external names, although this makes overloading of the function impossible.

(4) Setting and Referencing Parameters and Return Values

This section explains how to set and reference parameters and return values.

This section first explains the general rules concerning parameters and return values, and then how the parameters are allocated, and how to set return values.

(a) General rules concerning parameters and return values

— Passing parameters

A function is called after parameters have been copied to a parameter area in registers or on the stack. Since the caller does not reference the parameter area after control returns to it, the caller is not affected even if the callee modifies the parameters.

— Rules on type conversion

Type conversion may be performed automatically when parameters are passed or a return value is returned. The following explains the rules on type conversion.

- Type conversion of parameters whose types are declared

Parameters whose types are declared by a prototype declaration are converted to the declared types.

- Type conversion of parameters whose types are not declared

Parameters whose types are not declared by a prototype declaration are converted according to the following rules.

- (signed) char, unsigned char, (signed) short, and unsigned short type parameters are converted to (signed) int type parameters.

- float type parameters are converted to double type parameters.

- Types other than the above are not converted.

- Type conversion of a return value

A return value is converted to the data type returned by the function.

Examples:

```
(1) long f ( );
    long f ( )
    {   float x;
        return x;
    }
```

← The return value is converted to long by a prototype declaration.

```
(2) void p ( int, ... );
    void f ( )
    {   char c;
        P ( 1.0, c );
    }
```

↑ c is converted to int because a type is not declared for the parameter.

↑ 1.0 is converted to int because the type of the parameter is int.

(b) Parameter area allocation

Parameters are allocated to registers, or when this is impossible, to a parameter area on the stack. Figure 9.9 shows the parameter area allocation. Table 9.6 lists general rules on the parameter area allocation. The **this** pointer to a nonstatic function member in a C++ program is assigned to R4.

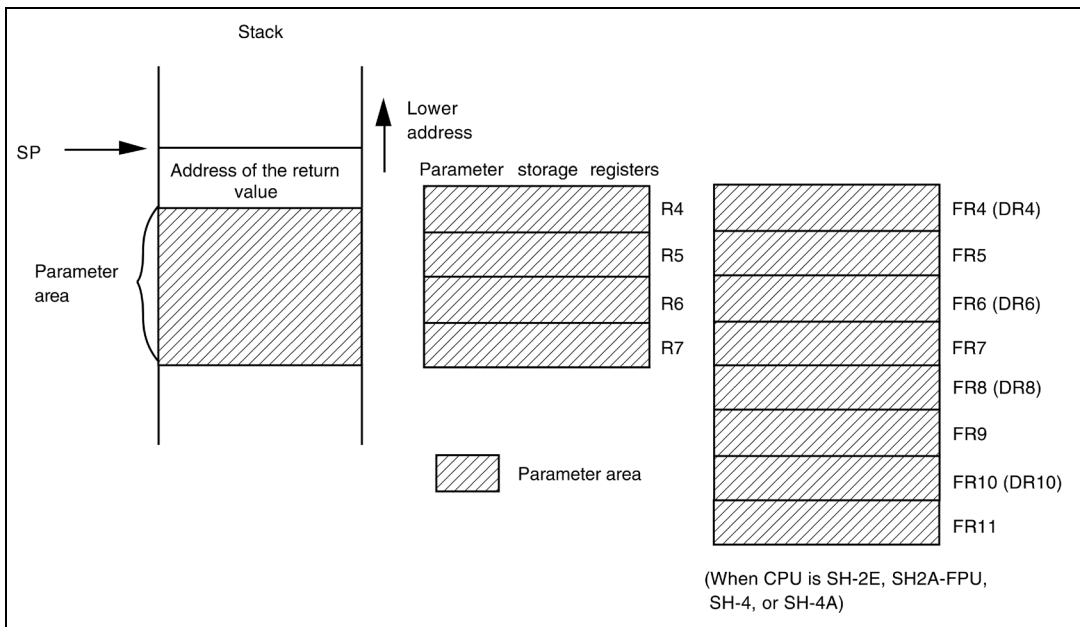


Figure 9.9 Parameter Area Allocation

Table 9.6 General Rules on Parameter Area Allocation

Parameters Allocated to Registers		
Parameter Storage Registers	Target Type	Parameters Allocated to a Stack
R4 to R7	char, unsigned char, bool, short, unsigned short, int, unsigned int, long, unsigned long, float (when CPU is other than SH-2E, SH2A-FPU, SH-4, or SH-4A), pointer, pointer to a data member, and reference	(1) Parameters whose types are other than target types for register passing (2) Parameters of a function which has been declared by a prototype declaration to have variable-number parameters* ³
FR4 to FR11* ¹	For SH-2E <ul style="list-style-type: none"> • Parameter is float type. • Parameter is double type and double=float is specified. For SH2A-FPU, SH-4, or SH-4A <ul style="list-style-type: none"> • Parameter type is float type and fpu=double is not specified. • Parameter type is double type or long double type and fpu=single is specified. 	(3) When other parameters are already allocated to R4 to R7. (4) When other parameters are already allocated to FR4 (DR4) to FR11 (DR10). (5) long long type and unsigned long long type parameters (6) <code>__fixed</code> type, <code>long __fixed</code> type, <code>__accum</code> type, and <code>long __accum</code> type parameters
DR4 to DR10* ²	For SH2A-FPU, SH-4, or SH-4A <ul style="list-style-type: none"> • Parameter type is double type or long double type and fpu=single is not specified. • Parameter type is float type and fpu=double is specified. 	

Notes: 1. Single-precision floating-point registers for SH-2E, SH2A-FPU, SH-4, and SH-4A.
 2. Double-precision floating-point registers for SH2A-FPU, SH-4, and SH-4A.
 3. If a function has been declared to have variable parameters by a prototype declaration, parameters which do not have a corresponding type in the declaration and the immediately preceding parameter are allocated to a stack.

Example:

```
int f2(int,int,int,int,...);
:
```

`f2(a, b, c, x, y, z);` ← `x`, `y`, and `z` are allocated to a stack.

(c) Parameter allocation

— Allocation to parameter storage registers

Following the order of their declaration in the source program, parameters are allocated to the parameter storage registers starting with the smallest numbered register. Figure 9.10 shows an example of parameter allocation to registers.

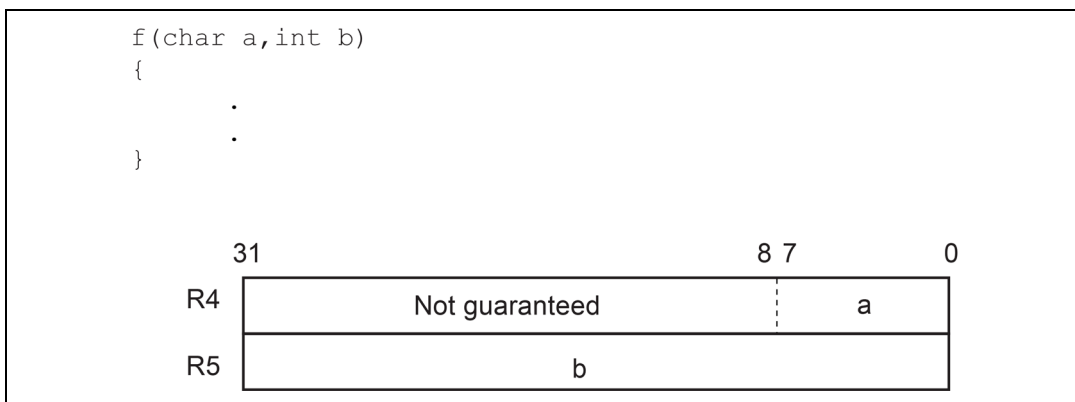


Figure 9.10 Example of Allocation to Parameter Registers

— Allocation to a stack parameter area

Parameters are allocated to the stack parameter area starting from lower addresses, in the order that they are specified in the source program.

Note: Regardless of the alignment determined by the structure type, union type, or class type, parameters are allocated using 4-byte alignment. Also, the area size for each parameter must be a multiple of four bytes. This is because the SuperH RISC engine microcomputer stack pointer is incremented or decremented in 4-byte units. Refer to section 9.3.3, Examples of Parameter Allocation, for examples of parameter allocation.

(d) Return value writing area

The return value is written to either a register or memory depending on its type. Refer to table 9.7 for the relationship between the return value type and area.

When a function return value is to be written to memory, the return value is written to the area indicated by the return value address. The caller must allocate the return value setting area in addition to the parameter area, and must set the address of the return value area in the return value address area before calling the function (see figure 9.11). The return value is not written if its type is void.

Table 9.7 Return Value Type and Setting Area

Return Value Type	Return Value Area
(signed) char, unsigned char, (signed) short, unsigned short, (signed) int, unsigned int, long, unsigned long, float, pointer, bool, reference, and pointer to a data member	<p>R0: 32 bits</p> <p>The contents of the upper three bytes of (signed) char, or unsigned char and the contents of the upper two bytes of (signed) short or unsigned short are not guaranteed. However, when the rtnext option is specified, sign extension is performed for (signed) char or (signed) short type, and zero extension is performed for unsigned char or unsigned short type.</p> <p>FR0: 32 bits</p> <p>(1) For SH-2E</p> <ul style="list-style-type: none"> • Return value is float type. • Return value is double type and double=float is specified. <p>(2) For SH2A-FPU, SH-4, or SH-4A</p> <ul style="list-style-type: none"> • Return value is float type and fpu=double is not specified. • Return value is floating-point type and fpu=single is specified.
double, long double, structure, union, class, and pointer to a function member	<p>Return value setting area (memory)</p> <p>DR0: 64 bits</p> <p>For SH2A-FPU, SH-4, or SH-4A</p> <ul style="list-style-type: none"> • Return value is double type and fpu=single is not specified. • Return value is floating-point type and fpu=double is specified.
(signed) long long and unsigned long long	Return value setting area (memory)
__fixed, long __fixed, __accum, and long __accum	Return value setting area (memory)

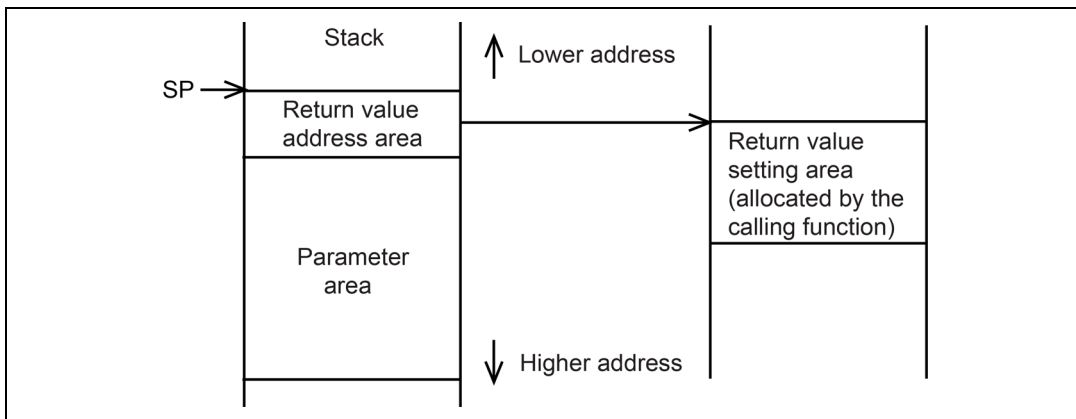


Figure 9.11 Return Value Setting Area Used When Return Value Is Written to Memory

9.3.3 Examples of Parameter Allocation

Example 1: Parameters passed by are allocated, in the order in which they are declared, to registers R4 to R7.

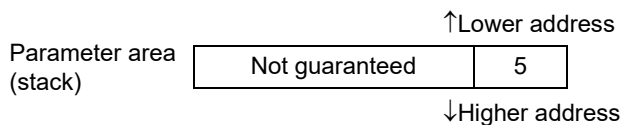
```
int f(char, short, int, float);
:
f(1, 2, 3, 4.0);
```

R4	Not guaranteed	1
R5	Not guaranteed	2
R6	3	
R7	4.0	

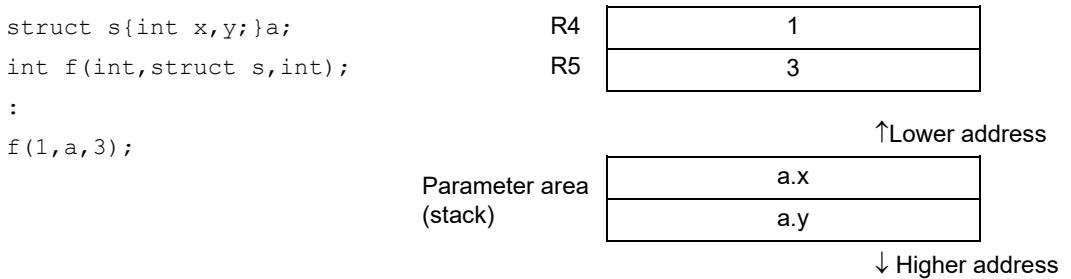
Example 2: Parameters that cannot be allocated to registers are allocated to the stack. When the parameters are (unsigned) char or (unsigned) short types and are allocated to the parameter area in the stack, they are first extended to 4 bytes.

```
int f(int, short, long, float, char);
:
f(1, 2, 3, 4.0, 5);
```

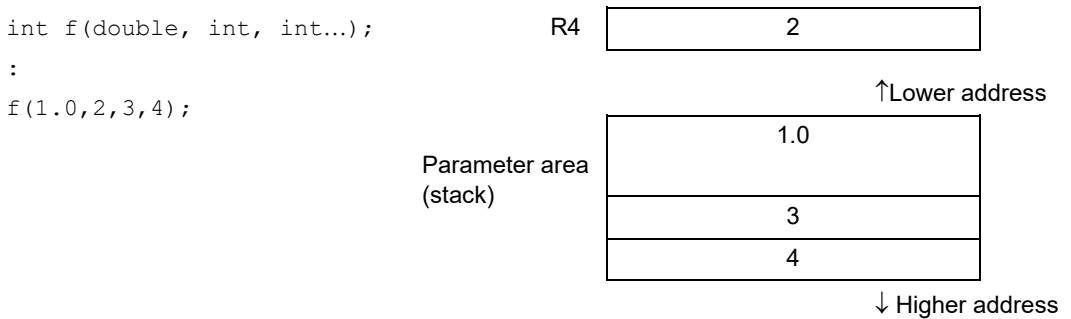
R4	1	
R5	Not guaranteed	2
R6	3	
R7	4.0	



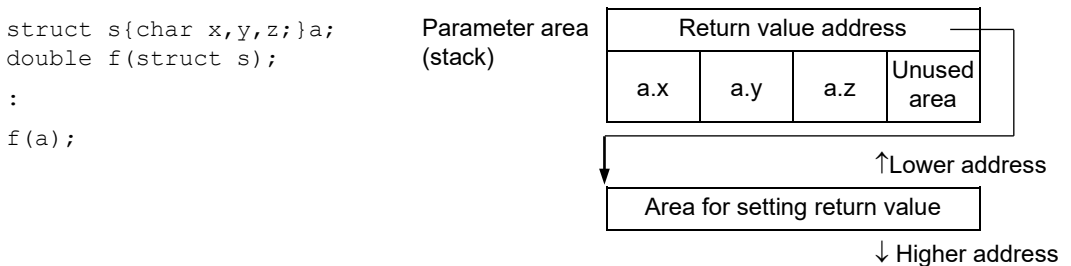
Example 3: Parameters of types that cannot be allocated to registers are allocated to the stack.



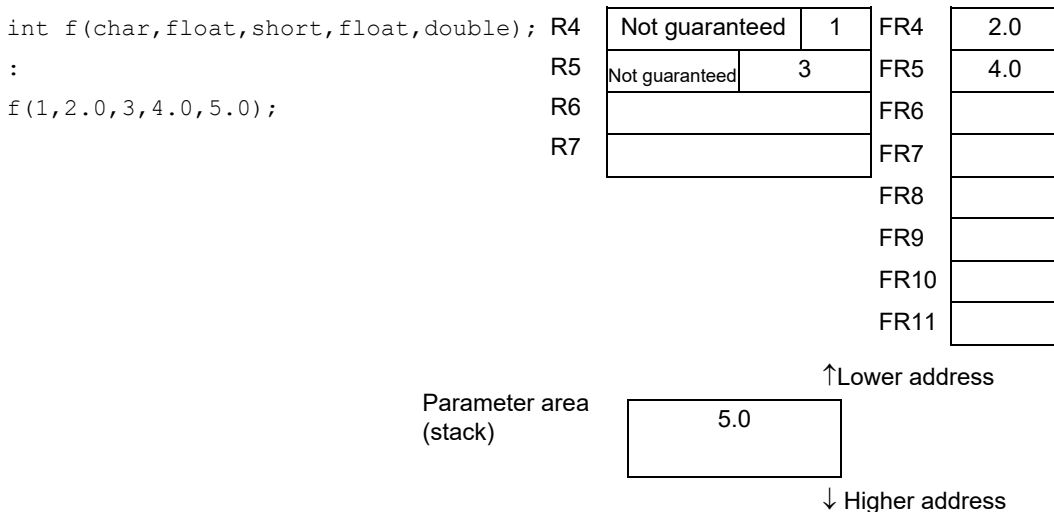
Example 4: When declared in a prototype declaration as a function with a variable parameters, the parameters without corresponding types and the immediately preceding parameter are allocated to the stack in the order in which they are declared.



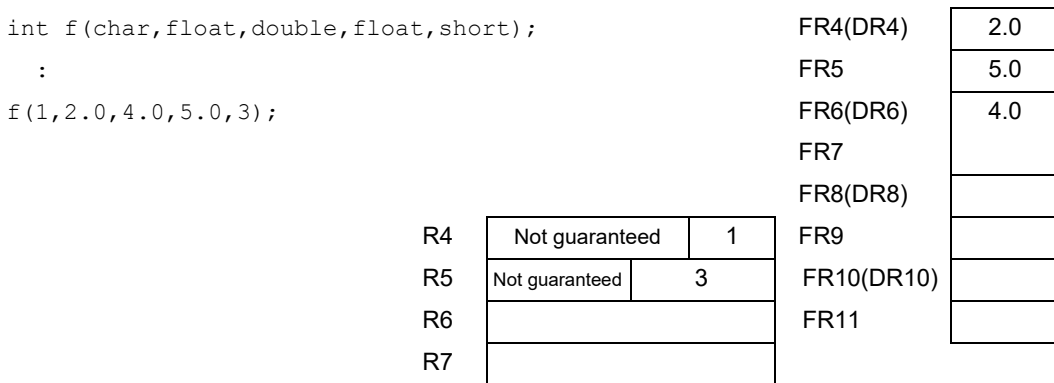
Example 5: When the type returned by a function is more than 4 bytes, or a class, the return value address is set immediately before the parameter area. If the size of the class is not a multiple of 4 bytes, unused space is padded.



Example 6: When the CPU is SH-2E, float type parameters are allocated to the FPU registers.



Example 7: When the CPU is SH2A-FPU, SH-4, or SH-4A, float and double type parameters are allocated to the FPU registers.



9.3.4 Using the Registers and Stack Area

This section describes how the compiler uses registers and stack areas. Registers and stack areas in functions are controlled by the compiler and the user is not required to have any particular understanding of how these areas are used. Figure 9.12 shows how the registers and stack areas are used.

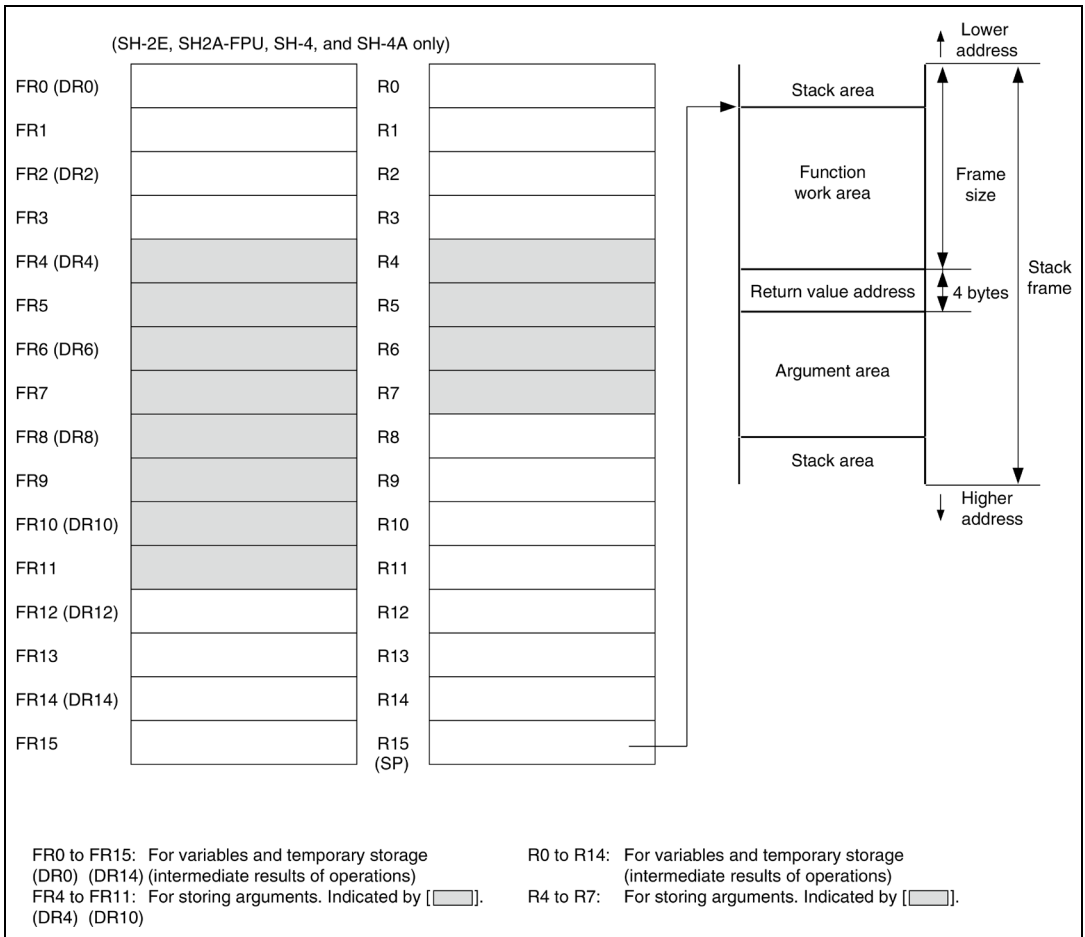


Figure 9.12 Using Registers and Stack Areas

9.4 Important Information on Programming

In this section, important information on writing program code for the compiler, and matters to bear in mind during development of a program from compiling through debugging, are discussed.

9.4.1 Important Information on Program Coding

(1) Functions with float Type Parameters

Functions must declare prototypes or change float type to double type when receiving and passing float type parameters. Data values cannot be guaranteed when a float type parameter without a prototype declaration receives data.

Example:

```
void f (float);
void g ()
{
    float a;
    ...
    f (a);
}
void f (float x)
{
    .
    .
    .
}
```

Function f has a float type parameter. Therefore, a prototype must be declared.

(2) Expressions whose Evaluation Order is not Specified by the C/C++ Language

The effect of the execution is not guaranteed in a program whose execution results differ depending on the evaluation order.

Example:

`a[i]=a[++i];` The value of `i` on the left side differs depending on whether the right side of the assignment expression is evaluated first.

`sub(++i, i);` The value of `i` for the second parameter differs depending on whether the first function parameter is evaluated first.

(3) Overflow Operation and Zero Division

An error message is not output if an operation leading to an overflow or floating-point division by zero is performed at run time. However, error messages will be output for any of the following operations.

- Integer constants of the **unsigned long long** type for which the absolute values are out of range
- Floating-point constants of the **float** type where the values have the suffix **f** or **F** and are out of range
- Floating-point constants of the **double** type where the values have no suffix or the suffix **l** or **L** and are out of range
- Division by Zero performed with integer constants or floating-point constants

Example:

```
unsigned long long la,lb,lc,ld,le=0;
float fa,fb,fc,fc,fd,fe=0.0f;
double da,db,dc,dd,de=0.0;
void main()
{
```

```

la = 32767;
fa = 3.5e+37f;
da = 1.8e+307;

lb = 18446744073709551616; /*(W) Overflow of an integer */
/* constant will be detected. */
fb = 3.5e+38f; /*(W) Overflow of a floating- */
/* point constant will be */
/* detected. */
db = 1.8e+308; /*(W) Overflow of a floating- */
/* point constant will be */
/* detected. */

lc = la + 18446744073709551615; /* No message is output. */
fc = fa + 3.4e+38f; /* No message is output. */
dc = da + 1.7e+308; /* No message is output. */

ld /= 0; /*(W) Division by zero of an */
/* integer constant will be */
/* detected. */
fd /= 0.0f; /*(W) Division by zero of a */
/* floating-point constant will */
/* be detected. */
dd /= 0.0; /*(W) Division by zero of a */
*/
/* floating-point constant will */
/* be detected. */

ld /= le; /* No message is output. */
fd /= fe; /* No message is output. */
dd /= de; /* No message is output. */
}

```

(4) Assignment to const Variables

Even if a variable is declared with const type, if assignment is done to a non-constant variable converted from const type or if a program compiled separately uses a parameter of a different type, the compiler cannot detect the error.

Example:

```
const char *p;          /* Because the first parameter p in library */
    .                  /* function strcat is a pointer for char, */
    .                  /* the area indicated by the parameter p */
strcat(p, "abc");      /* may change. */
```

file 1

```
const int i;
```

file 2

```
extern int i;          /* In file 2, parameter i is not declared as */
:                     /* const, therefore assignment to it in */
i=10;                 /* file 2 is not an error */
```

(5) Precision of Mathematical Function Libraries

For functions acos(x) and asin(x), an error is large around x=1. Therefore, precautions must be taken. Note the error range below.

Absolute error for acos(1.0 - ε)	double precision 2^{-39} ($\epsilon = 2^{-33}$)
	single precision 2^{-21} ($\epsilon = 2^{-19}$)

Absolute error for asin(1.0 - ε)	double precision 2^{-39} ($\epsilon = 2^{-28}$)
	single precision 2^{-21} ($\epsilon = 2^{-16}$)

(6) Interrupt Functions When the CPU Type is SH2A-FPU, SH4, or SH4A

In a CPU with floating-point precision mode (SH2A-FPU, SH4 or SH4A), when the `fpu` option is not specified or when `fpu=single` is specified, floating-point operation code is generated assuming that the precision mode is single-precision mode (the PR bit of the FPSCR register is 0) at the start of all functions. However, in the case of interrupt functions, they might actually be called in double-precision mode. Therefore, for an interrupt function that performs single-precision floating-point operation, be sure to make the following settings for FPSCR in the function. The settings are not required when `fpu=double` is specified.

When the `fpu` option is not specified

Set the precision mode of FPSCR to single precision (0) at the entrance of the interrupt function.

Setting example:

```
set_fpscr(get_fpscr()&0xFFF7FFFF);
```

When `fpu=single` is specified

Save the state of the PR bit of FPSCR, and then set the precision mode to single precision (0) at the entrance of the interrupt function. Then, restore the PR bit to the original state at the exit of the interrupt function.

Setting example:

At the entrance of the function

```
int original_fpscr = get_fpscr();
set_fpscr(original_fpscr&0xFFF7FFFF); // Set to single precision
```

At the exit of the function

```
set_fpscr(original_fpscr); // Restore the precision to original precision
return;
```

However, a program with `fpu=single` specification can enter double-precision mode only during execution of a standard library function that satisfies both of the following conditions.

- `fprintf()`, `printf()`, `sprintf()`, `vfprintf()`, `vprintf()`, or `vsprintf()` function
- In any of the functions above, format specification uses `%g`, `%G`, `%f`, `%e`, or `%E`.

If the program does not use a library function that satisfies these conditions, the above settings are not required even if there is an interrupt function that performs single-precision floating-point operation.

9.4.2 Important Information on Compiling a C Program with the C++ Compiler

(1) Function prototype declarations

Before using a function, a prototype declaration is necessary. At this time, the types of parameters should also be declared.

```
extern void func1();
void g()
{
    func1(1); // Error
}
```

```
extern void func1(int);
void g()
{
    func1(1); // OK
}
```

(2) Linkage of const objects

Whereas in C programs const objects are linked externally, in C++ programs they are linked internally. In addition, const objects require initial values.

```
const cvalue1;
    // Error

const cvalue2 = 1;
    // Internal
```

```
const cvalue1=0;
    // Gives initial value

extern const cvalue2 = 1;
    // Links externally
    // as a C program
```

(3) Assignment of void*

In C++ programs, if explicit casting is not used, assignment of pointers to other objects (excluding pointers to functions and to members) is not possible.

```
void func(void *ptrv, int *ptri)
{
    ptri = ptrv; // Error
}
```

```
void func(void *ptrv, int *ptri)
{
    ptri = (int *)ptrv; //OK
}
```

9.4.3 Important Information on Program Development

Important information for program development, from program creation through debugging, is described below.

(1) Information concerning selection of the CPU

- (a) The same CPU type should be specified at compilation time and assembly time.

The CPU type specified using the **cpu** option at compilation time and assembly time must always be the same. If object programs created for different CPU types are linked, operation of the object program at runtime is not guaranteed.

- (b) The same CPU type at compilation time should be specified at assembly time.

When assembling an assembly program generated by the compiler, the **cpu** option should be used to specify the same CPU type specified by the CPU at compilation time.

- (c) At linkage, the standard library appropriate to the CPU type should be linked.

A library appropriate to the CPU type should always be specified. Operation in the event that an inappropriate library is linked is not guaranteed.

(2) Important information on options

The options listed below should always be the same at compile time and when building libraries. If object programs created using different options are linked, operation of the object program at runtime is not guaranteed.

- endian = big | little (SH-3, SH3-DSP, SH-4, SH-4A, or SH4AL-DSP)
- pic = 0 | 1 (excluding SH-1)
- fpu = single | double (SH2A-FPU, SH-4, or SH-4A)
- fpscr = safe | aggressive (SH2A-FPU, SH-4, or SH-4A)
- round = zero | nearest (SH2A-FPU, SH-4, or SH-4A)
- denormalize = on | off (SH-4 or SH-4A)
- double = float (excluding SH2A-FPU, SH-4, and SH-4A)
- exception | noexception
- rtti = on | off
- pack = 1 | 4
- rtnext | nortnext
- macsave
- gbr = auto | user
- bit_order = left | right
- auto_enum

Section 10 C/C++ Language Specifications

10.1 Language Specifications

10.1.1 Compiler Specifications

The following shows compiler specifications for the implementation-defined items which are not prescribed by language specifications.

(1) Environment

Table 10.1 Environment Specifications

No.	Item	Compiler Specifications
1	Purpose of actual argument for the "main" function	Not stipulated
2	Structure of interactive I/O devices	Not stipulated

(2) Identifiers

Table 10.2 Identifier Specifications

No.	Item	Compiler Specifications
1	Number of valid letters in non externally-linked identifiers (internal names)	Up to 8189 letters in both external and internal names
2	Number of valid letters in externally-linked identifiers (external names)	Up to 8191 letters in both external and internal names
3	Distinction of uppercase and lowercase letters in externally-linked identifiers (external names)	Uppercase and lowercase letters are distinguished

(3) Characters

Table 10.3 Character Specifications

No.	Item	Compiler Specifications
1	Elements of source character sets and execution environment character sets	Source program character sets and execution environment character sets are both ASCII character sets. However, string literals and character constants can be written in shift JIS or EUC Japanese character code, or Latin1 code.
2	Shift states used in coding multi-byte characters	Shift states are not supported.
3	Number of bits in characters in character sets in program execution	8-bit
4	Relationship between source program character sets in character constants and string literals and characters in execution environment character sets	Corresponds to same ASCII characters.
5	Values of integer character constants that include characters or extended notation which are not stipulated in language specifications	Characters and extended notations which are not stipulated in the language specifications are not supported.
6	Values of character constants that include two or more characters, and wide character constants that include two or more multi-byte characters	The first two characters of character constants are valid. Wide character constants are not supported. Note that a warning error message is output if you specify more than one character.
7	Specifications of locale used for converting multi-byte characters to wide characters	locale is not supported.
8	char type value	Same value range as signed char type.

(4) Integers

Table 10.4 Integer Specifications

No.	Item	Compiler Specifications
1	Representation and values of integers	See table 10.5.
2	Values when integers are converted to shorter signed integer types or unsigned integers are converted to signed integer types of the same size (when a converted value cannot be represented as the target type)	After conversion, the integer value becomes the value of the eight lower-order bytes (when the size of the post-conversion type is eight bytes), four lower-order bytes (when the size of the post-conversion type is four bytes), two lower-order bytes (when the size of the post-conversion type is two bytes), or the lowest-order byte (when the size of the post-conversion type is one byte).
3	Result of bit-wise operations on signed integers	Signed value.
4	Remainder sign in integer division	Same sign as dividend.
5	Result of right shift of signed integral types with a negative value	Maintains sign bit.

Table 10.5 Range of Integer Types and Values

No.	Type	Value Range	Data Size
1	char	-128 to 127	1 byte
2	signed char	-128 to 127	1 byte
3	unsigned char	0 to 255	1 byte
4	short	-32768 to 32767	2 bytes
5	unsigned short	0 to 65535	2 bytes
6	int	-2147483648 to 2147483647	4 bytes
7	unsigned int	0 to 4294967295	4 bytes
8	long	-2147483648 to 2147483647	4 bytes
9	unsigned long	0 to 4294967295	4 bytes
10	long long	-9223372036854775808 to 9223372036854775807	8 bytes
11	unsigned long long	0 to 18446744073709551615	8 bytes

(5) Floating-point numbers

Table 10.6 Floating-Point Number Specifications

No.	Item	Compiler Specifications
1	Representation and values of floating-point type	There are three types of floating-point numbers: float, double, and long double types. See section 10.1.3, Floating-Point Number Specifications, for the internal representation of floating-point types and specifications for their conversion and operation. Table 10.7 shows the limits of floating-point type values that can be expressed.
2	Method of truncation when integers are converted into floating-point numbers that cannot accurately represent the actual value	
3	Methods of truncation or rounding when floating-point numbers are converted into shorter floating-point numbers	

Table 10.7 Limits of Floating-Point Type Values

No.	Item	Limits	
		Decimal Notation*	Hexadecimal Notation
1	Maximum value of float type	3.4028235677973364e+38f (3.4028234663852886e+38f)	7f7fffff
2	Minimum positive value of float type	1.0000000000000000E-45f (1.4012984643248171e-45f)	00000001
3	Maximum values of double type and long double type	1.7976931348623158e+308 (1.7976931348623157e+308)	7fefffffffffffff
4	Minimum positive values of double type and long double type	4.9406564584124655e-324 (4.9406564584124654e-324)	0000000000000001

- Notes: 1. The limits for decimal notation are the maximum value smaller than infinity and the minimum value greater than 0. Values in parentheses are theoretical values.
2. If **double=float** is specified, double type is treated as float type. If **fpu=single** is specified, double and long double types are treated as float type. If **fpu=double** is specified, float type is treated as double type.

(6) Arrays and Pointers

Table 10.8 Array and Pointer Specifications

No.	Item	Compiler Specifications
1	Integer type (<code>size_t</code>) required to hold maximum array size	unsigned long type
2	Conversion from pointer type to integer type (pointer type size \geq integer type size)	Value of least significant byte of pointer type
3	Conversion from pointer type to integer type (pointer type size $<$ integer type size)	Zero extension
4	Conversion from integer type to pointer type (integer type size \geq pointer type size)	Value of least significant byte of integer type
5	Conversion from integer type to pointer type (integer type size $<$ pointer type size)	Sign extension
6	Integer type (<code>ptrdiff_t</code>) required to hold difference between pointers to members in the same array	int type

(7) Registers

Table 10.9 Register Specifications

No.	Item	Compiler Specifications
1	Maximum number of variables that can be assigned to registers	7: char, unsigned char, bool, short, unsigned short, int, unsigned int, long, unsigned long, pointer 4: float ^{*2} 2: double ^{*3}
2	Types of variables that can be assigned to registers	char, unsigned char, bool, short, unsigned short, int, unsigned int, long, unsigned long, float ^{*2} , double ^{*3} , pointer

- Notes: 1. When register is assigned to variables, it does not matter whether or not the register-storage class has been declared.
If **enable_register** is specified, however, variables for which the register-storage class has been declared will be preferentially assigned to registers.
2. When the CPU is SH-2E, SH2A-FPU, SH-4, or SH-4A.
3. When the CPU is SH2A-FPU, SH-4, or SH-4A.

(8) Class, Structure, Union, and Enumeration Types, and Bit Fields**Table 10.10 Class, Structure, Union, and Enumeration Types, and Bit Field Specifications**

No.	Item	Compiler Specifications
1	Referencing members in union type accessed by members of another type	Can be referenced but value cannot be guaranteed.
2	Boundary alignment of class and structure members	The maximum data size of the class and structure members is used as the boundary alignment value. For details on assignment, see section 10.1.2 (2), Compound Type (C), Class Type (C++).
3	Sign of bit fields of simple int types	signed int type
4	Order of bit fields within int type size	Assigned from most significant bit.*1 *2
5	Method of assignment when the size of a bit field assigned after a bit field is assigned within an int type size exceeds the remaining size in the int type	Assigned to next int type area.*1
6	Permissible type specifiers in bit fields	char, unsigned char, bool, short, unsigned short, int, unsigned int, long, unsigned long, enum, long long, unsigned long long
7	Integer type representing value of enumeration type	int type

Note: 1. For details of assignment of bit fields, see section 10.1.2 (3), Bit Fields.

2. Specifying the `bit_order=right` option assigns bit fields from the least significant bit.

(9) Qualifiers**Table 10.11 Qualifier Specifications**

No.	Item	Compiler Specifications
1	Types of volatile data access	Not stipulated

(10) Declarations

Table 10.12 Declaration Specifications

No.	Item	Compiler Specifications
1	Number of declarations modifying basic types (arithmetic types, structure types, union types)	16 max.

The following shows examples of counting the number of types modifying basic types.

- i. `int a;` Here, `a` has an `int` type (basic type) and the number of types modifying the basic type is 0.
- ii. `char *f();` Here, `f` has a function type returning a pointer type to a `char` type (basic type), and the number of types modifying the basic type is 2.

(11) Statements

Table 10.13 Statement Specifications

No.	Item	Compiler Specifications
1	Number of case labels that can be declared in one switch statement	2,147,483,646 max.

(12) Preprocessor**Table 10.14 Preprocessor Specifications**

No.	Item	Compiler Specifications
1	Relationship between single-character character constants in constant expressions in a conditional compile, and character sets in the execution environment	Preprocessor statement character constants are the same as the execution environment character set.
2	Method of reading include files	Files enclosed in "<" and ">" are read from the directory specified in the include option. If the specified file is not found, the directory specified in environment variable SHC_INC is searched, followed by the system directory (SHC_LIB).
3	Support for include files enclosed in double quotation marks	Supported. Include files are read from the current directory. If not found in the current directory, the file is searched for as described in 2, above.
4	Space characters in string literals after a macro is expanded	A string of space characters are expanded as one space character.
5	Operation of #pragma statements	See section 10.3.1, #pragma Extension Specifiers.
6	__DATE__ and __TIME__ value	A value is specified based on the host computer's timer at the start of compiling.

10.1.2 Internal Data Representation

This section explains the data type and the internal data representation. The internal data representation is determined according to the following four items:

1. Size
Shows the memory size necessary to store the data.
2. Boundary alignment
Restricts the addresses to which data is allocated. There are three types of alignment; 1-byte alignment in which data can be allocated to any address, 2-byte alignment in which data is allocated to even byte addresses, and 4-byte alignment in which data is allocated to addresses of multiples of four bytes.
3. Data range
Shows the range of data of scalar type (C) or basic type (C++).
4. Data allocation example
Shows an example of assignment of element data of compound type (C) or class type (C++).

(1) Scalar Type (C), Basic Type (C++)

Table 10.15 shows internal representation of scalar type data in C and basic type data in C++.

Table 10.15 Internal Representation of Scalar-Type and Basic-Type Data

Data Type	Size (bytes)	Align- ment (bytes)	Sign	Data Range	
				Minimum Value	Maximum Value
char	1	1	Used	-2^7 (-128)	$2^7 - 1$ (127)
signed char	1	1	Used	-2^7 (-128)	$2^7 - 1$ (127)
unsigned char	1	1	Unused	0	$2^8 - 1$ (255)
short	2	2	Used	-2^{15} (-32768)	$2^{15} - 1$ (32767)
unsigned short	2	2	Unused	0	$2^{16} - 1$ (65535)
int	4	4	Used	-2^{31} (-2147483648)	$2^{31} - 1$ (2147483647)
unsigned int	4	4	Unused	0	$2^{32} - 1$ (4294967295)
long	4	4	Used	-2^{31} (-2147483648)	$2^{31} - 1$ (2147483647)
unsigned long	4	4	Unused	0	$2^{32} - 1$ (4294967295)
long long	8	4	Used	-2^{63} (-9223372036854775808)	$2^{63}-1$ (9223372036854775807)
unsigned long long	8	4	Unused	0	$2^{64}-1$ (18446744073709551615)
enum*¹	4	4	Used	-2^{31} (-2147483648)	$2^{31} - 1$ (2147483647)
float	4^{*4}	4	Used	$-\infty$	$+\infty$
double, long double	$8^{*2}, *4$	4	Used	$-\infty$	$+\infty$
Pointer	4	4	Unused	0	$2^{32} - 1$ (4294967295)
bool*³	4	4	Used	—	—
Reference*³	4	4	Unused	0	$2^{32} - 1$ (4294967295)
Pointer to a data member*³	4	4	Used	0	$2^{32} - 1$ (4294967295)
Pointer to a member function*^{3, *5}	12	4	—	—	—

- Notes:
1. The size of enum type is variable if **auto_enum** has been specified.
 2. The size of double type is 4 bytes if **double=float** has been specified.
 3. These data types are valid for C++ compilation only.
 4. If **cpu=sh2afpu**, **cpu=sh4**, or **cpu=sh4a** and **fpu=single** have been specified, double type and long double type are treated as 4 bytes (float type). If **cpu=sh2afpu**, **cpu=sh4**, or **cpu=sh4a** and **fpu=double** have been specified, float type is treated as 8 bytes (double type).
 5. Pointers to function and virtual member functions are represented by classes in the following data structure.

```
class _PMF{
public:
    long d;                //Object offset value.
    long i;                //Index in the virtual
                        //function table when
                        //the target function is the
                        //virtual function.

    union{
        void (*f)();      //Address of a function when
                        //the target function is a
                        //non-virtual function.

        long offset;      //Object offset value of the
                        //virtual function table
                        //when the target function
                        //is the virtual function.
    };
};
```

(2) Compound Type (C), Class Type (C++)

This section explains internal representation of array type, structure type, and union type data in C and class type data in C++.

Table 10.16 shows internal representation of compound type and class type data.

Table 10.16 Internal Representation of Compound Type and Class Type Data

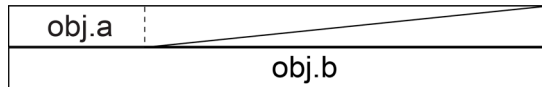
Data Type	Alignment (bytes)	Size (bytes)	Data Allocation Example
Array	Array element alignment	Number of array elements × element size	<code>char a[10];</code> Alignment: 1 byte Size: 10 bytes
Structure	Maximum structure member alignment	Total size of members. Refer to Structure Data Allocation, below.	<code>struct { char a,b; };</code> Alignment: 1 byte Size: 2 bytes
Union	Maximum union member alignment	Maximum size of member. Refer to Union Data Allocation, below.	<code>union { char a,b; };</code> Alignment: 1 byte Size: 1 byte
Class	1. Always 4 if a virtual function is included 2. Other than 1 above: maximum member alignment	Sum of data members, pointer to the virtual function table, and pointer to the virtual base class. Refer to Class Data Allocation, below.	<code>class B:public A { virtual void f(); };</code> Alignment: 4 bytes Size: 8 bytes <code>class A { char a; };</code> Alignment: 1 byte Size: 1 byte

In the following examples, a rectangle indicates four bytes. The diagonal line represents blank area for alignment.

Structure Data Allocation:

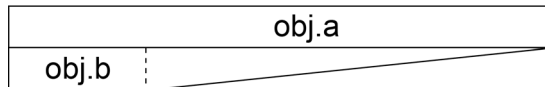
- When structure members are allocated, an unused area may be generated between structure members to align them to boundaries.

```
struct {  
  char a;  
  int b;  
} obj
```



- If a structure has 4-byte alignment and the last member ends at an 1-, 2-, or 3-byte address, the following three, two, or one byte is included in this structure.

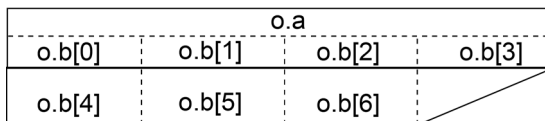
```
struct {  
  int a;  
  char b;  
} obj
```



Union Data Allocation:

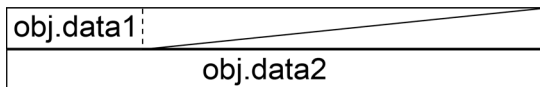
- When an union has 4-byte alignment and its maximum member size is not a multiple of four, the remaining bytes up to a multiple of four is included in this union.

```
union {
  int a;
  char b[7];
} o;
```

**Class Data Allocation:**

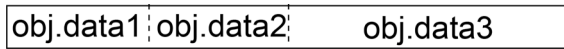
- For classes having no base class or virtual functions, data members are allocated according to the allocation rules of structure data.

```
class A{
  char data1;
  int data2;
public:
  A();
  int getData1(){return data1;}
}obj;
```



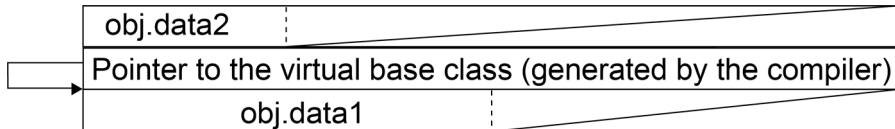
- If a class is derived from a base class of 1-byte alignment and the start member of the derived class is 1-byte data, data members are allocated without unused areas.

```
class A{
    char data1;
};
class B:public A{
    char data2;
    short data3;
}obj;
```



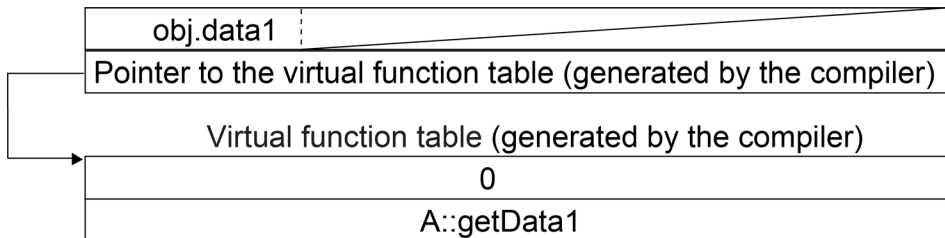
- For a class having a virtual base class, a pointer to the virtual base class is allocated.

```
class A{
    short data1;
};
class B: virtual protected A{
    char data2;
}obj;
```



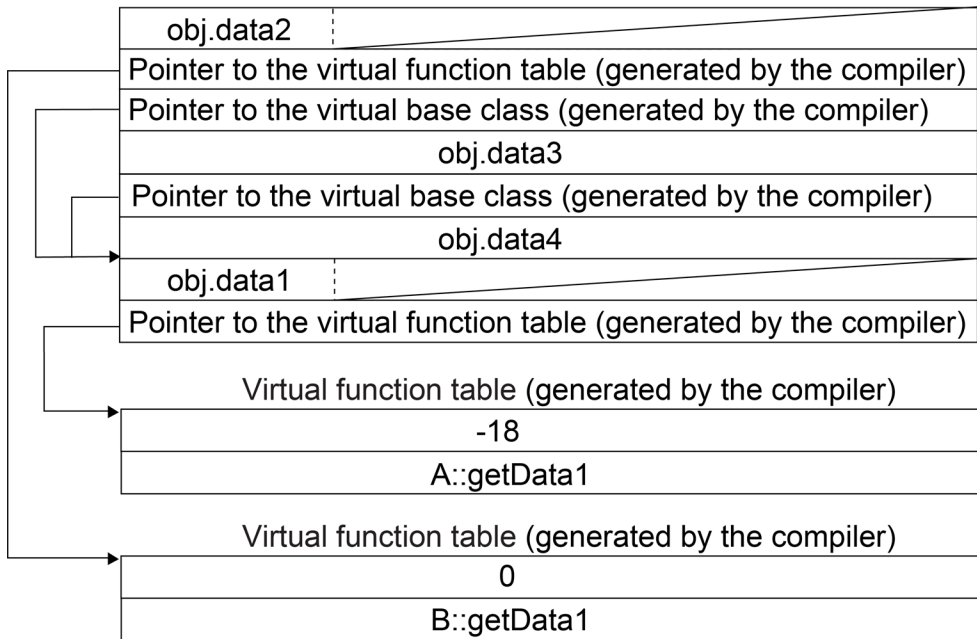
- For a class having virtual functions, the compiler creates a virtual function table and allocates a pointer to the virtual function table.

```
class A{
    char data1;
public:
    virtual int getData1();
}obj;
```



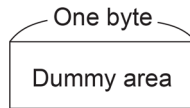
- An example is shown for class having virtual base class, base class, and virtual functions.

```
class A{
    char data1;
    virtual short getData1();
};
class B:virtual public A{
    char data2;
    char getData2();
    short getData1();
};
class C:virtual protected A{
    int data3;
};
class D:virtual public A,public B,public C{
    public:
    int data4;
    short getData1();
}obj;
```



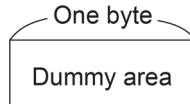
- For an empty class, a 1-byte dummy area is assigned.

```
class A{  
    void fun();  
}obj;
```



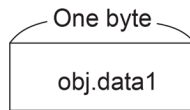
- For an empty class having an empty class as its base class, the dummy area is 1 byte.

```
class A{  
    void fun();  
};  
class B: A{  
    void sub();  
}obj;
```



- Dummy areas shown in the above two examples are allocated only when the class size is 0. No dummy area is allocated if a base class or a derived class has a data member or has a virtual function.

```
class A{
    void fun();
};
class B: A{
    char data1;
}obj;
```



(3) Bit Fields

A bit field is a member allocated with a specified size in a structure, union, or class. This part explains how bit fields are allocated.

Bit Field Members: Table 10.17 shows the specifications of bit field members.

Table 10.17 Bit Field Member Specifications

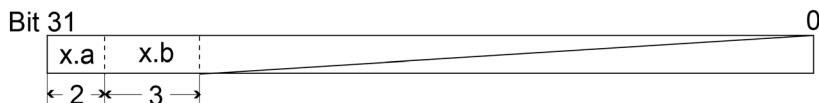
Item	Specifications
Type specifier allowed for bit fields	(signed) char, unsigned char, bool* ¹ (signed) short, unsigned short, enum (signed) int, unsigned int (signed) long, unsigned long (signed) long long, unsigned long long
How to treat a sign when data is extended to the declared type* ²	A bit field with no sign (unsigned is specified for type): Zero extension* ³ A bit field with a sign (unsigned is not specified for type): Sign extension* ⁴

- Notes:
1. The bool type is only valid at C++ compilation.
 2. To use a bit field member, data in the bit field is extended to the declared type. One-bit field data with a sign is interpreted as the sign, and can only indicate 0 and -1. To indicate 0 and 1, bit field data must be declared with unsigned.
 3. Zero extension: Zeros are written to the upper bits to extend data.
 4. Sign extension: The most significant bit of a bit field is used as a sign and the sign is written to all higher-order bits to extend data.

Bit Field Allocation: Bit field members are allocated according to the following five rules:

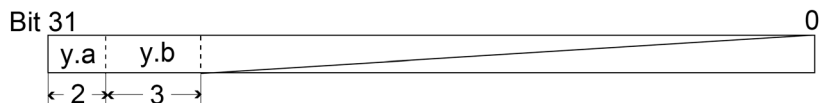
- Bit field members are placed in an area beginning from the left, that is, the most significant bit.

```
struct b1 {
    int a:2;
    int b:3;
} x;
```



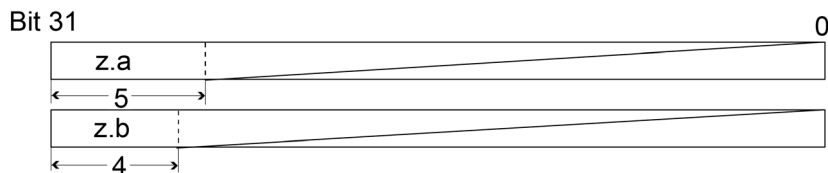
- Consecutive bit field members having type specifiers of the same size are placed in the same area as much as possible.

```
struct b1 {
    long      a:2;
    unsigned int b:3;
} y;
```



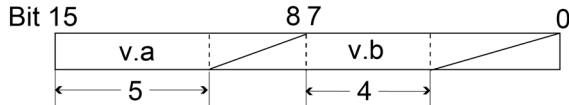
- Bit field members having type specifiers with different sizes are allocated to separate areas.

```
struct b1 {
    int      a:5;
    char     b:4;
} z;
```



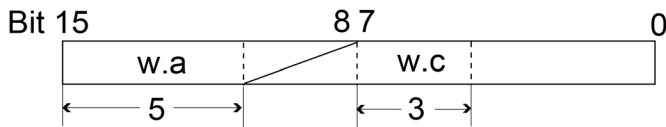
- If the number of remaining bits in an area is less than the next bit field size, though the type specifiers indicate the same size, the remaining area is not used and the next bit field is allocated to the next area.

```
struct b2 {
    char a:5;
    char b:4;
} v;
```



- If a bit field member with a bit field size of 0 is declared, the next member is allocated to the next area.

```
struct b2 {
    char a:5;
    char :0;
    char c:3;
} w;
```



Note: It is also possible to place bit field members from the lower bit. For details, refer to the description on the `bit_order` option in section 2.2, Interpretation of Options, and the description on `#pragma bit_order` in section 10.3.1, `#pragma` Extension Specifiers.

(4) Memory Allocation in Little Endian

In little endian, data are allocated in the memory as follows:

One-byte data ((signed) char, unsigned char, and bool types): The order of bits in one-byte data for the big endian and the little endian is the same.

Two-byte data ((signed) short and unsigned short types): The upper byte and the lower byte will be reversed in two-byte data between the big endian and the little endian.

Example: When two-byte data 0x1234 is allocated at address 0x100:

Big endian: Address 0x100: 0x12	Little endian: Address 0x100: 0x34
Address 0x101: 0x34	Address 0x101: 0x12

Four-byte data ((signed) int, unsigned int, (signed) long, unsigned long, and float types): The order of bytes will be reversed in four-byte data between the big endian and the little endian.

Example: When four-byte data 0x12345678 is allocated at address 0x100:

Big endian: Address 0x100: 0x12	Little endian: Address 0x100: 0x78
Address 0x101: 0x34	Address 0x101: 0x56
Address 0x102: 0x56	Address 0x102: 0x34
Address 0x103: 0x78	Address 0x103: 0x12

Eight-byte data ((signed) long long, unsigned long long, and double types): The order of bytes will be reversed in eight-byte data between the big endian and the little endian.

Example: When eight-byte data 0x123456789abcdef is allocated at address 0x100:

Big endian: Address 0x100: 0x01	Little endian: Address 0x100: 0xef
Address 0x101: 0x23	Address 0x101: 0xcd
Address 0x102: 0x45	Address 0x102: 0xab
Address 0x103: 0x67	Address 0x103: 0x89
Address 0x104: 0x89	Address 0x104: 0x67
Address 0x105: 0xab	Address 0x105: 0x45
Address 0x106: 0xcd	Address 0x106: 0x23
Address 0x107: 0xef	Address 0x107: 0x01

Compound-type and class-type data: Members of compound-type and class-type data will be allocated in the same way as that of the big endian. However, the order of byte data of each member will be reversed according to the rule of data size.

Example: When the following function exists at address 0x100:

```
struct {
    short a;
    int b;
}z= {0x1234, 0x56789abc};
```

Big endian: Address 0x100: 0x12	Little endian: Address 0x100: 0x34
Address 0x101: 0x34	Address 0x101: 0x12
Address 0x102: Empty area	Address 0x102: Empty area
Address 0x103: Empty area	Address 0x103: Empty area
Address 0x104: 0x56	Address 0x104: 0xbc
Address 0x105: 0x78	Address 0x105: 0x9a
Address 0x106: 0x9a	Address 0x106: 0x78
Address 0x107: 0xbc	Address 0x107: 0x56

Bit field: Bit fields will be allocated in the same way as that of the big endian. However, the order of byte data in each area will be reversed according to the rule of data size.

Example: When the following function exists at address 0x100:

```
struct {
    long a:16;
    unsigned int b:15;
    short c:5;
}y= {1,1,1};
```

Big endian: Address 0x100: 0x00	Little endian: Address 0x100: 0x02
Address 0x101: 0x01	Address 0x101: 0x00
Address 0x102: 0x00	Address 0x102: 0x01
Address 0x103: 0x02	Address 0x103: 0x00
Address 0x104: 0x08	Address 0x104: 0x00
Address 0x105: 0x00	Address 0x105: 0x08
Address 0x106: Empty area	Address 0x106: Empty area
Address 0x107: Empty area	Address 0x107: Empty area

10.1.3 Floating-Point Number Specifications

(1) Internal Representation of Floating-Point Numbers

Floating-point numbers handled by this compiler are internally represented in the standard IEEE format. This section outlines the internal representation of floating-point numbers in the IEEE format.

(a) Format for internal representation

float types are represented in the IEEE single-precision (32-bit) format, while double types and long double types are represented in the IEEE double-precision (64-bit) format.

(b) Structure of internal representation

Figure 10.1 shows the structure of the internal representation of float, double, and long double types.

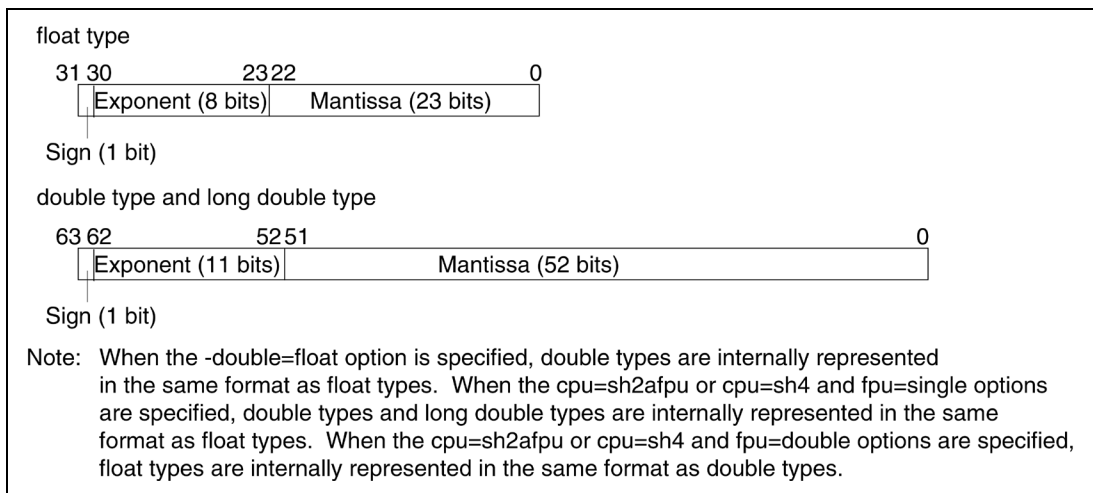


Figure 10.1 Structure of Internal Representation of Floating-Point Numbers

The internal representation format consists of the following parts:

- i. Sign
 - Shows the sign of the floating-point number. 0 is positive, and 1 is negative.
- ii. Exponent
 - Shows the exponent of the floating-point number as a power of 2.
- iii. Mantissa
 - Shows the data corresponding to the significant digits (fraction) of the floating-point number.

(c) Types of represented values of floating-point number

In addition to the normal real numbers, floating-point numbers can also represent values such as infinity. The following describes the types of values represented by floating-point numbers.

i. Normalized number

Represents a normal real value; the exponent is not 0 or not all bits are 1.

ii. Denormalized number

Represents real a value having a small absolute number; the exponent is 0 and the mantissa is other than 0.

iii. Zero

Represents the value 0.0; the exponent and mantissa are 0.

iv. Infinity

Represents infinity; all bits of the exponent are 1 and the mantissa is 0.

v. Not-a-number

Represents the result of operation such as "0.0/0.0", " ∞/∞ ", or " $\infty-\infty$ ", which does not correspond to a number or infinity; all bits of the exponents are 1 and the mantissa is other than 0.

Table 10.18 shows the types of values represented as floating-point numbers.

Table 10.18 Types of Values Represented as Floating-Point Numbers

Mantissa	Exponent		
	0	Not 0 or not all bits are 1	All bits are 1
0	0	Normalized number	Infinity
Other than 0	Denormalized number		Not-a-number

Note: Denormalized numbers are floating-point numbers of small absolute values that are outside the range represented by normalized numbers. There are fewer valid digits in a denormalized number than in a normalized number. Therefore, if the result or intermediate result of a calculation is a denormalized number, the number of valid digits in the result cannot be guaranteed. When **cpu=sh4** or **cpu=sh4a** and **denormalize=off** are specified, denormalized numbers are processed as 0. When **cpu=sh4** or **cpu=sh4a** and **denormalize=on** are specified, denormalized numbers are processed as denormalized numbers.

(2) float type

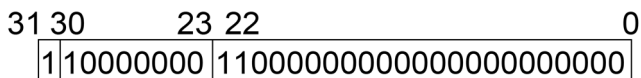
float types are internally represented by a 1-bit sign, an 8-bit exponent, and a 23-bit mantissa.

i. Normalized numbers

The sign indicates the sign of the value, either 0 (positive) or 1 (negative). The exponent is between 1 and 254 (2^8-2). The actual exponent is gained by subtracting 127 from this value. The range is between -126 and 127 . The mantissa is between 0 and $2^{23}-1$. The actual mantissa is interpreted as the value of which 2^{23} rd bit is 1 and this bit is followed by the decimal point. Values of normalized numbers are as follows:

$$(-1)^{\text{sign}} \times 2^{\text{exponent}-127} \times (1+(\text{mantissa}) \times 2^{-23})$$

Example:



Sign: -

Exponent: $10000000_{(2)} - 127 = 1$, where $_{(2)}$ indicates binary

Mantissa: $1.11_{(2)} = 1.75$

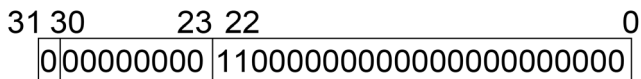
Value: $-1.75 \times 2^1 = -3.5$

ii. Denormalized numbers

The sign indicates the sign of the value, either 0 (positive) or 1 (negative). The exponent is 0 and the actual exponent is -126 . The mantissa is between 1 and $2^{23}-1$, and the actual mantissa is interpreted as the value of which 2^{23} rd bit is 0 and this bit is followed by the decimal point. Values of denormalized numbers are as follows:

$$(-1)^{\text{sign}} \times 2^{-126} \times ((\text{mantissa}) \times 2^{-23})$$

Example:



Sign: +

Exponent: -126

Mantissa: $0.11_{(2)} = 0.75$, where $_{(2)}$ indicates binary

Value: 0.75×2^{-126}

iii. Zero

The sign is 0 (positive) or 1 (negative), indicating +0.0 or -0.0, respectively. The exponent and mantissa are both 0.

+0.0 and -0.0 are both the value 0.0. See section 10.1.3 (4), Floating-Point Operation Specifications, for the functional differences deriving from the sign used with zero.

iv. Infinity

The sign is 0 (positive) or 1 (negative), indicating $+\infty$ or $-\infty$, respectively.

The exponent is 255 (2^8-1).

The mantissa is 0.

v. Not-a-number

The exponent is 255 (2^8-1).

The mantissa is a value other than 0.

Note: When the CPU is SH-2E, SH2A-FPU, SH-4, or SH-4A, not-a-number is called a qNaN when the MSB of the mantissa is 0, or sNaN when the MSB of the mantissa is 1. There are no specifications regarding the values of other mantissa fields or the sign.

(3) double types and long double types

double types and long double types are internally represented by a 1-bit sign, an 11-bit exponent, and a 52-bit mantissa.

i. Normalized numbers

The sign indicates the sign of the value, either 0 (positive) or 1 (negative). The exponent is between 1 and 2046 ($2^{11}-2$). The actual exponent is gained by subtracting 1023 from this value. The range is between -1022 and 1023 . The mantissa is between 0 and $2^{52}-1$. The actual mantissa is interpreted as the value of which 2^{52} nd bit is 1 and this bit is followed by the decimal point. Values of normalized numbers are as follows:

$$(-1)^{\text{sign}} \times 2^{\text{exponent}-1023} \times (1+(\text{mantissa}) \times 2^{-52})$$

Example:

63	62	52	51	0
0 01111111111 11100				

Sign: +

Exponent: $111111111_2 - 1023 = 0$, where $_2$ indicates binary

Mantissa: $1.111_2 = 1.875$

Value: $1.875 \times 2^0 = 1.875$

ii. Denormalized numbers

The sign indicates the sign of the value, either 0 (positive) or 1 (negative). The exponent is 0 and the actual exponent is -1022 . The mantissa is between 1 and $2^{52}-1$, and the actual mantissa is interpreted as the value of which 2^{52} nd bit is 0 and this bit is followed by the decimal point. Values of denormalized numbers are as follows:

$$(-1)^{\text{sign}} \times 2^{-1022} \times ((\text{mantissa}) \times 2^{-52})$$

Example:

63	62	52	51	0
1 00000000000 11100				

Sign: -

Exponent: -1022

Mantissa: $0.111_2 = 0.875$, where $_2$ indicates binary

Value: 0.875×2^{-1022}

iii. Zero

The sign is 0 (positive) or 1 (negative), indicating +0.0 or -0.0, respectively. The exponent and mantissa are both 0.

+0.0 and -0.0 are both the value 0.0. See section 10.1.3 (4), Floating-Point Operation Specifications, for the functional differences deriving from the sign used with zero.

iv. Infinity

The sign is 0 (positive) or 1 (negative), indicating $+\infty$ or $-\infty$, respectively. The exponent is 2047 ($2^{11}-1$).

The mantissa is 0.

v. Not-a-number

The exponent is 2047 ($2^{11}-1$).

The mantissa is a value other than 0.

Note: When the CPU is SH-2E, SH2A-FPU, SH-4, or SH-4A, not-a-number is called a qNaN when the MSB of the mantissa is 0, or sNaN when the MSB of the mantissa is 1. There are no specifications regarding the values of other mantissa fields or the sign.

(4) Floating-Point Operation Specifications

This section describes the specifications for arithmetic operations on floating-point numbers in C/C++, and for conversion between the decimal representation of floating-point numbers and their internal representation during compilation and in library processing.

(a) Specifications for arithmetic operations

i. Rounding of results

When the result of arithmetic operations on floating-point numbers exceeds the number of valid limit in the mantissa in internal representation, the result is rounded according to the following rules:

- a. For results of single-precision arithmetic when the CPU is SH-2E, any portion that exceeds the number of valid digits is truncated.
- b. When the CPU is SH2A-FPU, SH-4, or SH-4A, and **round = zero** is specified, the portion that exceeds the valid digits is rounded toward zero.
- c. Other than in the above cases, the result is rounded toward the closer of the two possible internal representations of the approximating floating-point number.

When the result is exactly equidistant from the two approximating floating-point numbers, it is rounded to the floating-point number for which the last digit of the mantissa is 0.

ii. Processing of overflows, underflows, and illegal operations

The following is performed in the event of an overflow, underflow, or illegal operation.

- a. In the case of an overflow, the result is a positive or negative infinity, depending on the sign of the result.
- b. In the case of an underflow, the result is as follows depending on the setting in the CPU.
 - b-1 In the SH-2E, the float-type result is a positive or negative zero depending on the sign of the result, and the double-type or long double-type result is a denormalized number.
 - b-2 In the SH2A-FPU, the result is a positive or negative zero depending on the sign of the result.
 - b-3 In the SH-4 or SH-4A, the result is a denormalized number when **denormalize=on** is specified or a positive or negative zero depending on the sign of the result when **denormalize=off** is specified.
 - b-4 In the other CPUs, the result is a denormalized number.
- c. In the case of an illegal operation, in which infinity values of the opposite sign have been added, in which an infinity has been subtracted from another infinity of the same sign, in which zero has been multiplied by infinity, in which zero is divided by zero, or in which infinity is divided by infinity, the result is a not-a-number.

- d. If an overflow results from conversion of a floating-point number to an integer, the result is not guaranteed.

Note: Operations are performed on constant expressions during compilation. If an overflow, underflow, or illegal operation occurs, a warning level error message is output.

iii. Notes on operations on special values

The following are notes on operations on special values (zero, infinity, and not-a-number).

- a. The sum of a positive zero and a negative zero is a positive zero.
- b. The difference between two zeros of the same sign is a positive zero.
- c. The result of operations that include not-a-number in one or both operands is always a not-a-number.
- d. In comparative operations, positive zeros and negative zeros are processed as equal.
- e. The result of comparative operations or equivalence operations where either one or both operands are not-a-number is true for "!=" and false in all other cases.

(b) Conversion between decimal and internal representation

This section describes the specifications for conversions between floating-point numbers in a source program and internal representation, and conversion by library functions between the decimal representation of floating-point numbers in ASCII strings and their internal representation.

- i. When converting from decimal to internal representation, the decimal value is first converted to its normalized form. The normalized form of a decimal value is $\pm M \times 10^{\pm N}$, where M and N are in the following range:
 - a. Normalized form of float types
$$0 \leq M \leq 10^9 - 1$$
$$0 \leq N \leq 99$$
 - b. Normalized form of double and long double types
$$0 \leq M \leq 10^{17} - 1$$
$$0 \leq N \leq 999$$

If a decimal value cannot be converted to its normalized form, an overflow or underflow occurs. If the decimal representation contains more valid numerals than the normalized form, the trailing digits are truncated. In this case, a warning level error message is output when compiling and the corresponding error number is set in **errno** when the program is executed. For conversion to its normalized form, the original decimal representation must, in the form of ASCII strings, be within 511 characters. If not, an error occurs when compiling and the corresponding error number is set in **errno** when the program is executed. When converting from internal representation to decimal, the value is first converted to the normalized decimal form, then converted to ASCII strings according to the specified format.

ii. Conversion between normalized form of decimals and internal representation

When converting from the normalized form of decimals to internal representation, and vice versa, errors cannot be avoided when the exponent is large or small. The following describes the range within which conversion is accurate, and the error limits when the values are outside that range.

a. Range for accurate conversion

The rounding shown in (a) i, "Rounding of results" is correctly applied for floating-point numbers within the ranges shown below. No overflow or underflow will occur within these ranges.

(1) float types: $0 \leq M \leq 10^9 - 1$, $0 \leq N \leq 13$

(2) double and long double types: $0 \leq M \leq 10^{17} - 1$, $0 \leq N \leq 27$

b. Error limits

The difference between the error that occurs when converting values that do not fall in the ranges shown in a. above and the error that occurs when rounding is correctly performed does not exceed 0.47 times the smallest digit of the valid numerals. If the value exceeds the ranges shown in a. above, an overflow or underflow may occur during conversion. In this case, a warning level error message is output during compilation, and the corresponding error number is set in **errno** when the program is executed.

10.1.4 Operator Evaluation Order

If an expression includes multiple operators, the evaluation order of these operators is determined according to the precedence and the associativity indicated by right or left.

Table 10.19 shows each operator precedence and associativity.

Table 10.19 Operator Precedence and Associativity

Precedence	Operators	Associativity	Applicable Expression
1	++ -- (postfix) () [] -> .	Left	Postfix expression
2	++ -- (prefix) ! ~ + - * & sizeof	Right	Monomial expression
3	(Type name)	Right	Cast expression
4	* / %	Left	Multiplicative expression
5	+ -	Left	Additive expression
6	<< >>	Left	Shift expression
7	< <= > >=	Left	Relational expression
8	== !=	Left	Equality expression
9	&	Left	Bitwise AND expression
10	^	Left	Bitwise XOR expression
11		Left	Bitwise OR expression
12	&&	Left	Logical AND operation
13		Left	Logical OR expression
14	?:	Right	Conditional expression
15	= += -= *= /= %= <<= >>= &= = ^=	Right	Assignment expression
16	,	Left	Comma expression

10.2 DSP-C Specifications

This section describes the compiler specifications of the DSP-C language, which can be used when the **dspe** option is specified.

10.2.1 Fixed-Point Data Types

Table 10.20 Internal Representation of the Fixed-Point Data Types

Type	Size (Size in Memory)	Alignment (byte)	Data Range		Suffix of Constant
			Minimum Value	Maximum Value	
<code>__fixed</code>	16 bits (16 bits)	2	-1.0	1.0-2 ⁻¹⁵ (0.999969482421875)	r
<code>long __fixed</code>	32 bits (32 bits)	4	-1.0	1.0-2 ⁻³¹ (0.9999999953433871 26922607421875)	R
<code>__accum</code>	24 bits (32 bits)*	4	-256.0	256.0-2 ⁻¹⁵ (255.999969482421875)	a
<code>long __accum</code>	40 bits (64 bits)*	4	-256.0	256.0-2 ⁻³¹ (255.99999999534338 7126922607421875)	A

Note: The number of bits is right-aligned in the memory. The sign bit is extended through the higher-order bits.

Example:

(i) `(__accum)128.5a:`

00 40 40 00

(ii) `(long __accum)(-256.0A):`

FF FF FF 80 00 00 00 00

10.2.2 Qualifiers

(1) Memory Qualifiers

The following qualifiers are used to explicitly specify storage in either the X or Y memory.

- `__X`: The data is stored in the X memory.
- `__Y`: The data is stored in the Y memory.

Table 10.21 shows the relationship between memory qualifiers and sections.

Table 10.21 Specifications of Memory Qualifiers

Name	Section	Description
Constant area	\$XC	const-type data (stored in the X memory)
	\$YC	const-type data (stored in the Y memory)
Initialized data area	\$XD	Data with an initial value (stored in the X memory)
	\$YD	Data with an initial value (stored in the Y memory)
Uninitialized data area	\$XB	Data without an initial value (stored in the X memory)
	\$YB	Data without an initial value (stored in the Y memory)

- Notes:
1. Do not specify two memory qualifiers for the same variable. An error message is displayed.
 2. For the variable with a memory qualifier, no section is switched by specifying **#pragma section**.
 3. A memory qualifier cannot change the function where the memory is stored.
 4. When a memory qualifier has been specified for a local variable which has not been specified as static, a warning message is displayed and the specification of the memory qualifier becomes invalid. However, it is valid to specify a pointer to the data with the memory qualifier.

The following shows examples of storage in memory when qualifiers `__X` and `__Y` are used.

- `__X int a;` //Stored in the X memory.
- `int __X b;` //Stored in the X memory.
- `__Y int *c;` //A pointer to an int-type variable in the Y memory (memory area is //undefined).
- `int __Y *d;` //A pointer to an int-type variable in the Y memory (memory area is //undefined).
- `int *__Y e;` //A pointer (stored in the Y memory) to an int-type variable.
- `__X int *__Y f;` //A pointer (stored in the Y memory) to int-type variables in the X //memory.

(2) Saturation Qualifier

The following qualifier is used to specify saturation arithmetic.

- `__sat`

The `__sat` qualifier can only be used with the `__fixed` and long `__fixed` data types. An error will occur if this qualifier is specified with any other type.

When there is at least one `__sat` specification in an expression, saturation arithmetic will be applied in the operation.

Example:

```

__fixed a;
__sat __fixed b;
__fixed c;

a = -0.75r;
b = -0.75r;
c = a + b;           //c = -1.0r

```

(3) Circular Qualifier

The following qualifier is used to specify modulo addressing.

- `__circ`

Modulo addressing can only be specified for `__fixed`-type one-dimensional arrays or pointers for which memory qualifiers have been specified (`__X` or `__Y`). If such qualifiers are specified when other conditions apply, an error will occur.

The targets of modulo addressing are one-dimensional arrays or pointers between intrinsic functions `set_circ_x()` or `set_circ_y()` and `clr_circ()`. For the specifications of the intrinsic functions, refer to section 10.3.3, Intrinsic Functions.

Operation is not guaranteed if multiple arrays are specified for modulo addressing at the same time or an array or a pointer with the `__circ` specification is referred to outside the above combinations of intrinsic functions.

Operations for which negative modulo addressing is specified are not guaranteed.

Data for modulo addressing should be arranged such that the upper 16 bits of the addresses are the same at linkage.

Content of an array cannot be directly referred to.

Note: Operations are not guaranteed in any of the following cases (a warning message may be displayed):

- Specifies `optimize = 0`.
- Specifies the `__circ` pointer as other than the local variable.
- Specifies `volatile` as the `__circ` pointer.
- Only updates the `__circ` pointer; not referred to.
- Calls a function between `set_circ_x()` / `set_circ_y()` and `clr_circ()` intrinsic functions.

10.2.3 Constants

Attaching a suffix of a constant (table 10.20) to a numeric value explicitly indicates that the value is a fixed-point constant.

However, constants with suffixes `r` and `R` are processed as `__accum` and `long __accum` when their numeric values include integer sections.

When a suffix of a constant is omitted, the value is processed as a double-type constant. When the `fixed_const` option is specified, the value is processed as a fixed-point constant.

Although no fixed-point constant is the saturation type, explicit conversion of the type enables saturation arithmetic.

Example:

```
__fixed a;  
__fixed b;  
a = -0.75r;  
b = a + (__sat __fixed) (-0.75r); // b = -1.0r
```

Since a unary negation operator cannot be part of a fixed-point constant, `-1.0r` is not valid as a `__fixed` type; it should be described as `(-0.5r-0.5r)` (In this manual, `-1.0r` is simply described as `-1.0` of `__fixed` type).

When the limits on precision for the decimal fraction are exceeded or the integer section without a sign exceeds 255 which is the maximum value of `__accum` or `long __accum`, a warning message

is displayed and the decimal fraction above the precision is rounded down. For the integer section, the least significant bit of the overflow is processed as a sign bit and the other bits are discarded.

10.2.4 Type Conversion

Table 10.22 shows the rules used in type conversion.

Table 10.22 Rules Used in Type Conversion

Conversion	Specification
<code>__fixed</code> → <code>long __fixed</code> <code>__accum</code> → <code>long __accum</code>	The 16 lower-order bits are padded with zeroes. The value is not changed.
<code>long __fixed</code> → <code>__fixed</code> <code>long __accum</code> → <code>__accum</code>	The 16 lower-order bits are discarded. Precision of the decimal fraction is lowered.
<code>__fixed</code> → <code>__accum</code> <code>long __fixed</code> → <code>long __accum</code>	Sign extension to fill the eight higher-order bits. The value is not changed.
<code>__fixed</code> → <code>long __accum</code>	Sign extension to fill the eight higher-order bits. The 16 lower-order bits are padded with zeroes. The value is not changed.
<code>long __fixed</code> → <code>__accum</code>	Sign extension to fill the eight higher-order bits. The 16 lower-order bits are discarded. Precision of the decimal fraction is lowered.
<code>__accum</code> → <code>__fixed</code> <code>long __accum</code> → <code>long __fixed</code>	The eight higher-order bits are discarded. The sign is assigned to the ninth bit. When the integer section is 0, the value is not changed.
<code>__accum</code> → <code>long __fixed</code>	The eight higher-order bits are discarded. The sign is assigned to the ninth bit. When the integer section is 0, the value is not changed.
<code>long __accum</code> → <code>__fixed</code>	The eight higher-order bits are discarded. The 16 lower-order bits are discarded. The sign is assigned to the ninth bit. When the integer section is 0, the value is not changed. Precision of the decimal fraction is lowered.

Table 10.22 Rules Used in Type Conversion (cont)

Conversion	Specification
__fixed → signed integer long __fixed → signed integer	-1 for -1.0r and -1.0R; 0 in other cases.
__accum → signed integer long __accum → signed integer	The value of the decimal fraction is discarded. The value after conversion is an integer in the range from -256 to 255.
__fixed → unsigned integer long __fixed → unsigned integer	The maximum value of the target type for -1.0r and -1.0R. 0 in other cases.
__accum → unsigned integer long __accum → unsigned integer	The decimal fraction is discarded. For a positive value, the value after conversion is an integer in the range from 0 to 255. For a negative value: (value before conversion + 1 + maximum value of the target type).
signed integer → __fixed signed integer → long __fixed	The most significant bit before conversion is changed as the most significant bit after conversion. All other bits become 0.
signed integer → __accum signed integer → long __accum	The nine lower-order bits of the value become the integer section. The decimal fraction is 0.
unsigned integer → __fixed unsigned integer → long __fixed	All bits after conversion become 0.
unsigned integer → __accum unsigned integer → long __accum	The nine lower-order bits of the value become the integer section. The decimal fraction is 0.
fixed point → floating point	If the pre-conversion value can be expressed in the floating-point type, the value remains the same. If the same value cannot be expressed, it is rounded off to the nearest value.
floating point → fixed point	The specification for the decimal fraction is the same as for 'fixed point → floating point' conversion. The specification for the integer section is the same as for 'floating point → integer' conversion. When the integer section is in the range that can be expressed as a fixed-point value, the original value will be kept. When the integer section is outside that range, the least-significant bit of the portion that overflowed becomes the sign bit. Saturation operation is not applied, even if it has been specified for the target type.

10.2.5 Arithmetic Conversion

When two operands differ in type, calculation is done in accordance with the type that is higher in the hierarchy of figure 10.2.

An error occurs if a calculation includes types that are neither above nor below each other in this hierarchy (e.g., between integer type and fixed-point type, or between `__accum` and `long __fixed`). When calculation is required in such cases, explicit cast should be applied to adjust the types.

However, for the sake of efficiency and convenience, the above rules for conversion may be ignored when a result is guaranteed.

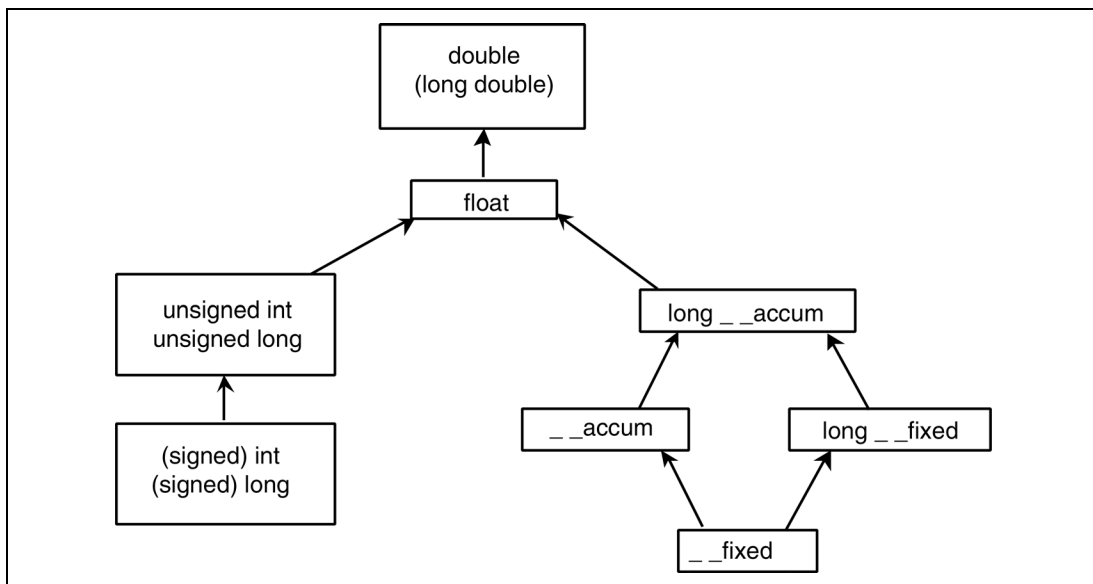


Figure 10.2 Hierarchy of Arithmetic Conversion

10.2.6 Pointer Conversion

(a) `__circ` Qualifier

When a pointer with the `__circ` qualifier is converted to a pointer without the `__circ` qualifier, a warning message is displayed and modulo addressing is not applicable.

When `__circ` is specified for a pointer without the `__circ` qualifier, a warning message is not displayed. However, modulo addressing is still not applicable.

(b) Memory Qualifier (`__X` or `__Y`)

An attempt to assign a memory qualifier to a variable already declared with another qualifier will cause an error.

10.2.7 Operators

The following operators cannot be specified for the fixed-point type; if specified, an error will occur.

- Operator for the 1's complement (`~`)
- Bitwise AND operator (`&` or `&=`)
- Bitwise OR operator (`|` or `|=`)
- Bitwise XOR operator (`^` or `^=`)
- Shift operator (`<<`, `>>`, `<<=`, or `>>=`)
- Remainder operator (`%` or `%=`)

Table 10.23 shows the values returned by the `sizeof` operator.

Table 10.23 Values Returned by the `sizeof` Operator

Type	Value
<code>__fixed</code>	2
<code>long __fixed</code>	4
<code>__accum</code>	4
<code>long __accum</code>	8

10.2.8 Libraries

(a) fixed.h

The include-file <fixed.h> defines the limit values of the fixed-point type. For details, refer to section 10.4.1, Standard C Libraries.

(b) stdio.h

Table 10.24 shows the conversion specifiers for fixed-point values.

Table 10.24 Conversion Specifiers for Fixed-Point Values

Conversion Specifier	Meaning
%r	__fixed value
%lr	long __fixed value
%a	__accum value
%la	long __accum value
%P	__circ pointer value

The conversion of fixed-point values is based on the %f conversion (floating-point conversion). The %P is converted in the same way as %p (pointer conversion).

(c) `stdlib.h`

Table 10.25 shows the functions for the handling of fixed-point values. For details, refer to section 10.4.1, Standard C Libraries.

Table 10.25 Functions

Type	Function Name
String-value conversion	<code>long __fixed atolfixed(const char * nptr);</code>
	<code>long __accum atolaccum(const char * nptr);</code>
	<code>long __fixed strtolfixed(const char * nptr, char ** endptr);</code>
	<code>long __accum strtolaccum(const char * nptr, char ** endptr);</code>
Storage-area management	<code>void __X *calloc__X(size_t nelem, size_t elsize);</code>
	<code>void free__X(void __X *ptr);</code>
	<code>void __X *malloc__X(size_t size);</code>
	<code>void __X *realloc__X(void __X *ptr, size_t size);</code>
	<code>void __Y *calloc__Y(size_t nelem, size_t elsize);</code>
	<code>void free__Y(void __Y *ptr);</code>
	<code>void __Y *malloc__Y(size_t size);</code>
	<code>void __Y *realloc__Y(void __Y *ptr, size_t size);</code>

Note: The user should also prepare a low-level interface routine for the `__X` or `__Y` memory:

`char __X *sbrk__X(int size);`

`char __Y *sbrk__Y(int size);`

For details, refer to section 9.2.2 (6), Low-level interface routines.

(d) string.h

Table 10.26 shows the functions for the handling of fixed-point values. For details, refer to section 10.4.1, Standard C Libraries.

Table 10.26 Functions

Type	Function Name
Storage-area copy	<code>void __X * memcpy__X__X(void __X * s1, const void __X * s2, size_t n);</code>
	<code>void __X * memcpy__X__Y(void __X * s1, const void __Y * s2, size_t n);</code>
	<code>void __Y * memcpy__Y__X(void __Y * s1, const void __X * s2, size_t n);</code>
	<code>void __Y * memcpy__Y__Y(void __Y * s1, const void __Y * s2, size_t n);</code>

(e) DSP Library

When the **dspe** option is specified, `__fixed`-type arrays and pointers can be specified instead of short-type arrays and pointer parameters. For details, refer to section 10.4.5, DSP Library.

10.3 Extended Specifications

The compiler supports the following extended specifications:

- **#pragma** extension specifiers
- Section address operators
- Intrinsic functions

10.3.1 #pragma Extension Specifiers

Tables 10.27 to 10.29 list **#pragma** extension specifiers. Note that conditions apply to the application of some **#pragma** directives which are related to optimization, i.e. some may not be applicable. Check the output code to see whether or not the optimization has actually been performed.

Table 10.27 Extended Specifications Relating to Memory Allocation

#pragma Extension Specifier	Function
#pragma section	Switches sections
#pragma abs16	Specifies address range
#pragma abs20	
#pragma abs28	
#pragma abs32	
#pragma stacksize	Creates stack section

Table 10.28 Extended Specifications Relating to Functions

#pragma Extension Specifier	Function
#pragma interrupt	Creates an interrupt function
#pragma inline	Performs inline expansion of functions
#pragma inline_asm	Expands an assembly-language description function.
#pragma regsave, #pragma noregsave, #pragma noregalloc	Generates or does not generate save and restore code at the start and end of functions
#pragma entry	Creates an entry function
#pragma ifunc	Suppresses saving and restoring of the floating-point registers
#pragma tbr	Calls functions by using TBR relative addresses
#pragma align4	Branch destination addresses in the specified function are placed on 4-byte boundaries

Table 10.29 Other Extended Specifications

#pragma Extension Specifier	Function
#pragma global_register	Allocates global variables to registers
#pragma gbr_base, #pragma gbr_base1	Specifies GBR base variables
#pragma bit_order	Switches the order of bit assignment
#pragma pack #pragma unpack	Specifies the boundary alignment value for structures, unions, and classes.
#pragma address	Specifies absolute addresses for variables

For some of the extended functions above, data members and member functions can be specified. Specification format is (class name::member name). For the specifiable member types, see the format of each function.

(1) Extended Specifications Related to Memory Allocation

#pragma section

Description Format: #pragma section [{<name> | <numeric value>}]

Description: Switches the section to be output by the compiler.
Table 10.30 lists the default section names and section names after switching sections.

Table 10.30 Section Switching and Section Name

Target Area	Specification	Default Section Name	After Switching Section
Program area	#pragma section <xx>	P*	P<xx>
Constant area		C*	C<xx>
Initialized data area		D*	D<xx>
Uninitialized data area		B*	B<xx>

Note: The default section name can be modified by the **section** option.
If <name> and <number> are not specified, the default section names will be used.

```
Example:      #pragma section abc
              int a;                /* a is assigned to section Babc */
              const int c=1;        /* c is assigned to section Cabc */
              void f(void)          /* f is assigned to section Pabc */
              {
                a=c;
              }
              #pragma section
              int b;                /* b is assigned to section B      */
              void g(void)          /* g is assigned to section P      */
              {
                b=c;
              }
```

- Remarks:
1. **#pragma section** can be declared only outside the function definition.
 2. Up to 2045 section names can be declared for each of **#pragma section** in one file.
 3. When specified together with a memory specifier (**__X** or **__Y**), the specification of **#pragma section** will be invalid.

#pragma abs16
#pragma abs20
#pragma abs28
#pragma abs32

Description Format: #pragma abs16 [(]<identifier> [...] [)]
 #pragma abs20 [(]<identifier> [...] [)]
 #pragma abs28 [(]<identifier> [...] [)]
 #pragma abs32 [(]<identifier> [...] [)]

Description: The variable or function declared with **#pragma abs16**, **abs20**, **abs28**, or **abs32** is treated as being allocated in the memory area shown in table 10.31. Then, program size can be reduced.
 For the identifier, a variable, a global function, a static data member, and a member function can be specified.

Table 10.31 Address Ranges

#pragma Extension	Address Range	
	Beginning	End
abs16	0x00000000	0x00007FFF
	0xFFFF8000	0xFFFFFFFF
abs20	0x00000000	0x0007FFFF
	0xFFF80000	0xFFFFFFFF
abs28	0x00000000	0x07FFFF7F*
	0xF8000000	0xFFFFFFFF
abs32	0x00000000	0xFFFFFFFF

Note: Be aware that the end of the range is 0x07FFFF7F.

Remarks:

- #pragma abs16**, **abs20**, **abs28**, or **abs32** cannot be used to specify an automatic object or non-static data member.
- Variables and functions declared using **#pragma abs16**, **abs20**, **abs28**, or **abs32** must be allocated in the corresponding address range shown above.
- Multiple address ranges cannot be specified for a single identifier.
- When **#pragma abs16**, **abs20**, **abs28**, or **abs32** is specified together with the **abs16**, **abs20**, **abs28**, or **abs32** option, the **#pragma** specification becomes valid.
#pragma abs16, **abs20**, **abs28**, or **abs32** is invalid when it is specified together with **#pragma gbr_base** or **gbr_base1**.

#pragma stacksize

Description Format: `#pragma stacksize <constant>`

Description: Creates a stack section of size `<constant>` for the section with name S.

Example: `#pragma stacksize 100`

```
<Example of code expansion>  
.SECTION S, STACK, ALIGN=4  
.RES.B 100
```

Remarks: The size, `<constant>`, must always be specified as a multiple of four.
#pragma stacksize can only be specified once in a file.

(2) Extended Specifications Related to Functions

#pragma interrupt

Description Format: #pragma interrupt [(**<**function name**>**[(interrupt specification)][,...][**;**])]

Description: Declares an interrupt function.
Global functions and static member functions can be specified for the function name. Table 10.32 lists interrupt specifications.

Table 10.32 Interrupt Specifications

Item	Form	Options	Specifications
Stack switching	sp=	{<variable> &<variable> <constant> <variable> + <constant> &<variable> + <constant> }	The address of a new stack is specified with a variable or a constant. <variable>: Variable (pointer type) &<variable>: Variable (object type) address <constant>: Constant value
Trap-instruction return	tn=	<constant>	The interrupt function exits with the TRAPA instruction. <constant>: Constant value (trap vector number)
Register bank	resbank	None	Output of code for saving the following registers is suppressed. R0 to R14, GBR, MACH, MACL, PR If tn is not specified, a RESBANK instruction is output immediately before the RTE instruction.
Register bank switching and RTS-instruction return	sr_rts	None	The interrupt function exits with the RTS instruction. The code for saving only the registers used in the function is output. The RB and BL bits of the SR are set at the end of the function.
Interrupt handling function	bank	None	When a sr_jsr() intrinsic function is used, the code for saving the SSR and SPC is generated and output of the code for saving the R0 to R7 is suppressed. The code for saving the other registers used in the function is generated.
RTS-instruction return	rts	None	The interrupt function exits with the RTS instruction. Output of the code for saving the SSR, SPC, or R0 to R7 is suppressed. The code for saving the other registers used in the function is generated.

An interrupt function will guarantee register values before and after processing (all registers used by the function are pushed onto and popped from the stack when entering and exiting the function). The **RTE** instruction directs the function to return. However, if the trap-instruction return is specified, the **TRAPA** instruction is executed at the end of the function. An

interrupt function with no specifications is processed in the usual procedure. The stack switching specification and the trap-instruction return specification can be specified together.

Example:

```
extern int STK[100];
#pragma interrupt(f(sp =STK+100, tn = 10),A::g)
class A{
public:
    static void g();
};
```

Explanation:

- (a) Stack switching specification: STK+100 is set as the stack pointer used by interrupt function **f**.
- (b) Trap-instruction return specification: After the interrupt function has completed its processing, **TRAPA #H'10** is executed. The SP at the beginning of trap exception processing is shown in figure 10.3. After the previous PC (program counter) and SR (status register) are popped from the stack by the **RTE** instruction in the trap routine, control is returned from the interrupt function.
- (c) The member function that can be specified in C++ program is a static member function. In the example, static member function **g** of class **A** is specified as an interrupt function. Note that nonstatic member functions cannot be specified.

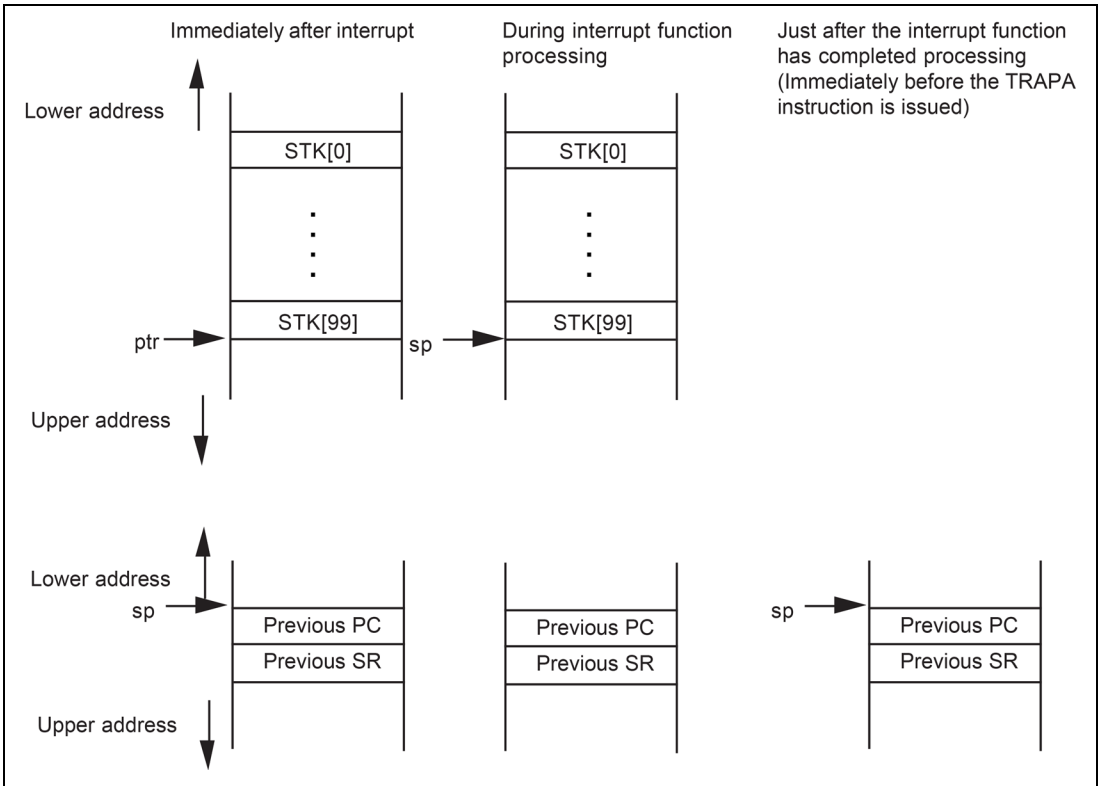


Figure 10.3 Stack Processing by an Interrupt Function

Nested interrupt functions can be created through the **sr_rts** and **bank** settings and the **sr_jsr()** intrinsic function.

Example:

```
#include <machine.h>

// Handling function declaration
#pragma interrupt (func(bank))
void func();

// Interrupt processing function declaration
#pragma interrupt (sub(sr_rts))
void sub();
void func() {
    :
    sr_jsr(sub,8); // Calls sub()
                  // with RB = 0, BL = 0, and
                  // interrupt level = 8
    :
}

void sub() {
    :
}
```


func:

← RB = 1, BL = 1

```

MOV.L    R14, @-R15
STS.L    PR, @-R15
STC      SSR, @-R15
STC      SPC, @-R15

```

} Saves the registers used in the function, SPC, and SSR, except R0 to R7.

:

```

STC      SR, R6
MOV.L    L12+6, R1 ; H'FFFFFF0F
MOV      #-128, R4 ; H'FFFFFF80
EXTU.B   R4, R4
MOV.L    L12+10, R14 ; _sub
AND      R1, R6
OR       R4, R6
LDC      R6, SR
JSR      @R14

```

} Changes the settings to RB = 0, BL = 0, and IMASK = 8.

NOP

← Calls the sub() function. Execution will return with the settings changed to RB = 1 and BL = 1.

:

```

LDC      @R15+, SPC
LDC      @R15+, SSR
LDS.L    @R15+, PR
MOV.L    @R15+, R14
RTE
NOP

```

} Restores the registers used in the function, SPC, and SSR, except R0 to R7. Changes the setting to IMASK = 8.

_sub:

← RB = 0 and BL = 0

```

MOV.L    R0, @-R15
MOV.L    R1, @-R15

```

} Saves the registers used in the function.

:

STC	SR, R0	} Changes the settings to RB = 1 and BL = 1, and restores the registers used in the function.
MOV.L	L12+2, R1 ; H'30000000	
OR	R1, R0	
MOV.L	@R15+, R1	
LDC	R0, SR	
RTS		
LDC.L	@R15+, R0_BANK	

← Because the setting has been changed to RB = 1.

An efficient interrupt function using register banks can be created through the **rts** and **bank** settings.

Example:

```
#include <machine.h>

// Handling function declaration
#pragma interrupt (func(bank))
void func();

// Interrupt processing function declaration
#pragma interrupt (sub(rts))
void sub();
void func() {
    :
    sub();
    :
}

void sub() {
    :
}
```

```

_func:
    STS.L    PR, @-R15
    :
    MOV.L    L12, R14; _sub
    JSR      @R14
    NOP

    :
    LDS.L    @R15+, PR
    RTE
    NOP

_sub:
    MOV.L    R14, @-R15
    MOV.L    R13, @-R15
    :
    MOV.L    @R15+, R13
    RTS
    MOV.L    @R15+, R14
    
```

← RB = 1 and BL = 1

} Saves the registers used in the function except R0 to R7.

} Restores the registers used in the function except R0 to R7.

} Saves the registers used in the function except R0 to R7.

} Restores the registers used in the function except R0 to R7.

Remarks:

1. **resbank** is only valid when **cpu = sh2a** or **sh2afpu** is specified.
2. Register bank usage must be enabled before an interrupt for the function with **resbank** specification occurs.
3. When both **resbank** and **tn** are specified, neither register saving code nor RESBANK instruction is output. In this case, generate a RESBANK instruction in the trap routine.
4. When returning from the function with the **resbank** specification, the value of the variable specified with **#pragma global_register** is restored to its original value before the interrupt even when it is modified during interrupt processing.
5. The interrupt operation in the SH-3, SH3-DSP, SH-4, SH-4A, and SH4AL-DSP is different from that in the SH-1, SH-2, SH-2E, SH-2A, SH2A-FPU, and SH2-DSP, and requires interrupt handlers. When the same function is specified for **#pragma interrupt** and **#pragma noregsave**, in the SH-3, SH3-DSP, SH-4, SH-4A, and SH4AL-DSP, only

the contents of callee-save registers used within the function are saved and restored.

6. When the **repeat** option is specified, the contents of the RS and RE registers are saved and restored.
When the **dspc** option is specified, the contents of the DSP registers (X0, X1, Y0, Y1, M0, M1, A0, A0G, A1, and A1G), DSR register, and MOD register are saved and restored.
7. Functions that can be specified for an interrupt function definition are the global function (in C/C++ program) and static member function (in C++ program).

The function must return only void data. The return statement cannot have a return value. If attempted, an error is output.

Example:

```
#pragma interrupt (f1 (sp=100) , f2)
void f1 () {...} ..... (a)
int f2 () {...} ..... (b)
```

Description: (a) is a correct declaration.
(b) returns type that is not void, thus (b) is an incorrect declaration. An error will occur.

8. **sr_rts**, **bank**, and **rts** are valid when **cpu=sh3|sh3dsp|sh4|sh4a|sh4aldsp** is specified. The following shows the combinations of **sr_rts**, **bank**, or **rts** and other interrupt specifications that can be set together.

	#pragma interrupt					#pragma noregsave
	sp	tn	sr_rts	bank	rts	
sr_rts	Error	Error	Error	Error	Error	Error
bank	Valid	Error	Error	Error	Error	Valid
rts	Error	Error	Error	Error	Error	Error

An error will be output in the following cases.

- A function with the **sr_rts** setting is called from a function other than the **sr_jsr()** intrinsic function.
 - A function with the **bank** setting is called.
 - A function with the **rts** setting is called from a function without **bank** or **rts** setting.
9. A function declared as an interrupt function cannot be called within the program. If attempted, an error will occur. However, if the function is called within a program which does not have a declaration of the interrupt function, an error does not occur but correct program execution is not guaranteed.

Example 1 (An interrupt function is declared):

```
#pragma interrupt(f1)
void f1(){...}
int f2(){ f1();} ..... (a)
```

Description: Function f1 cannot be called in the program because it is declared as an interrupt function. An error occurs at (a).

Example 2 (An interrupt function is not declared):

```
int f1();
int f2(){ f1();} ..... (b)
```

Description: Because function f1 is not declared as an interrupt function, an object is generated as a non-interrupt function, **int f1()**;. If function f1 is declared as an interrupt function in another file, correct program execution cannot be guaranteed.

Note: In a CPU with floating-point precision mode (SH2A-FPU, SH4, or SH4A), when the `fpu` option is not specified or when `fpu=single` is specified, the precision mode might need to be set to perform single-precision floating-point operation in an interrupt function. For details, see section 9.4.1 (6) Interrupt Functions When the CPU Type Is SH2A-FPU, SH4, or SH4A.

#pragma inline

Description Format: #pragma inline [(|<function name>[,...][|)]

Description: Declares a function for which inline expansion is performed.
A name of a global function or a static member function can be specified as a function name.
A function specified by **#pragma inline** or a function with specifier inline (C++) will be expanded where the function is called.

Example:

Source Program

```
#pragma inline (func)
static int func (int a, int b)
{
    return (a+b)/2;
}
int x;
main ()
{
    x = func(10,20);
}
```

Inline Expansion Image

```
int x;
main( )
{
    int func_result;
    {
        int a_1 = 10, b_1 = 20;
        func_result = (a_1+b_1)/2;
    }
    x = func_result;
}
```

Remarks:

1. A function will not be expanded in the following cases:
 - a function definition exists before the **#pragma inline** specification
 - a function has variable parameters
 - a parameter address is referenced in a function
 - an address of a function to be expanded is used to call the function
 - recursive calls are used
2. Specify **#pragma inline** before defining a function.
3. When a program file includes the definition of a function to be inlined, be sure to specify **static** before the function declaration because an external definition is generated for a function specified by **#pragma inline**. If **static** is specified, an external definition will not be created. External definition will not be created for functions for which inline (C++) is specified.
4. Also, when a **scope** option is specified, inline expansion may not be performed.

#pragma inline_asm

Description Format: #pragma inline_asm [(**[**]**<**function name**>****[**(size=**<**numeric value**>****)]****[**,...**]****[**D**]**)

Description: Performs inline expansion for the functions written in assembly language declared by **#pragma inline_asm**.

Parameters of a function that is written in an assembly language are referenced from an **inline_asm** function because they are stacked or stored in registers in the same way as general function calls. The return value of an inline function written in an assembly language should be set in R0. When the **cpu** is SH-2E, SH2A-FPU, SH-4, or SH-4A, return values of single-precision floating-point type should be set in FR0. When the **cpu** is SH2A-FPU, SH-4, or SH-4A, return values of double-precision floating-point type should be set in DR0. A different register may be used depending on the combination of options. For details, see table 9.7.

The length of an inline function written in an assembly language can be specified by (size=**<**numeric value**>**).

Example:

Source program

```
#pragma inline_asm(rotl)
static int rotl (int a)
{
    ROTL R4
    MOV R4,R0
}
int x;
main( )
{
    x = 0x55555555;
    x = rotl(x);
}
```


Output result (partial)

```

:
_main                                ;function main
                                       ;frame size = 4

        MOV.L    R14,@-R15
        MOV.L    L220+2,R14           ;_x
        MOV.L    L220+6,R3           ;H'55555555
        MOV.L    R3,@R14
        MOV      R3,R4
        BRA      L219
        NOP
L220:
        .RES.W    1
        .DATA.L  _x
        .DATA.L  H'55555555
L219:
        ROTL     R4
        MOV      R4,R0
        .ALIGN   4
        MOV.L    R0,@R14
        RTS
        MOV.L    @R15+,R14
        .SECTION B,DATA,ALIGN=4
_x:
        .RES.L    1
        .END
;static: x
    
```

Remarks:

1. Specify **#pragma inline_asm** before the definition of a function. External definition will be created for functions specified by **#pragma inline_asm**.
2. Be sure to use local labels in a function written in an assembly language.
3. When the registers whose values are saved and restored at the start and end of a function (see table 9.5) are used in a function written in an assembly language, the contents of these registers must be saved and restored at the start and end of the function. Also, when registers FR12 to FR15 (if CPU is SH-2E, SH2A-FPU, SH-4, or SH-4A) are used, or when registers DR12 to DR14 (if CPU is SH2A-FPU, SH-4, or SH-4A) are used, the contents of these registers must be saved and restored at the start and end of the inline function written in the assembly language.
4. Do not use **RTS** at the end of a function written in an assembly language.
5. When **#pragma inline_asm** is used, be sure to compile programs by specifying **code=asmcode** to generate assembly code.
6. When specifying a number by (**size=<numeric value>**), specify a number larger than the actual object size. If a value smaller than the actual object size is specified, correct operation is not guaranteed. If a floating point or a numeric value less than 0 is specified, an error will occur.
7. Even when a register specified by the **#pragma global_register** function is used, the contents of this register must be saved and restored at the start and end of the inline function written in an assembly language.
8. A member function cannot be specified for the function name.
9. Do not use a statement that generates a literal pool. (**MOV.L #100000, R0** etc.)

#pragma regsave
#pragma noregsave
#pragma noregalloc

Description Format: #pragma regsave [(]<function name>[,...][D]
#pragma noregsave [(]<function name>[,...][D]
#pragma noregalloc [(]<function name>[,...][D]

- Description:
1. Global functions and member functions can be specified as the function name.
 2. Functions specified by **#pragma regsave** save and restore the contents of callee-save registers (see table 9.5) at the start and end of the functions, respectively. Inside the function specified by **#pragma regsave**, callee-save registers (R8 to R14, and FR12 to FR15 if CPU is SH-2E, SH2A-FPU, SH-4, or SH-4A) will not carry a value over a child function call.
 3. Functions specified by **#pragma noregsave** do not save or restore the contents of callee-save registers at the start and end of the functions.
 4. Functions specified by **#pragma noregalloc** do not save or restore the contents of callee-save registers at the start and end of the functions. Inside the function specified by **#pragma noregsave**, callee-save registers (R8 to R14, and FR12 to FR15 if CPU is SH-2E, SH2A-FPU, SH-4, or SH-4A) will not carry a value over a child function call.
 5. **#pragma regsave** and **#pragma noregalloc** can specify the same function at the same time. In this case, the contents of registers R8 to R14 (and FR12 to FR15 if CPU is SH-2E, SH2A-FPU, SH-4, or SH-4A) are saved and restored at the start and end of the function if they are used. Inside the function specified by **#pragma regsave**, callee-save registers (R8 to R14, and FR12 to FR15 if CPU is SH-2E, SH2A-FPU, SH-4, or SH-4A) will not carry a value over a child function call.
 6. Functions specified by **#pragma noregsave** can be used in the following conditions:
 - a. A function is the first function activated and is not called from any other function.
 - b. A function is called from a function that is specified by **#pragma regsave**.
 - c. A function is called from a function that is specified by **#pragma regsave** via **#pragma noregalloc**.

```

Example:      #pragma noregsave(f, A::j)
              #pragma noregalloc(g)
              #pragma regsave(h)
              class A{
              public:
                static void j();
              };
              void f();
              void g();
              void h();
              void h(){
                g();
                f(); /* Function f declared with #pragma          */
                   /* noregsave is directly called by h          */
              } /* declared with #pragma regsave                  */

              void g(){
                f(); /* Functions f and A::j declared with          */
                   /* #pragma noregsave are indirectly called    */
                   /* by h via g declared with #pragma            */
                   /* noregalloc                                  */
                A::j();
              }

              void f( )
              {
              }

```

Remarks: The result of a call of a function declared with **#pragma noregsave** is not guaranteed if it is called in a way other than that shown above.

#pragma entry

Description Format: #pragma entry [(]<function name>[(sp=<constant>)][]]

Description: Handles the function specified in <function name> as an entry function. The entry function is created without any code to save and restore the contents of registers. When SH-3, SH3-DSP, SH-4, SH-4A, or SH4AL-DSP is specified as the CPU and **sp=<constant>** is specified, or **#pragma stacksize** is declared, the code that makes the initial setting of the stack pointer will be output at the beginning of the function.

Example 1:

```
#pragma entry INIT(sp=0x10000)
void INIT() {
    :
```

<Example of code expansion>

```
.SECTION P, CODE
_INIT:
    MOV.L    L1, R15
    :
L1:    .DATA.L H'00010000
    :
```

Example 2:

```
#pragma stacksize 100
#pragma entry INIT
void INIT() {
    :
```

<Example of code expansion>

```
.SECTION S, STACK
.RES.B    100
.SECTION P, CODE
_INIT:
    MOV.L    L1, R15
    :
L1:    .DATA.L STARTOF S + SIZEOF S
    :
```

Remarks: **#pragma entry** must be specified before the function is declared. Only one entry function can be specified in a single load module. Always specify `<constant>` as a multiple of four.
When **cpu=sh1**, **sh2**, **sh2e**, **sh2a**, **sh2afpu**, or **sh2dsp** has been specified, the specification of **sp=<constant>** will be invalid.

#pragma ifunc

Description Format: `#pragma [(]ifunc <function name>[)]`

Description: Suppresses saving and restoring of the floating-point registers during execution of the function specified by `<function name>`.

Remarks: **#pragma ifunc** must be specified before the function is declared. It is only valid when **cpu=sh2e**, **cpu=sh2afpu**, **cpu=sh4**, or **cpu=sh4a** is specified. If a floating-point number is used in the function specified in **#pragma ifunc**, an error will occur.

Example:

```
float f;
#pragma ifunc(func)
void func(void) {
    f=0.0f; /* Error */
}
```

#pragma tbr

Description Format: #pragma tbr [(0)<function name> [({sn=<section name> | ov=<offset>})]
[,...][D)]

Description: Declares functions to be called by using TBR relative addresses. See the following detailed specifications.

(a) #pragma tbr <function name>

The function specified by <function name> is called by using an TBR relative address.

When there is a definition of <function name>, the address of func is output in \$TBR section.

Example

```
#pragma tbr func
void func() {}
#pragma section AA
void func2() {
    func();
}
```

<Example of code expansion>

```
_func:
    RTS/N

_func2:
    STS.L  PR,@-R15
    JSR/N  @@($_func-(START OF $TBR),TBR)
    LDS.L  @R15+,PR
    RTS/N

    .SECTION $TBR,DATA,ALIGN=4
$_func:
    .DATA.L _func
```

(b) #pragma tbr <function name> (sn=<section name>)

The function specified by <function name> is called by using an TBR relative address.

When there is a definition of <function name>, the address of func is output in \$TBR<section name> section.

Example

```
#pragma tbr func(sn=_A)
void func() {}
#pragma section AA
void func2() {
    func();
}
```

<Example of code expansion>

```
_func:
    RTS/N

_func2:
    STS.L   PR,@-R15
    JSR/N   @@($_func-(START OF $TBR_A),TBR)
    LDS.L   @R15+,PR
    RTS/N

    .SECTION $TBR_A,DATA,ALIGN=4
$_func:
    .DATA.L _func
```

(c) #pragma tbr <function name> (ov=<offset>)

The function specified by <function name> is called by using an TBR relative address.

A multiple of 4 within the range from 0 to 1020 should be specified for <offset>.

The compiler outputs no TBR address table.

Example

```
#pragma tbr func(ov=32)
void func() {}
#pragma section AA
void func2() {
    func();
}
```

<Example of code expansion>

```
_func:
    RTS/N
```



```

_func2:
    STS.L   PR, @-R15
    JSR/N   @@ (32, TBR)
    LDS.L   @R15+, PR
    RTS/N
    
```

Remarks: **#pragma tbr** is only valid when **cpu=sh2a** or **sh2afpu** is specified. **#pragma tbr** overrides the **tbr** option if they are specified simultaneously. When **pic=1** is specified, **#pragma tbr** is invalid. If both **sn** and **ov** are specified for a single function, the first specification is valid. Before calling the specified function, the start address of the corresponding section must be specified in TBR by using intrinsic function **set_tbr()**. Up to 255 functions can be specified by **#pragma tbr** in each section.

#pragma align4

Command Line Format: **#pragma align4** [(|<function name>=<type>[,...])]

Description: This directive aligns the branch destination address of the function specified as <function name> to the 4-byte boundary. Table 10.33 shows the selectable types.

Table 10.33 Types

Type	Description
all	Aligns all branch destination addresses within the specified function to the 4-byte boundary.
loop	Aligns the start addresses of all loops within the specified function to the 4-byte boundary.
inmostloop	Aligns the start addresses of the innermost loops within the specified function to the 4-byte boundary.

Remarks: When **#pragma align4** is specified for a function, the start address of the function is always aligned to a 4-byte boundary. All functions with **#pragma align4** will not be optimized at linkage. When **align4** and **#pragma align4** are specified at the same time, the type specified with **#pragma align4** will be valid. When **align16** or **align32** and **#pragma align4** are specified at the same time, branch destination addresses within a function will be aligned with four-byte boundaries. The address

where a function starts is aligned with a four-byte boundary if it is immediately preceded by a function for which **#pragma align4** was specified, but otherwise is aligned with a 16- or 32-byte boundary.

(3) Other Extended Specifications

#pragma global_register

Description Format: `#pragma global_register [(]<variable name>=<register name>[,...][)]`

Description: Allocates the global variable specified in <variable name> to the register specified in <register name>.

Global variables and static data members can be specified as the variable name.

Example:

```
#pragma global_register(a = R8,A::b = R9)
class A(
public:
static int b;
);
int a;
void g()
{
a = A::b;
}
```

- Remarks:
1. This function is used for a simple or pointer type variable in the global variable; it cannot be used for an (unsigned) long long type variable. If CPU is other than SH2A-FPU, SH-4, or SH-4A, a double type variable can be specified only when **double=float** is specified.
 2. Only use registers R8 to R14, FR12 to FR15 (if CPU is SH-2E, SH2A-FPU, SH-4, or SH-4A) and DR12 to DR14 (if CPU is SH2A-FPU, SH-4, or SH-4A).
 3. The initial value cannot be set. In addition, the address of the specified variable cannot be referenced.
 4. The reference of the specified variable from outside of the file is not guaranteed.
 5. Static data members can be specified. Nonstatic data members cannot be specified.
 - Type of variables that can be set in FR12 to FR15:
 - For SH-2E CPU**
float type variables
double type variables (when **double=float** is specified)
 - For SH2A-FPU, SH-4, or SH-4A CPU**
float type variables (when **fpu=double** is not specified)
double type variables (when **fpu=single** is specified)
 - Type of variables that can be set in DR12 to DR14
 - For SH2A-FPU, SH-4, or SH-4A CPU**
float type variables (when **fpu=double** is specified)
double type variables (when **fpu=single** is not specified)

#pragma gbr_base
#pragma gbr_base1

Description Format: `#pragma gbr_base [(]variable name[,...][)]`
`#pragma gbr_base1 [(]variable name[,...][)]`

Description: Specifies variables to be accessed using a GBR register and an offset value. For the variable name, variables and static data members can be specified.

The variable specified by **#pragma gbr_base** is assigned to section \$G0, and the variable specified by **#pragma gbr_base1** is assigned to section \$G1.

#pragma gbr_base specifies that the variable is located in an offset of 0 to 127 bytes from the address specified by the GBR register. **#pragma gbr_base1** specifies that the variable is located in an offset of 128 or more bytes from the address specified by the GBR register, that is, a variable is in a range beyond the range specified by **#pragma gbr_base**. An offset value is 255 bytes at maximum for a char or unsigned char type, 510 bytes at maximum for a short or unsigned short, and 1020 bytes at maximum for an int, unsigned int, long, unsigned long, float, or double type. Based on the above specification, the compiler generates an object program in a GBR relative addressing mode that is optimized according to variable reference and settings.

The compiler also generates an optimized bit instruction in the GBR indirect addressing to char or unsigned char type data in the \$G0 section.

- Remarks:
1. If the total data size after the linker gathers sections \$G0 exceeds 128 bytes, the correct operation is not guaranteed. In addition, if there is data that has an offset value exceeding those specified above for **#pragma gbr_base1** in section \$G1, correct operation is not guaranteed.
 2. Section \$G1 must be allocated immediately after 128 bytes of section \$G0 in linkage.
 3. In using these **#pragma**'s, be sure to set the start address of section \$G0 in the GBR register at the start of program execution.
 4. Static data members can be specified, but non-static data members cannot be specified.
 5. When **gbr=auto** is specified, the specification of **#pragma gbr_base** or **#pragma gbr_base1** will be invalid.

#pragma bit_order

Description Format: #pragma bit_order [{left|right}]

Description: Switches the order of bit field assignment.

When **left** is specified, bit field members are assigned from the upper-bit side.
When **right** is specified, members are assigned from the lower-bit side.

The default is **left**.


If **left** or **right** is omitted, follow the options.

Example:

```

#pragma bit_order left
typedef struct{
  unsigned char a:2;
  unsigned char b:3;
}x;

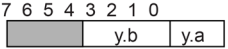
```

⇒ 

```

#pragma bit_order right
typedef struct{
  unsigned char a:2;
  unsigned char b:3;
}y;

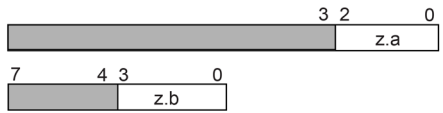
```

⇒ 

```

// Different size
#pragma bit_order right
typedef struct{
  unsigned short a:3;
  unsigned char b:4;
}z;


```

⇒ 

```

// Large size
#pragma bit_order right
typedef struct{
  unsigned char a:5;
  unsigned char b:4;
}v;

```

⇒ 

Remarks: The specified order of assignment is valid until it is switched again.
For details of bit fields, refer to section 10.1.2 (3), Bit Fields.

#pragma pack
#pragma unpack

Description Format: #pragma pack {1|4}
 #pragma unpack

Description: Specifies the boundary alignment value for structure, union, and class members after **#pragma pack** is specified in the source program.

The boundary alignment value specified by the **pack** option is used for structure, union, and class members declared when this extension has not been specified or after **#pragma unpack** has been specified. Table 10.34 shows **#pragma pack** specifications and the corresponding boundary alignment values.

Table 10.34 #pragma pack Specifications and Corresponding Member Alignment Values

Extension and Member Type	#pragma pack 1	#pragma pack 4	#pragma unpack or No Extension Specified
[unsigned]char	1	1	1
[unsigned]short, and long __fixed	1	2	Value specified by pack option
[unsigned]int, [unsigned]long, [unsigned]long long, long __fixed, __accum, long __accum, floating-point type, and pointer type	1	4	Value specified by pack option
Structure, union, and class of boundary alignment value of 1	1	1	1
Structure, union, and class of boundary alignment value of 2	1	2	Value specified by pack option
Structure, union, and class of boundary alignment value of 4	1	4	Value specified by pack option

Example:

```
#pragma pack 1
struct S1 {
    char a;    /* offset:0 */
    int b;    /* offset:1 */
    char c;    /* offset:5 */
} ST1;
#pragma pack 4
struct S2 {
```

```

char a;    /* offset:0    */
           /* gap:3 bytes */
int b;    /* offset:4    */
           /* gap:0 bytes */
char c;    /* offset:8 */
           /* gap:3 bytes */
} ST2;

```

Remarks:

1. The structure, union, and class member for which **pack=1** or **#pragma pack 1** is specified cannot be accessed using a pointer (including an access within a member function using a pointer). If the address of a structure member is used in an assignment statement, as an actual argument, or as a return value, a warning message will be output.

Example

```

#pragma pack 1
struct st {
    char x;
    int y;
} ST;
int *p=&ST.y; /* The ST.y address may be an odd value. */

void func(void) {
    ST.y=1; /* Can be accessed correctly. */
    *p=1; /* Cannot be accessed correctly in some cases. */
}

```

2. The boundary alignment value for structure, union, and class members can also be specified by the **pack** option. When both the option and **#pragma** extension are specified together, the **#pragma** extension takes priority.
3. A single structure, union or class cannot include members with different numbers of bytes for boundary alignment. If code includes such a case, a warning is output.


```
struct X {  
  
    int m;  
  
    } x;  
  
#pragma pack 1  
struct S {  
    char c;  
    struct X a[2]; // Alignment is 4 byte →  
                  // a warning is output  
  
};
```

4. When the **iodefine.h** file created by the Renesas High-Performance Embedded Workshop is in use, if **#pragma** or an option is used to set the alignment value to 1, the members of I/O register structures will not specify the correct addresses. To avoid this problem, place **#pragma pack4** at the start of **iodefine.h** and place **#pragma unpack** at the end of **iodefine.h**.

In addition, when having accessed using a pointer for the member of the structure, the union, and the class, or when having accessed using a pointer within a member function, please keep in mind that warning may not be outputted at the time of compile.

#pragma address

Description Format: `#pragma address [(]<variable name>=<absolute address>[...][)]`

Description: Allocates specified variables to specified addresses. The compiler assigns a section for each specified variable, and the variable is allocated to the specified absolute address during linkage. If variables are specified for contiguous addresses, these variables are assigned to a single section.

Example 1: **Scalar variable**

```
#pragma address A=0x100
int A;
void func() {
    A=0;
}
```

<Example of code expansion>

```
_func:
    MOV    #1,R2
    SHLL8  R2
    MOV    #0,R4
    RTS
    MOV.L  R4,@R2

    .SECTION $ADDRESS$B100,DATA,LOCATE=H'100
_A:
    .RES.L 1
```

Example 2: **Structure**

```
#pragma address ST=0x100
struct {
    int a;
    int b;
} ST;
void func() {
    ST.b=0;
}
```

<Example of code expansion>

```
_func:
```

```

        MOV    #1,R2
        SHLL8  R2
        MOV    #0,R4
        RTS
        MOV.L  R4,@(4,R2)

        .SECTION $ADDRESS$B100,DATA,LOCATE=H'100
    _ST:
        .RES.L 2
    
```

Example 3: Allocating multiple variables to contiguous area

```

#pragma address A=0x100,B=0x104
int A,B;
void func() {
    A=0;
    B=0;
}
    
```

<Example of code expansion>

```

    _func:
        MOV    #1,R2
        SHLL8  R2
        MOV    #0,R4
        MOV.L  R4,@R2
        RTS
        MOV.L  R4,@(4,R2)

        .SECTION $ADDRESS$B100,DATA,LOCATE=H'100
    _A:
        .RES.L 1
    _B:
        .RES.L 1
    
```

Example 4: Allocating multiple variables to non-contiguous areas

```

#pragma address A=0x100,B=0x108
int A,B;
void func() {
    A=0;
    B=0;
}
    
```

}

<Example of code expansion>

```

_func:
    MOV    #1,R2
    SHLL8  R2
    MOV    #0,R4
    MOV.L  R4,@R2
    RTS
    MOV.L  R4,@(8,R2)

    .SECTION $ADDRESS$B100,DATA,LOCATE=H'100
_A:
    .RES.L 1

    .SECTION $ADDRESS$B108,DATA,LOCATE=H'108
_B:
    .RES.L 1

```

Example 5:**Allocating multiple variables with different attributes to contiguous area**

```

#pragma address A=0x100,B=0x104
int A;
const int B=0;
void func() {
    A=0;
}

```

<Example of code expansion>

```

_func:
    MOV    #1,R2
    SHLL8  R2
    MOV    #0,R4
    RTS
    MOV.L  R4,@R2

    .SECTION $ADDRESS$B100,DATA,LOCATE=H'100
_A:
    .RES.L 1

```

```

        .SECTION $ADDRESS$C104,DATA,LOCATE=H'104
    _B:
        .DATA.L H'00000000
    
```

Remarks:

1. **#pragma address** must be specified before variables are declared.
2. If a compound-type member or an object other than a variable is specified, an error will occur.
3. If an odd address is specified for a variable or structure with boundary alignment value 2 or if an address which is not a multiple of 4 is specified for a variable or structure with boundary alignment value 4, an error will occur.
4. If **#pragma address** is specified for a single variable more than one time, an error will occur.
5. If a single address is specified for different variables or if specified variable addresses overlap each other, an error will occur.
6. If any one of the following **#pragma** extensions is specified together with **#pragma address** for a single variable, an error will occur.
#pragma section
#pragma abs16, abs20, abs28, or abs32
#pragma gbr_base or gbr_base1
#pragma global_register

10.3.2 Section Address Operator

__sectop
__secend
__seclen

Description Format: `__sectop("<section name>")`
`__secend("<section name>")`
`__seclen("<section name>")`

Description: This function refers to the start address of the <section name> specified by `__sectop`.
This function refers to the end address of the <section name> specified by `__secend`.
This function generates the size of the <section name> specified by `__seclen`.

Example:

```
<__sectop, __secend>
#include <machine.h>
#pragma section $DSEC
static const struct {
    void *rom_s; /* Start address of initialized data */
                /* section in ROM */
    void *rom_e; /* End address of initialized data */
                /* section in ROM */
    void *ram_s; /* Start address of initialized data */
                /* section in RAM */
} DTBL[]={__sectop("D"), __secend("D"),
          __sectop("R")};
#pragma section $BSEC
static const struct {
    void *b_s; /* Start address of uninitialized */
              /* data section */
    void *b_e; /* End address of uninitialized data */
              /* section */
} BTBL[]={__sectop("B"), __secend("B")};
#pragma section
#pragma stacksize 0x100
#pragma entry INIT
void main(void);
```

```
void INIT(void)
{
    INITSTCT();
    main();
    sleep();
}

<__secdsize>
unsigned int size = __secdsize("NAME");
    ↓
_size:
    .DATA.L    SIZEOF NAME
```

10.3.3 Intrinsic Functions

The compiler provides the following functions that cannot be written in C/C++, as intrinsic functions.

- Setting and referencing the status register
- Setting and referencing the vector base register
- I/O functions using the global base register
- System instructions which do not compete with register sources in C/C++ language
- Multimedia instructions using the floating-point unit and setting and referencing control registers

Intrinsic functions can be written in the same call format as regular functions.

Table 10.35 lists intrinsic functions.

Table 10.35 Intrinsic Functions

Item	Specifications	Function
Status register (SR)	void set_cr(int cr)	Writes to SR
	int get_cr(void)	Reads SR
	void set_imask(int mask)	Writes to the interrupt mask bit
	int get_imask(void)	Reads the interrupt mask bit
Vector base register (VBR)	void set_vbr(void *base)	Writes to VBR
	void *get_vbr(void)	Reads VBR
Global base register (GBR)	void set_gbr(void *base)	Writes to GBR
	void *get_gbr(void)	Reads GBR
	unsigned char gbr_read_byte(int offset)	Reads a GBR-based byte
	unsigned short gbr_read_word(int offset)	Reads a GBR-based word
	unsigned short gbr_read_long(int offset)	Reads a GBR-based longword
	void gbr_write_byte (int offset, unsigned char data)	Writes a GBR-based byte
	void gbr_write_word (int offset, unsigned short data)	Writes a GBR-based word

Table 10.35 Intrinsic Functions (cont)

Item	Specification	Function
Global base register (GBR) (cont)	void gbr_write_long (int offset, unsigned long data)	Writes a GBR-based longword
	void gbr_and_byte (int offset, unsigned char mask)	ANDs a GBR-based byte
	void gbr_or_byte (int offset, unsigned char mask)	ORs a GBR-based byte
	void gbr_xor_byte (int offset, unsigned char mask)	XORs a GBR-based byte
	int gbr_tst_byte (int offset, unsigned char mask)	Tests a GBR-based byte
Special instructions	void sleep(void)	SLEEP instruction
	int tas(char *addr)	TAS instruction
	Int trapa(int trap_no)	TRAPA instruction
	int trapa_svc (int trap_no, int code, type1 para1, type2 para2, type3 para3, type4 para4)	OS system call
	void prefetch (void *p)	PREF instruction
	void trace(long v)	TRACE instruction
	void ldtlb(void)	LDTLB instruction
void nop(void)	NOP instruction	
64-bit multiplication	long dmuls_h(long data1, long data2)	Upper 32 bits of the numbers for a signed 64-bit multiplication
	unsigned long dmuls_l(long data1, long data2)	Lower 32 bits of the numbers for a signed 64-bit multiplication
	unsigned long dmulu_h(unsigned long data1, unsigned long data2)	Upper 32 bits of the numbers for an unsigned 64-bit multiplication
	unsigned long dmulu_l(unsigned long data1, unsigned long data2)	Lower 32 bits of the numbers for an unsigned 64-bit multiplication
Exchange of upper and lower bits of data	unsigned short swapb(unsigned short data)	SWAP.B instruction
	unsigned long swapw(unsigned long data)	SWAP.W instruction
	unsigned long end_cnv1(unsigned long data)	Reverses the byte order inside 4-byte data

Table 10.35 Intrinsic Functions (cont)

Item	Specification	Function
Multiply and accumulate operation	int macw(short *ptr1, short *ptr2, unsigned int count)	MAC.W instruction
	int macwl(short *ptr1, short *ptr2, unsigned int count, unsigned int mask)	
	int macL(int *ptr1, int *ptr2, unsigned int count)	MAC.L instruction
	int macll(int *ptr1, int *ptr2, unsigned int count, unsigned int mask)	
Floating-point unit	void set_fpscr(int cr)	Sets FPSCR
	int get_fpscr()	Refers to FPSCR
Single-precision floating-point vector operation	float fipr(float vect1[4], float vect2[4])	FIPR instruction
	void ftrv(float vec1[4], float vec2[4])	FTRV instruction
	void ftrvadd(float vec1[4], float vec2[4], float vec3[4])	Transforms 4-dimensional vector by 4×4 matrix, and adds the result to 4-dimensional vector
	void ftrvsub(float vec1[4], float vec2[4], float vec3[4])	Transforms 4-dimensional vector by 4×4 matrix, and subtracts 4-dimensional vector from the result
Single-precision floating-point vector operation	void add4(float vec1[4], float vec2[4], float vec3[4])	Performs addition of 4-dimension vectors
	void sub4(float vec1[4], float vec2[4], float vec3[4])	Performs subtraction of 4-dimension vectors
	void mtrx4mul(float mat1[4][4], float mat2[4][4])	Performs multiplication of 4×4 matrices
	void mtrx4muladd(float mat1[4][4], float mat2[4][4], float mat3[4][4])	Performs multiplication and addition of 4×4 matrices
	void mtrx4mulsub(float mat1[4][4], float mat2[4][4], float mat3[4][4])	Performs multiplication and subtraction of 4×4 matrices
Access to extension register	void ld_ext(float mat[4][4])	Loads mat (4×4 matrix) to extension register
	void st_ext(float mat[4][4])	Stores contents of extension register to mat (4×4 matrix)

Table 10.35 Intrinsic Functions (cont)

Item	Specification	Function
DSP instructions	<code>long __fixed pabs_lf(long __fixed data)</code>	Computes the absolute value
	<code>long __accum pabs_la (long __accum data)</code>	
	<code>__fixed pdmsb_lf(long __fixed data)</code>	Detects the MSB
	<code>__fixed pdmsb_la(long __accum data)</code>	
	<code>long __fixed psha_lf(long __fixed data, int count)</code>	Shifts data arithmetically
	<code>long __accum psha_la (long __accum data,int count)</code>	
	<code>__accum rndtoa(long __accum data)</code>	Rounds data
	<code>__fixed rndtof(long __fixed data)</code>	
	<code>long __fixed long_as_lfixed(long data)</code>	Copies a bit pattern
	<code>long lfixed_as_long (long __fixed data)</code>	
	<code>void set_circ_x (__X__circ __fixed array[], size_t size)</code>	Specifies modulo addressing
	<code>void set_circ_y (__Y__circ __fixed array[], size_t size)</code>	
	<code>void clr_circ(void)</code>	Cancels modulo addressing
	<code>void set_cs(unsigned int mode)</code>	Specifies the CS bit value (DSR register)
Sine and cosine	<code>void fsca(long angle, float *sinv, float *cosv)</code>	Computes the sine and cosine values
Inverse of square root	<code>float fsrra(float data)</code>	Computes the inverse of the square root
Instruction cache invalidation	<code>void icbi(void *p)</code>	Invalidates the instruction cache block
Cache block operation	<code>void ocbi(void *p)</code>	Invalidates the cache block
	<code>void ocbp(void *p)</code>	Purges the cache block
	<code>void ocbwb(void *p)</code>	Writes back the cache block
Instruction cache prefetch	<code>void prefi(void *p)</code>	Prefetches instructions into the instruction cache

Table 10.35 Intrinsic Functions (cont)

Item	Specification	Function
System synchronization	void synco(void)	Synchronizes data operation
T bit reference and setting	int movt(void)	Refers to T bit
	void clrt(void)	Clears T bit
	void sett(void)	Sets T bit
Midsection extract from combined registers	unsigned long xtrct(unsigned long data1, unsigned long data2)	Extracts middle 32 bits from contiguous 64 bits
Addition with carry	long addc(long data1, long data2)	Adds two values and T bit, and sets the carry to T bit
	int ovf_addc(long data1, long data2)	Adds two values and T bit, and refers to the carry
	long addv(long data1, long data2)	Adds two values, and sets the carry to T bit
	int ovf_addv(long data1, long data2)	Adds two values, and refers to the carry
Subtraction with borrow	long subc(long data1, long data2)	Subtracts data2 and T bit from data1, and sets the borrow to T bit
	int unf_subc(long data1, long data2)	Subtracts data2 and T bit from data1, and refers to the borrow
	long subv(long data1, long data2)	Subtracts data2 from data1, and sets the borrow to T bit
	int unf_subv(long data1, long data2)	Subtracts data2 from data1, and refers to the borrow
Sign inversion	long negc(long data)	Subtracts data and T bit from 0, and sets the borrow to T bit
1-bit division	unsigned long div1(unsigned long data1, unsigned long data2)	Performs division data1/data2 for one step, and sets the result to T bit
	int div0s(long data1, long data2)	Performs initial settings for signed division data1/data2, and refers to T bit
	void div0u(void)	Performs initial settings for unsigned division

Table 10.35 Intrinsic Functions (cont)

Item	Specification	Function
Rotation	unsigned long rotl(unsigned long data)	Rotates data to left by one bit, and sets the bit pushed out of the operand to T bit
	unsigned long rotr(unsigned long data)	Rotates data to right by one bit, and sets the bit pushed out of the operand to T bit
	unsigned long rotcl(unsigned long data)	Rotates data including T bit to left by one bit, and sets the bit pushed out of the operand to T bit
	unsigned long rotcr(unsigned long data)	Rotates data including T bit to right by one bit, and sets the bit pushed out of the operand to T bit
Shift	unsigned long shll(unsigned long data)	Shifts data to left by one bit, and sets the bit pushed out of the operand to T bit
	unsigned long shlr(unsigned long data)	Shifts data logically to right by one bit, and sets the bit pushed out of the operand to T bit
	long shar(long data)	Shifts data arithmetically to right by one bit, and sets the bit pushed out of the operand to T bit
Saturation operation	long clipsb(long data)	Performs signed saturation operation for 1-byte data
	long clipsw(long data)	Performs signed saturation operation for 2-byte data
	unsigned long clipub(unsigned long data)	Performs unsigned saturation operation for 1-byte data
	unsigned long clipuw(unsigned long data)	Performs unsigned saturation operation for 2-byte data
TBR setting and reference	void set_tbr(void *data)	Sets data to TBR
	void *get_tbr(void)	Refers to TBR value
Nested interrupts	void sr_jsr(void *func, int imask);	Clears the RB and BL bits of SR to 0, sets the imask value in the I0 to I3 bits of SR, and calls the func function.

Table 10.35 Intrinsic Functions (cont)

Item	Specification	Function
Manipulate bits in memory	<code>void bset(unsigned char *addr, unsigned char bit_num);</code>	Sets 1 to the specified bit (<code>bit_num</code>) of the specified address (<code>addr</code>).
	<code>void bclr(unsigned char *addr, unsigned char bit_num);</code>	Sets 0 to the specified bit (<code>bit_num</code>) of the specified address (<code>addr</code>).
	<code>void bcopy(unsigned char *from_addr, unsigned char from_bit_num, unsigned char *to_addr, unsigned char to_bit_num);</code>	Sets the value of bit [1] (<code>from_bit_num</code>) of address [1] (<code>from_bit_num</code>) to bit T and bit [2] (<code>to_bit_num</code>) of address [2] (<code>to_addr</code>).
	<code>void bnotcopy(unsigned char *from_addr, unsigned char from_bit_num, unsigned char *to_addr, unsigned char to_bit_num);</code>	Sets the inverted value of bit [1] (<code>from_bit_num</code>) of address [1] (<code>from_bit_num</code>) to bit T and bit [2] (<code>to_bit_num</code>) of address [2] (<code>to_addr</code>).

`<machine.h>`, `<umachine.h>`, or `<smachine.h>` must be specified when intrinsic functions are used.

`<machine.h>` is divided into `<umachine.h>` and `<smachine.h>` as shown in table 10.36 to correspond to the SH-3, SH3-DSP, SH-4, SH-4A, or SH4AL-DSP execution mode:

Table 10.36 Dividing <machine.h>

Include File	Contents
<code><machine.h></code>	Overall intrinsic functions
<code><smachine.h></code>	Intrinsic functions that can be used in the privileged mode
<code><umachine.h></code>	Intrinsic functions other than those in <code><smachine.h></code>

void set_cr(int cr)

Description: Sets **cr** (32 bits) to the status register (SR).

Header: <machine.h> or <smachine.h>

Parameters: **cr** Setting value

Example:

```
#include <machine.h>
void main(void)
{
    set_cr(0x60000000); /* Supervisor, RBank=1, BL=0, Imask=0 */
}
```

int get_cr(void)

Description: Reads the status register (SR).

Header: <machine.h> or <smachine.h>

Return value: Status register value

Example:

```
#include <machine.h>
void main(void)
{
    set_cr(get_cr() | 0x1000000); /* Set BL bit */
}
```

void set_imask(int mask)

Description: Sets **mask** (4 bits) to the interrupt mask bits (4 bits).

Header: <machine.h> or <smachine.h>

Parameters: mask Setting value (4 bits)

Example:

```
#include <machine.h>
void main(void)
{
    set_imask(15);
}
```

int get_imask(void)

Description: Reads the interrupt mask bits (4 bits).

Header: <machine.h> or <smachine.h>

Return value: Value of the interrupt mask bits

Example:

```
#include <machine.h>
void main(void)
{
    int mask;
    mask = get_imask();
}
```


void set_vbr(void base)

Description: Sets **base** (32 bits) to the vector base register (VBR).

Header: <machine.h> or <smachine.h>

Parameters: base Setting value

Example:

```
#include <machine.h>
#define VBR 0x0000FC00
void main(void)
{
    set_vbr((void *)VBR);
}
```

void *get_vbr(void)

Description: Reads the vector base register (VBR).

Header: <machine.h> or <smachine.h>

Return value: Value of the vector base register

Example:

```
#include <machine.h>
void main(void)
{
    void *vbr;
    vbr = get_vbr();
}
```

void set_gbr(void *base)

Description: Sets **base** (32 bits) to the global base register (GBR).

Header: <machine.h> or <umachine.h>

Parameters: base Setting value

```
Example: #include <machine.h>
#define IOBASE 0x05fffec0
void main(void)
{
    set_gbr((void *)IOBASE);
}
```

Remarks: As GBR is a control register whose contents are not guaranteed by all functions in this compiler, take care when changing GBR settings. This function is invalid when **gbr=auto** is specified.

void *get_gbr(void)

Description: Reads the global base register (GBR).

Header: <machine.h> or <umachine.h>

Return value: Value of the global base register

```
Example: #include <machine.h>
void main(void)
{
    void *gbr;
    gbr = get_gbr();
}
```

Remarks: This function is invalid when **gbr=auto** is specified.

unsigned char gbr_read_byte (int offset)

Description: Reads a byte (8 bits) at the address indicated by adding GBR and the offset specified.

Header: <machine.h> or <umachine.h>

Return value: Byte data (8 bits) reference value

Parameter: offset Offset address

Example:

```
#include <machine.h>
#define BDATA 0
void main(void)
{
    if(gbr_read_byte(BDATA) !=0)
        :
}
```

- Remarks:
1. **offset** must be a constant.
 2. The specifiable range for **offset** is +255 bytes.
 3. This function is invalid when **gbr=auto** is specified.

unsigned short gbr_read_word (int offset)

Description: Reads a word (16 bits) at the address indicated by adding GBR and the offset specified.

Header: <machine.h> or <umachine.h>

Return value: Word data (16 bits) reference value

Parameter: offset Offset address

Example:

```
#include <machine.h>
#define WDATA 0
void main(void)
{
    if (gbr_read_word(WDATA) !=0)
        :
}
```

Remarks:

1. **offset** must be a constant.
2. The specifiable range for **offset** is +510 bytes.
3. This function is invalid when **gbr=auto** is specified.

unsigned long gbr_read_long (int offset)

Description: Reads a longword (32 bits) at the address indicated by adding GBR and the offset specified.

Header: <machine.h> or <umachine.h>

Return value: Longword data (32 bits) reference value

Parameter: offset Offset address

Example:

```
#include <machine.h>
#define LDATA 0
void main(void)
{
    if(gbr_read_long(LDATA) !=0)
        :
}
```

- Remarks:
1. **offset** must be a constant.
 2. The specifiable range for **offset** is +1020 bytes.
 3. This function is invalid when **gbr=auto** is specified.

void gbr_write_byte(int offset, unsigned char data)

Description: Sets a byte (8 bits) at the address indicated by adding GBR and the offset specified.

Header: <machine.h> or <umachine.h>

Parameter: offset Offset address
 data Setting value (8 bits)

Example:

```
#include <machine.h>
#define BDATA 0
void main(void)
{
    gbr_write_byte(BDATA, 0);
}
```

Remarks:

1. **offset** must be a constant.
2. The specifiable range for **offset** is +255 bytes.
3. This function is invalid when **gbr=auto** is specified.

void gbr_write_word(int offset, unsigned short data)

Description: Sets a word (16 bits) at the address indicated by adding GBR and the offset specified.

Header: <machine.h> or <umachine.h>

Parameter: offset Offset address
 data Setting value (16 bits)

Example:

```
#include <machine.h>
#define WDATA 0
void main(void)
{
    gbr_write_word(WDATA, 0);
}
```

Remarks:

1. **offset** must be a constant.
2. The specifiable range for **offset** is +510 bytes.
3. This function is invalid when **gbr=auto** is specified.

void gbr_write_long(int offset, unsigned long data)

Description: Sets a longword (32 bits) at the address indicated by adding GBR and the offset specified.

Header: <machine.h> or <umachine.h>

Parameter: offset Offset address
 data Setting value (32 bits)

Example:

```
#include <machine.h>
#define LDATA 0
void main(void)
{
    gbr_write_long(LDATA, 0);
}
```

Remarks:

1. **offsets** must be a constant.
2. The specifiable range for **offset** is +1020 bytes.
3. This function is invalid when **gbr=auto** is specified.

void gbr_and_byte(int offset, unsigned char mask)

Description: ANDs **mask** and a byte (8 bits) at the address indicated by adding GBR and the offset specified, and stores the result to the address indicated by adding GBR and the specified offset.

Header: <machine.h> or <umachine.h>

Parameter: offset Offset address
 mask Data (8 bits)

Example: #include <machine.h>
 #define BDATA 0
 void main(void)
 {
 gbr_and_byte(BDATA, 0x01);
 }

Remarks: 1. **offsets** must be a constant.
 2. The specifiable range for **offset** is +255 bytes.
 3. The specifiable range for **mask** is 0 to +255.
 4. This function is invalid when **gbr=auto** is specified.

void gbr_or_byte(int offset, unsigned char mask)

Description: ORs **mask** and a byte (8 bits) at the address indicated by adding GBR and the offset specified, and stores the result to the address indicated by adding GBR and the specified offset.

Header: <machine.h> or <umachine.h>

Parameter: offset Offset address
 mask Data (8 bits)

Example:

```
#include <machine.h>
#define BDATA 0
void main(void)
{
    gbr_or_byte(BDATA, 0x01);
}
```

Remarks:

1. **offsets** must be a constant.
2. The specifiable range for **offset** is +255 bytes.
3. The specifiable range for **mask** is 0 to +255.
4. This function is invalid when **gbr=auto** is specified.

void gbr_xor_byte(int offset, unsigned char mask)

Description: Exclusively ORs **mask** and a byte (8 bits) at the address indicated by adding GBR and the offset specified, and stores the result to the address indicated by adding GBR and the specified offset.

Header: <machine.h> or <umachine.h>

Parameter: offset Offset address
 mask Data (8 bits)

Example:

```
#include <machine.h>
#define BDATA 0
void main(void)
{
    gbr_xor_byte(BDATA, 0x01);
}
```

Remarks:

1. **offsets** must be a constant.
2. The specifiable range for **offset** is +255 bytes.
3. The specifiable range for **mask** is 0 to +255.
4. This function is invalid when **gbr=auto** is specified.

int gbr_tst_byte(int offset, unsigned char mask)

Description: ANDs **mask** and a byte (8 bits) at the address indicated by adding GBR and the offset specified, checks whether the result is 0 or not, and sets the T bit according to the result of the check.

Header: <machine.h> or <umachine.h>

Parameter: offset Offset address
 mask Data (8 bits)

```
Example: #include <machine.h>
          #define BDATA 0
          int a;
          void main(void)
          {
            if(gbr_tst_byte(BDATA,0))
              a = 0;
          }
```

- Remarks:
1. **mask** must be a constant.
 2. The specifiable range for **offset** is +255 bytes.
 3. The specifiable range for **mask** is 0 to +255.
 4. This function is invalid when **gbr=auto** is specified.

GBR Intrinsic Function Example:

```
#include <machine.h>
#define CDATA1 0
#define CDATA2 1
#define CDATA3 2
#define SDATA1 4
#define IDATA1 8
#define IDATA2 12

struct{
    char  cdata1;           /* offset 0      */
    char  cdata2;           /* offset 1      */
    char  cdata3;           /* offset 2      */
    short sdata1;          /* offset 4      */
```

```
        int    idata1;           /* offset 8      */
        int    idata2;           /* offset 12     */
    }table;
void f();

void f()
{
    set_gbr( &table); /* Sets the start address of */
                    : /* table to GBR.           */
    gbr_write_byte( CDATA2, 10);
                    /* Sets 10 to table.cdata2. */
    gbr_write_long( IDATA2, 100);
                    /* Sets 100 to table.idata2.*/
                    :
    if(gbr_read_byte( CDATA2) != 10)
                    /* Reads table.cdata2.           */
        gbr_and_byte( CDATA2, 10);
                    /* ANDs 10 and table.cdata2, */
                    /* and sets it in table.cdata2.*/
    gbr_or_byte( CDATA2, 0x0F);
                    /* ORs 0x0F and table.cdata2, */
                    : /* and sets it in table.cdata2.*/
    sleep(); /* Expanded to the SLEEP */
            /* instruction */
}
}
```

Effective Use of GBR Intrinsic Functions:

1. Allocate a frequently accessed object to memory and set the start address of the object to GBR.
2. Byte data that frequently uses logical operations should be declared within 128 bytes of the start address of the structure.
As a result, the load instruction of start address for accessing a structure can be reduced and load/store instructions necessary for performing logical operation can be reduced.

void sleep(void)

Description: Expanded to the **SLEEP** instruction, which makes the CPU enter the low-power consumption mode.

Header: <machine.h> or <smachine.h>

Example:

```
#include <machine.h>
void main(void)
{
    sleep();
}
```

int tas(char *addr)

Description: Expanded to the **TAS.B @Rn** instruction.

Header: <machine.h> or <umachine.h>

Parameters: addr Address specified in the TAS instruction

Example:

```
#include <machine.h>
char a;
void main(void)
{
    tas(&a);
}
```

int trapa(int trap_no)

Description: Expanded to **TRAPA #trap_no**.

Header: <machine.h> or <umachine.h>

Parameters: trap_no Trap number

Example:

```
#include <machine.h>
void main(void)
{
    trapa(0);
}
```

Remarks: **trap_no** should be a constant from 0 to 255.

int trapa_svc(int trap_no, int code, type1 para1, type2 para2, type3 para3, type4 para4)

Description: Enables executing HI7000 and other OS system calls. When **trapa_svc** is executed, **code** is specified in R0, and **para1** to **para4** in R4 to R7, respectively.
Then, **TRAPA #trap_no** is executed.

Header: <machine.h> or <umachine.h>

Parameters: trap_no Trap number
code Function code
para1 to para4 Parameters (0 to 4 variables)
 Types type1 to type4 are integer type or pointer type.

Example:

```
#include <machine.h>
#define SIG_SEM 0xffc8
void main(void)
{
    trapa_svc(63, SIG_SEM, 0x05);
}
```

Remarks: **trap_no** should be a constant from 0 to 255.

void prefetch(void *p)

Description: An area indicated by the pointer (16-byte data from (int)p&0xfffff0) is written to the cache memory.

Header: <machine.h> or <umachine.h>

Parameters: p Prefetch address

Example:

```
#include <machine.h>
char a[1200];
void main(void)
{
    char *pa = a;
    prefetch(pa);
}
```

Remarks: This function is valid only when **cpu=sh2a, sh2afpu, sh3, sh3dsp, sh4, sh4a, or sh4aldsp** is specified. This function does not affect the operation of the program.

void trace(long v)

Description: Supports the software trace function provided by some emulators.

Header: <machine.h> or <umachine.h>

Parameters: v Variable to be specified

Example:

```
#include <machine.h>
void main(void)
{
    long v;
    trace(v);
}
```

Remarks: This function is valid only when other than **cpu=sh1** is specified. For details of the software trace function, refer to the user's manual of the target emulator. This function is available only during debugging with an emulator connected. Do not use this function when no emulator is connected.

void ldtlb(void)

Description: Expanded to the **LDTLB** instruction.

Header: <machine.h> or <smachine.h>

Example:

```
#include <machine.h>
void main(void)
{
    ldtlb();
}
```

Remarks: This function is only valid when **cpu=sh3, sh3dsp, sh4, sh4a, or sh4aldsp** is specified.

void nop(void)

Description: Expanded to the **NOP** instruction.

Header: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
void main(void)
{
    int a;
    if (a) {
        nop();
    }
}
```

long dmuls_h(long data1, long data2)

Description: Multiplies a pair of signed 32-bit data to produce a signed 64-bit data, and refers to the upper 32 bits of the product.

Header: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
extern long data1, data2;
extern long result;
void main(void)
{
    result = dmuls_h(data1, data2);
}
```

Remarks: This function is invalid when **cpu= sh1** is specified.

unsigned long dmuls_l(long data1, long data2)

Description: Multiplies a pair of signed 32-bit data to produce a signed 64-bit data, and refers to the lower 32 bits of the product.

Header: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
extern long data1, data2;
extern unsigned long result;
void main(void)
{
    result = dmuls_l(data1, data2);
}
```

Remarks: This function is invalid when **cpu= sh1** is specified.

unsigned long dmulu_h(unsigned long data1, unsigned long data2)

Description: Multiplies a pair of unsigned 32-bit data to produce an unsigned 64-bit data, and refers to the upper 32 bits of the product.

Header: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
extern unsigned long data1, data2;
extern unsigned long result;
void main(void)
{
    result = dmulu_h(data1, data2);
}
```

Remarks: This function is invalid when **cpu= sh1** is specified.

unsigned long dmulu_l(unsigned long data1, unsigned long data2)

Description: Multiplies a pair of unsigned 32-bit data to produce an unsigned 64-bit data, and refers to the lower 32 bits of the product.

Header: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
extern unsigned long data1, data2;
extern unsigned long result;
void main(void)
{
    result = dmulu_l(data1, data2);
}
```

Remarks: This function is invalid only when **cpu= sh1** is specified.

unsigned short swapb(unsigned short data)

Description: Exchanges the upper byte and the lower byte in the two-byte data.

Header: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
extern unsigned short data;
extern unsigned short result;
void main(void)
{
    result = swapb(data);
    /* For example, when data=0x1234,
       the results will be result=0x3412 */
}
```

unsigned long swapw(unsigned long data)

Description: Exchanges the upper two bytes and the lower two bytes in the four-byte data.

Header: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
extern unsigned long data;
extern unsigned long result;
void main(void)
{
    result = swapw(data);
    /* For example, when data=0x12345678
       the results will be result=0x56781234 */
}
```

unsigned long end_cnv1(unsigned long data)

Description: Reverses the order of bytes in the four-byte data.

Header: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
extern unsigned long data;
extern unsigned long result;
void main(void)
{
    result = end_cnv1(data);
    /* For example, when data=0x12345678 */
    /* the results will be result=0x78563412 */
}
```

int macw(short *ptr1,short*ptr2,unsigned int count)
int macwl(short *ptr1,short*ptr2,unsigned int count,unsigned int mask)

Description: Multiplies and accumulates the contents of two data tables.

Header: <machine.h> or <umachine.h>

Return value: Operation result

Parameters: ptr1 Start address of data to be multiplied or accumulated
 ptr2 Start address of data to be multiplied or accumulated
 count Number of times the operation is performed
 mask Address mask that corresponds to the ring buffer

Example:

```
#include <machine.h>
short tbl1[]={a1,a2,a3,a4};
short tbl2[]={b1,b2,b3,b4};
int result1,result2;
void main(void)
{
    result1=macw(tbl1,tbl2,3);
                                /* Executes a1*b1 + a2*b2 */
                                /* + a3*b3 */
    result2=macwl(tbl1,tbl2,4,0xffffffffb);
                                /* Executes a1*b1 + a2*b2 */
                                /* + a3*b1 + a4*b2 */
}
```

Remarks: This function does not check parameters. Therefore, keep the following in mind:

- a. Tables indicated by **ptr1** and **ptr2** must be aligned on the boundaries of multiples of 2 bytes.
- b. The table indicated by **ptr2** in **macwl** must be aligned on the boundary of a multiple of (ring buffer **mask** × 2).

int macl(int *ptr1,int*ptr2,unsigned int count)
int macll(int *ptr1,int*ptr2,unsigned int count,unsigned int mask)

Description: Multiplies and accumulates contents of two data tables.

Header: <machine.h> or <umachine.h>

Return value: Operation result

Parameters:	ptr1	Start address of data to be multiplied or accumulated
	ptr2	Start address of data to be multiplied or accumulated
	count	Number of times the operation is performed
	mask	Address mask that corresponds to the ring buffer

Example:

```
#include <machine.h>
short tbl1[]={a1,a2,a3,a4};
short tbl2[]={b1,b2,b3,b4};
int result1,result2;
void main(void)
{
    result1=macl(tbl1,tbl2,3);
                                /* Executes a1*b1 + a2*b2 */
                                /* + a3*b3 */
                                /*
    result2=macll(tbl1,tbl2,4,0xffffffff7);
                                /* Executes a1*b1 + a2*b2 */
                                /* + a3*b1 + a4*b2 */
                                /*
}
```

- Remarks:
1. This function is invalid when the **cpu=sh1** is specified.
 2. This function does not check parameters. Therefore, keep the following in mind:
 - a. Tables indicated by **ptr1** and **ptr2** must be aligned on the boundaries of multiples of 4 bytes.
 - b. The table indicated by **ptr2** in **macll** must be aligned on the boundary of a multiple of (ring buffer **mask** × 2).

void set_fpscr(int cr)

Description: Sets **cr** (32 bits) to the floating-point status control register FPSCR.

Header: <machine.h> or <umachine.h>

Parameters: **cr** Setting value (32 bits)

Example:

```
#include <machine.h>
void main(void)
{
    set_fpscr(0);
}
```

Remarks: This function is valid only when **cpu=sh2e, sh2afpu, sh4, or sh4a** is specified.

int get_fpscr (void)

Description: Refers to the floating-point status control register FPSCR.

Header: <machine.h> or <umachine.h>

Return value: FPSCR value

Example:

```
#include <machine.h>
int cr;
void main(void)
{
    cr = get_fpscr();
}
```

Remarks: This function is valid only when **cpu=sh2e, sh2afpu, sh4, or sh4a** is specified.

float fipr(float vect1[4], float vect2[4])

Description: Calculates inner product of two vectors.

Header: <machine.h> or <umachine.h>

Return value: Operation result

Parameters: vect1 Vector
 vect2 Vector

Example:

```
#include <machine.h>
extern float data1[4],data2[4];
float result;
void main(void)
{
    result=fipr(data1,data2);
}
```

Remarks: This function is valid only when **cpu=sh4** or **sh4a** is specified.

float ftrv(float vec1[4], float vec2[4])

Description: Transforms **vec1** (vector) by **tbl** (4×4 matrix), and stores the result to **vec2** (vector). Note that **tbl** needs to be loaded using intrinsic function **ld_ext()**.

Header: <machine.h> or <umachine.h>

Parameters: vec1 Vector
 vec2 Vector

Example:

```
#include <machine.h>
extern float tbl[4][4];
extern float data1[4],data2[4];
void main(void)
{
    ld_ext(tbl);
    ftrv(data1,data2);
    /* As i=0,1,2,3 the result in data2 will be as */
    /* follows: data2[i]=data1[0]*tbl[0][i]+      */
}
```

```

        /* data1[1]*tbl[1][i] + data1[2]*tbl[2][i]          */
        /* data1[3]*tbl[3][i]                             */
    }

```

Remarks:

1. This function is valid only when **cpu=sh4** or **sh4a** is specified.
2. Intrinsic functions **ld_ext()** and **st_ext()** change the floating-point register bank bit (FR) of the floating-point status control register (FPSCR) to access the extension registers. Therefore, when using intrinsic function **ld_ext()** or **st_ext()** in an interrupt function, change the interrupt mask before and after the vector operation intrinsic function as shown in the following example.

Example

```

extern float mat1[4][4];
extern float vec1[4],vec2[4];
#pragma interrupt (intfunc)
void intfunc(){
    :
    ld_ext();
    :
}
void normfunc(){
    :
    int maskdata=get_imask();
    set_imask(15);
    ld_ext(mat1);
    ftrv(vec1,vec2);
    set_imask(maskdata);
    :
}

```

void ftrvadd(float vec1[4], float vec2[4], float vec3[4])

Description: Transforms **vec1** (vector) by **tbl** (4×4 matrix), adds the result to **vec2** (vector), then stores the sum to **vec3** (vector). Note that **tbl** needs to be loaded using intrinsic function **ld_ext()**.

Header: <machine.h> or <umachine.h>

Parameters:

vec1	Vector
vec2	Vector
vec3	Vector

Example:

```
#include <machine.h>
extern float tbl[4][4];
extern float data1[4];
extern float data2[4];
extern float data3[4];
void main(void)
{
    ld_ext(tbl);
    ftrvadd(data1,data2,data3);
    /* data3 = data1 x tbl + data2 */
    /* As i=0,1,2,3 the result in data3 will be as */
    /* follows: data3[i]=data1[0]*tbl[0][i] */
    /*          +data1[1]*tbl[1][i] */
    /*          +data1[2]*tbl[2][i] */
    /*          +data1[3]*tbl[3][i] */
    /*          +data2[i] */
}
```

Remarks: This function is valid only when **cpu=sh4** or **sh4a** is specified.

void ftrvsub(float vec1[4], float vec2[4], float vec3[4])

Description: Transforms **vec1** (vector) by **tbl** (4×4 matrix), subtracts **vec2** (vector) from the result, then stores the difference to **vec3** (vector). Note that **tbl** needs to be loaded using intrinsic function **ld_ext()**.

Header: <machine.h> or <umachine.h>

Parameters:

vec1	Vector
vec2	Vector
vec3	Vector

Example:

```
#include <machine.h>
extern float tbl[4][4];
extern float data1[4];
extern float data2[4];
extern float data3[4];
void main(void)
{
    ld_ext(tbl);
    ftrvsub(data1,data2,data3);
    /* data3 = data1 x tbl - data2 */
    /* As i=0,1,2,3 the result in data3 will be as */
    /* follows: data3[i]=data1[0]*tbl[0][i] */
    /*                +data1[1]*tbl[1][i] */
    /*                +data1[2]*tbl[2][i] */
    /*                +data1[3]*tbl[3][i] */
    /*                -data2[i] */
}
```

Remarks: This function is valid only when **cpu=sh4** or **sh4a** is specified.

void add4(float vec1[4], float vec2[4], float vec3[4])

Description: Stores the sum of **vec1** (vector) and **vec2** (vector) to **vec3** (vector).

Header: <machine.h> or <umachine.h>

Parameters: **vec1** Vector
 vec2 Vector
 vec3 Vector

Example:

```
#include <machine.h>
extern float data1[4];
extern float data2[4];
extern float data3[4];
void main(void)
{
    add4(data1,data2,data3);    /* data3 = data1 + data2 */
}
```

Remarks: This function is valid only when **cpu=sh2afpu, sh4, or sh4a** is specified.

void sub4(float vec1[4], float vec2[4], float vec3[4])

Description: Stores the difference between **vec1** (vector) and **vec2** (vector) to **vec3** (vector).

Header: <machine.h> or <umachine.h>

Parameters: **vec1** Vector
 vec2 Vector
 vec3 Vector

Example:

```
#include <machine.h>
extern float data1[4];
extern float data2[4];
extern float data3[4];
void main(void)
{
    sub4(data1,data2,data3);    /* data3 = data1 - data2 */
}
```

Remarks: This function is valid only when **cpu=sh2afpu, sh4, or sh4a** is specified.

void mtrx4mul(float mat1[4], float mat2[4])

Description: Transforms **mat1** (4×4 matrix) by **tbl** (4×4 matrix), and stores the result to **mat2**.

Note that **tbl** needs to be loaded using intrinsic instruction **ld_ext()**.

Header: <machine.h> or <umachine.h>

Parameters: mat1 4×4 matrix
mat2 4×4 matrix

```
Example: #include <machine.h>
extern float tbl[4][4];
extern float tbl1[4][4];
extern float tbl2[4][4];
void main(void)
{
    ld_ext(tbl);
    mtrx4mul(tbl1,tbl2); /* tbl2 = tbl1 x tbl */
}
```

Remarks: This function is valid only when **cpu=sh4** or **sh4a** is specified.

This function is 4×4 matrix operation and therefore is not commutative.

Example

```
extern float matA[][];
extern float matB[][];
int judge(){
    float data1[4][4], data2[4][4];
    set_imask(15);
    ld_ext(matA);
    mtrx4mul(matB,data1);/* data1=matB x matA */
    ld_ext(matB);
    mtrx4mul(matA,data2);/* data2=matA x matB */
    /* elements of data1[][] and data2[][] do */
    /* not necessarily match. */
}
```

void mtrx4muladd(float mat1[4], float mat2[4], float mat3[4])

Description: Transforms **mat1** (4×4 matrix) by **tbl** (4×4 matrix), adds the result of **mat2** (4×4 matrix), and stores the sum to **mat3** (4×4 matrix).

Note that **tbl** needs to be loaded using intrinsic instruction **ld_ext()**.

Header: <machine.h> or <umachine.h>

Parameters: **mat1** 4×4 matrix
 mat2 4×4 matrix
 mat3 4×4 matrix

Example:

```
#include <machine.h>
extern float tbl[4][4];
extern float tbl1[4][4];
extern float tbl2[4][4];
extern float tbl3[4][4];
void main(void)
{
    ld_ext(tbl);
    mtrx4muladd(tbl1, tbl2, tbl3);
                                     /* tbl3 = tbl1 x tbl +tbl2 */
}
```

Remarks: This function is valid only when **cpu=sh4** or **sh4a** is specified.

This function is 4×4 matrix operation and therefore is not commutative.

void mtrx4mulsub(float mat1[4], float mat2[4], float mat3[4])

Description: Transforms **mat1** (4×4 matrix) by **tbl** (4×4 matrix), subtracts **mat2** (4×4 matrix) from the result, and stores the difference to **mat3** (4×4 matrix).

Note that **tbl** needs to be loaded using intrinsic instruction **ld_ext()**.

Header: <machine.h> or <umachine.h>

Parameters: mat1 4×4 matrix
 mat2 4×4 matrix
 mat3 4×4 matrix

Example:

```
#include <machine.h>
extern float tbl[4][4];
extern float tbl1[4][4];
extern float tbl2[4][4];
extern float tbl3[4][4];
void main(void)
{
    ld_ext(tbl);
    mtrx4mulsub(tbl1, tbl2, tbl3);
                                     /* tbl3 = tbl1 x tbl - tbl2 */
}
```

Remarks: This function is valid only when **cpu=sh4** or **sh4a** is specified.

This function is 4×4 matrix operation and therefore is not commutative.

void ld_ext(float mat[4] [4])

Description: Loads **mat** (4×4 matrix) to extension register.

Header: <machine.h> or <umachine.h>

Parameters: **mat** 4×4 matrix

Example:

```
#include <machine.h>
extern float tbl[4][4];
void main(void)
{
    ld_ext(tbl);
}
```

Remarks:

1. This function is valid only when **cpu=sh4** or **sh4a** is specified.
2. Intrinsic function **ld_ext()** changes the floating-point register bank bit (FR) of the floating-point status control register (FPSCR) to access extension register. Therefore, when this function is used in an interrupt function, change the interrupt mask before and after the vector operation intrinsic function.

void st_ext(float mat[4] [4])

Description: Stores contents of extension register to **mat** (4×4 matrix).

Header: <machine.h> or <umachine.h>

Parameters: **mat** 4×4 matrix

Example:

```
#include <machine.h>
extern float tbl[4][4];
void main(void)
{
    st_ext(tbl);
}
```

- Remarks:
1. This function is valid only when **cpu=sh4** or **sh4a** is specified.
 2. Intrinsic function **st_ext()** changes the floating-point register bank bit (FR) of the floating-point status control register (FPSCR) to access the extension register. Therefore, when this function is used in an interrupt function, change the interrupt mask before and after the vector operation intrinsic function.

long __fixed pabs_lf (long __fixed data)

long __accum pabs_la (long __accum data)

Description: Computes the absolute value of a number.

Header file: <machine.h> or <umachine.h>

Return values: Operation result

Parameters: data Data of which absolute value is to be computed

Example:

```
#include <machine.h>
long __fixed result;
long __fixed ptr;
void main(void)
{
    result=pabs_lf(ptr);
}
```

- Remarks:
- This function is valid only when **cpu= sh2dsp, sh3dsp, sh4aldsp**, and **dspe** are specified.
- If the result cannot be expressed as a type of return value (long __fixed or long __accum), correct operation is not guaranteed.

__fixed pdmsb_lf (long __fixed data)
__fixed pdmsb_la (long __accum data)

Description: Detects the MSB (computes the shift count necessary to normalize data).

Header file: <machine.h> or <umachine.h>

Return values: Operation result

Parameters: data Data of which MSB is to be detected

Example:

```
#include <machine.h>
__fixed result;
long __fixed ptr;
void main(void)
{
    result=pdmsb_lf(ptr);
}
```

Remarks: This function is valid only when **cpu= sh2dsp, sh3dsp, sh4aldsp,** and **dspc** are specified.

long __fixed psha_lf (long __fixed data,int count)
long __accum psha_la (long __accum data,int count)

Description: Shifts data arithmetically.

Header file: <machine.h> or <umachine.h>

Return values: Operation result

Parameters: data Data to be shifted arithmetically
count Shift count

Example:

```
#include <machine.h>
long __fixed result;
long __fixed ptr;
int count;
void main(void)
{
    result=psha_lf(ptr,count);
}
```

Remarks: This function is valid only when **cpu= sh2dsp, sh3dsp, sh4aldsp**, and **dspc** are specified.
The specifiable range for **count** is -32 to +32. When a positive value is specified, data is shifted to the left. When a negative value is specified, data is shifted to the right up to its absolute value. If the specified value is out of range, the behavior is not guaranteed.

long __fixed long_as_lfixed (long data)

long lfixed_as_long (long __fixed data)

Description: Copies a bit pattern (copy between a general register and a DSP register).

Header file: <machine.h> or <umachine.h>

Return values: Copy result

Parameters: data Data to be copied

Example:

```
#include <machine.h>
long __fixed result;
long ptr;
void main(void)
{
    result=long_as_lfixed(ptr);
}
```

Remarks: This function is valid only when **cpu= sh2dsp, sh3dsp, sh4aldsp,** and **dspe** are specified.

__accum rndtoa (long __accum data)

__fixed rndtof (long __fixed data)

Description: Rounds data.

Header file: <machine.h> or <umachine.h>

Return values: Operation result

Parameters: data Data to be rounded

Example:

```
#include <machine.h>
__accum result;
long __accum ptr;
void main(void)
{
    result=rndtoa(ptr);
}
```

Remarks: This function is valid only when **cpu= sh2dsp, sh3dsp, sh4aldsp**, and **dspc** are specified.

```
void set_circ_x ( __X__circ __fixed array[ ],size_t size)
```

```
void set_circ_y ( __Y__circ __fixed array[ ],size_t size)
```

Description: Specifies modulo addressing.

Header file: <machine.h> or <smachine.h>

Parameters: array[] Data to which modulo addressing is to be applied
size Data size

Example:

```
#include <machine.h>
__circ __X__fixed input[4] = {0.0r, 0.25r, 0.5r, 0.25r};
__Y__fixed output[8];
void main(void)
{
    int i;
    set_circ_x(input, sizeof(input)); /* Specifies modulo addressing. */
    for (i = 0; i < 8; i++) {
        output[i] = input[i];
    }
    clr_circ(); /* Cancels modulo addressing. */
}
```

Remarks: This function is valid only when **cpu= sh2dsp, sh3dsp, sh4aldsp**, and **dspc** are specified.

void clr_circ ()

Description: Cancels modulo addressing.
 Clears SR bits 10 and 11 counted from the right to zero.

Header file: <machine.h> or <smachine.h>

Example:

```
#include <machine.h>
__circ __X __fixed input[4] = {0.0r, 0.25r, 0.5r, 0.25r};
__Y __fixed output[8];
void main(void)
{
    int i;
    set_circ_x(input, sizeof(input)); /* Specifies modulo addressing. */
    for (i = 0; i < 8; i++) {
        output[i] = input[i];
    }
    clr_circ(); /* Cancels modulo addressing. */
}
```

Remarks: This function is valid only when **cpu= sh2dsp, sh3dsp, sh4aldsp,** and **dspe** are specified.

void set_cs (unsigned int mode)

Description: Specifies the CS bit value.

Header file: <machine.h> or <umachine.h>

Parameters: mode Mode to be specified (0 to 5)

Specified Value	Mode
0	Carry/borrow mode
1	Negative mode
2	Zero mode
3	Overflow mode
4	Signed greater mode
5	Signed equal or greater mode

Example:

```
#include <machine.h>
#define MODE 1
void main(void)
{
    set_cs(MODE);
}
```

Remarks: This function is valid only when **cpu= sh2dsp, sh3dsp, sh4aldsp**, and **dspe** are specified.

void fsca(long angle,float *sinv,float *cosv)

Description: Computes the approximate values of the sine and cosine from the angle specified by **angle** and stores the results in an area specified by **sinv** and **cosv**.

Header file: <machine.h> or <umachine.h>

Parameters: **angle** Angle from which the sine and cosine are to be obtained
(Specify a bit image for **angle** when a long-type 32-bit area is expressed as the fixed-point data with a decimal point at the right of 2^{16} bits.)
sinv Address to store the obtained sine value
cosv Address to store the obtained cosine value

Example:

```
#include <machine.h>
long angle = (45<<16)/360; /* 45 degrees */
float sinv;
float cosv;
void main(void)
{
    fsca(angle, &sinv, &cosv);
}
```

Remarks: This function is valid only when **cpu=sh4a** is specified.

float fsrra (float data)

Description: Computes the approximate values of the inverse of the square root of a value.

Header file: <machine.h> or <umachine.h>

Parameters: data Data of which inverse of the square root is to be computed

Return values: Operation result

Example:

```
#include <machine.h>
float data;
float result;
void main(void)
{
    result=fsrra(data);
}
```

Remarks: This function is valid only when **cpu=sh4a** is specified.

void icbi (void *p)

Description: Invalidates the instruction cache.

Header file: <machine.h> or <umachine.h>

Parameters: p Address of a variable or a function

Example:

```
#include <machine.h>
extern int *p;
void main(void)
{
    icbi(p);
}
```

Remarks: This function is valid only when **cpu=sh4a** or **sh4aldsp** is specified.

void ocbi (void *p)
void ocbp (void *p)
void ocbwb (void *p)

Description: Operates the cache block.
ocbi: Invalidates the cache block
ocbp: Purges the cache block
ocbwb: Writes back the cache block

Header file: <machine.h> or <umachine.h>

Parameters: p Address of a variable or a function

Example:

```
#include <machine.h>
extern int *p;
void main(void)
{
    ocbi(p);
}
```

Remarks: This function is valid only when **cpu=sh4, sh4a**, or **sh4aldsp** is specified.

void prefetch (void *p)

Description: Reads a 32-byte instruction block located at a 32-byte boundary into the instruction cache.

Header file: <machine.h> or <umachine.h>

Parameters: p Prefetch address

```
Example: #include <machine.h>
void *pa;
void main(void)
{
    prefetch(pa);
}
```

Remarks: This function is valid only when **cpu=sh4a** or **sh4aldsp** is specified.

void synco (void)

Description: This function is expanded into a **SYNCO** instruction. A **SYNCO** instruction synchronizes data operation so that the instructions issued before the **SYNCO** instruction are completed before the instructions after the **SYNCO** instruction are started.

Header file: <machine.h> or <umachine.h>

```
Example: #include <machine.h>
void main(void)
{
    synco();
}
```

Remarks: This function is valid only when **cpu=sh4a** or **sh4aldsp** is specified.

int movt (void)

Description: Refers to the value of T bit in SR.

Header file: <machine.h> or <umachine.h>

Return values: T bit value

Example:

```
#include <machine.h>
extern int sr_t;
void main(void)
{
    sr_t = movt();
}
```

void clrt (void)

Description: Clears the T bit in SR.

Header file: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
void main(void)
{
    clrt();
}
```

void sett (void)

Description: Sets the T bit in SR.

Header file: <machine.h> or <umachine.h>

Example:

```
#include <machine.h>
void main(void)
{
    sett();
}
```

unsigned long xtrct (unsigned long data1, unsigned long data2)

Description: Extracts middle 32 bits from 64-bit data obtained by combining data1 and data2.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Upper 32 bits of data
data2 Lower 32 bits of data

Return values: (lower 16 bits of data1):(upper 16 bits of data2)

Example:

```
#include <machine.h>
extern unsigned long result,data1,data2;
void main(void)
{
    result = xtrct(data1,data2);
}
```

long addc (long data1, long data2)

Description: Adds data1, data2, and T bit, and sets the carry to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Data 1 for addition
data2 Data 2 for addition

Return values: Addition result

Example:

```
#include <machine.h>
extern long result,data1,data2;
void main()
{
    result = addc(data1,data2);
}
```

Remarks: As this function refers to the T bit value, it must be ensured that the T bit value is correct immediately before this function. If a comparison or shift operation is written immediately before this function, the T bit reflects the operation result and this function cannot be executed correctly.

```
if (a) {...} /* Sets comparison result to T bit */
result[1] = addc(data1[1], data2[1]); /* Adds comparison result */
result[0] = addc(data1[0], data2[0]); /* Reflects previous operation result */
```

int ovf_addc (long data1, long data2)

Description: Adds data1, data2, and T bit, and refers to the carry.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Data 1 for addition
 data2 Data 2 for addition

Return values: Carry

Example:

```
#include <machine.h>
extern long result,data1,data2;
void main()
{
    if (ovf_addc(data1,data2)) {
        result = 0;
    }
}
```

Remarks: As this function refers to the T bit value, it must be ensured that the T bit value is correct immediately before this function. If a comparison or shift operation is written immediately before this function, the T bit reflects the operation result and this function cannot be executed correctly.

```
if (a) {...} /* Sets comparison result to T bit */
if (ovf_addc(data1,data2)) { /* Adds comparison result */
```

long addv (long data1, long data2)

Description: Adds data1 and data2, and sets the carry to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Data 1 for addition
data2 Data 2 for addition

Return values: Addition result

```
Example: #include <machine.h>
extern long result,data1,data2;
void main()
{
    result = addv(data1,data2);
}
```

int ovf_addv (long data1, long data2)

Description: Adds data1 and data2, and refers to the carry.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Data 1 for addition
data2 Data 2 for addition

Return values: Carry

```
Example: #include <machine.h>
extern long result,data1,data2;
void main()
{
    if (ovf_addv(data1,data2)) {
        result = 0;
    }
}
```


long subc (long data1, long data2)

Description: Subtracts data2 and T bit from data1, and sets the borrow to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Data 1 for subtraction
data2 Data 2 for subtraction

Return values: Subtraction result

Example:

```
#include <machine.h>
extern long result,data1,data2;
void main()
{
    result = subc(data1,data2);
}
```

Remarks: As this function refers to the T bit value, it must be ensured that the T bit value is correct immediately before this function. If a comparison or shift operation is written immediately before this function, the T bit reflects the operation result and this function cannot be executed correctly.

```
if (a) {...} /* Sets comparison result to T bit */
result[0] = subc(data1[0], data2[0]); /* Subtracts comparison result */
result[1] = subc(data1[1], data2[1]); /* Reflects previous operation result */
```

int unf_subc (long data1, long data2)

Description: Subtracts data2 and T bit from data1, and refers to the borrow.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Data 1 for subtraction
data2 Data 2 for subtraction

Return values: Borrow

Example:

```
#include <machine.h>
extern long result,data1,data2;
void main()
{
    if (unf_subc(data1,data2)) {
        result = 0;
    }
}
```

Remarks: As this function refers to the T bit value, it must be ensured that the T bit value is correct immediately before this function. If a comparison or shift operation is written immediately before this function, the T bit reflects the operation result and this function cannot be executed correctly.

```
if (a) {...} /* Sets comparison result to T bit */
if (unf_subc(data1,data2)) { /* Subtracts comparison result */
```

long subv (long data1, long data2)

Description: Subtracts data2 from data1, and sets the borrow to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Data 1 for subtraction
data2 Data 2 for subtraction

Return values: Subtraction result

Example:

```
#include <machine.h>
extern long result,data1,data2;
void main()
{
    result = subv(data1,data2);
}
```

int unv_subv (long data1, long data2)

Description: Subtracts data2 from data1, and refers to the borrow.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Data 1 for subtraction
data2 Data 2 for subtraction

Return values: Borrow

Example:

```
#include <machine.h>
extern long result,data1,data2;
void main()
{
    if (unv_subv(data1,data2)) {
        result = 0;
    }
}
```

long negc (long data)

Description: Subtracts data and T bit from 0, and sets the borrow to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: Sign inversion result

Example:

```
#include <machine.h>
extern long result,data;
void main()
{
    result = negc(data);
}
```

Remarks: As this function refers to the T bit value, it must be ensured that the T bit value is correct immediately before this function. If a comparison or shift operation is written immediately before this function, the T bit reflects the operation result and this function cannot be executed correctly.

```
if (a) {...}
result[0] = negc(data[0]);          /* Subtracts comparison result */
result[1] = negc(data[1]);          /* Reflects previous operation result */
```

unsigned long div1 (unsigned long data1, unsigned long data2)

Description: Performs division data1/data2 for one step, and sets the result to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Dividend
 data2 Divisor

Return values: Updated dividend value

Example: #include <machine.h>
 extern unsigned long data1, data2;
 void main(void)
 {
 div0u();
 data1 = div1(data1, data2);
 }

Remarks: Division can be implemented by repeating this function, but the M, Q, and T bits must not be modified during the repeat (note that a comparison or shift operation will modify the T bit).
 Execute div0s() or div0u() immediately before this function to initialize the M, Q, and T bits.

int div0s (long data1, long data2)

Description: Performs initial settings for signed division data1/data2, and refers to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data1 Dividend
data2 Divisor

Return values: T bit value

```
Example: #include <machine.h>
extern long data1,data2;
void main(void)
{
    (void) div0s (data1,data2);
    data1 = div1 (data1,data2);
}
```

void div0u (void)

Description: Performs initial settings for unsigned division.

Header file: <machine.h> or <umachine.h>

```
Example: #include <machine.h>
extern unsigned long data1,data2;
void main(void)
{
    div0u ();
    data1 = div1 (data1,data2);
}
```

unsigned long rotl (unsigned long data)

Description: Rotates data to left by one bit, and sets the bit pushed out of the operand to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: Result of 1-bit left rotation

Example:

```
#include <machine.h>
extern unsigned long result, data;
void main()
{
    result = rotl(data);
}
```

unsigned long rotr (unsigned long data)

Description: Rotates data to right by one bit, and sets the bit pushed out of the operand to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: Result of 1-bit right rotation

Example:

```
#include <machine.h>
extern unsigned long result, data;
void main()
{
    result = rotr(data);
}
```

unsigned long rotcl (unsigned long data)

Description: Rotates data including the T bit to left by one bit, and sets the bit pushed out of the operand to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: Result of 1-bit left rotation

Example:

```
#include <machine.h>
extern unsigned long result,data;
void main()
{
    result = rotcl(data);
}
```

Remarks: As this function refers to the T bit value, it must be ensured that the T bit value is correct immediately before this function. If a comparison or shift operation is written immediately before this function, the T bit reflects the operation result and this function cannot be executed correctly.

```
if (a) {...} /* Sets comparison result to T bit */
result[1] = rotcl(data[1]); /* Rotates comparison result */
```


unsigned long rotcr (unsigned long data)

Description: Rotates data including the T bit to right by one bit, and sets the bit pushed out of the operand to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: Result of 1-bit right rotation

```
Example: #include <machine.h>
extern unsigned long result,data;
void main()
{
    result = rotcr(data);
}
```

Remarks: As this function refers to the T bit value, it must be ensured that the T bit value is correct immediately before this function. If a comparison or shift operation is written immediately before this function, the T bit reflects the operation result and this function cannot be executed correctly.

```
if (a) {...}                               /* Sets comparison result to T bit */
result[1] = rotcr(data[1]);               /* Rotates comparison result */
```

unsigned long shll (unsigned long data)

Description: Shifts data to left by one bit, and sets the bit pushed out of the operand to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: Result of 1-bit left shift

```
Example: #include <machine.h>
extern unsigned long result,data;
void main()
{
    result = shll(data);
}
```

unsigned long shlr (unsigned long data)

Description: Shifts data logically to right by one bit, and sets the bit pushed out of the operand to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: Result of 1-bit right shift

```
Example: #include <machine.h>
extern unsigned long result,data;
void main()
{
    result = shlr(data);
}
```

long shar (long data)

Description: Shifts data arithmetically to right by one bit, and sets the bit pushed out of the operand to the T bit.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: Result of 1-bit right shift

```
Example: #include <machine.h>
extern long result,data;
void main()
{
    result = shar(data);
}
```

long clipsb (long data)

Description: Returns the value of data when data is in the range from -128 to 127, or returns the upper limit or lower limit when data is outside the range.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: -128 (data < -128)
data (-128 <= data <= 127)
127 (127 < data)

Example:

```
#include <machine.h>
extern long result,data;
void main()
{
    result = clipsb(data);
}
```

Remarks: This function is only valid when **cpu = sh2a** or **sh2afpu**.

long clipsw (long data)

Description: Returns the value of data when data is in the range from -32768 to 32767, or returns the upper limit or lower limit when data is outside the range.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: -32768 (data < -32768)
data (-32768 <= data <= 32767)
32767 (32767 < data)

Example:

```
#include <machine.h>
extern long result,data;
void main()
{
    result = clipsw(data);
}
```

Remarks: This function is only valid when **cpu = sh2a** or **sh2afpu**.

unsigned long clipub (unsigned long data)

Description: Returns the value of data when data is in the range from 0 to 255, or returns the upper limit when data is outside the range.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: data (data <= 255)
255 (255 < data)

Example:

```
#include <machine.h>
extern unsigned long result,data;
void main()
{
    result = clipub(data);
}
```

Remarks: This function is only valid when **cpu = sh2a** or **sh2afpu**.

unsigned long clipuw (unsigned long data)

Description: Returns the value of data when data is in the range from 0 to 65535, or returns the upper limit when data is outside the range.

Header file: <machine.h> or <umachine.h>

Parameters: data Data

Return values: data (data <= 65535)
65535 (65535 < data)

Example:

```
#include <machine.h>
extern unsigned long result,data;
void main()
{
```

```
        result = clipuw(data);  
    }
```

Remarks: This function is only valid when **cpu = sh2a** or **sh2afpu**.

void set_tbr (void *data)

Description: Sets data to TBR.

Header file: <machine.h> or <umachine.h>

Parameters: **data** Data

Example:

```
#include <machine.h>  
void *data;  
void main(void)  
{  
    set_tbr(data);  
}
```

Remarks: This function is only valid when **cpu = sh2a** or **sh2afpu**.

void *get_tbr (void)

Description: Refers to the TBR value.

Header file: <machine.h> or <umachine.h>

Return values: TBR value

Example:

```
#include <machine.h>  
void *result;  
void main(void)  
{  
    result = get_tbr();  
}
```

Remarks: This function is only valid when **cpu = sh2a** or **sh2afpu**.

void *sr_jsr (void *func, int imask)

Description: Clears the RB and BL bits in the SR, sets the imask value as the interrupt mask, and then calls the func function. A value from 0 to 15 can be specified for imask. When 0 is specified for imask, the interrupt mask is not set and only the RB and BL bits are cleared.

Header file: <machine.h> or <smachine.h>

Return values: None

Example:

```
#include <machine.h>
#pragma interrupt func1(bank)
extern void func2(void);
void func1(void)
{
    sr_jsr(func2, 15);
}

_func1:
    MOV.L    R14,@-R15
    STS.L    PR,@-R15
    STC      SSR,@-R15
    STC      SPC,@-R15
    STC      SR,R4
    MOV.L    L11,R1    ; H'FFFFFF0F
    MOV      #-16,R5   ; H'FFFFFFF0
    AND      R1,R4     ; Clears the RB and BL bits.
    EXTU.B   R5,R5
    MOV.L    L11+4,R14 ; _func2
    OR      R5,R4     ; Sets the interrupt mask to 15.
    LDC      R4,SR
    JSR      @R14
    NOP
    LDC      @R15+,SPC
    LDC      @R15+,SSR
    LDS.L    @R15+,PR
    MOV.L    @R15+,R14
    RTE
    NOP
```

Remarks: This function is only valid when **cpu = sh3, sh3dsp, sh4, sh4a, or sh4aldsp**. Only a function with a parameter or a return value or the pointer to such a function can be specified for **func**.
 If all of R8 to R14 are specified in **#pragma global_register** when the **sr_jsr()** function is used, an error will be output.
 If the **sr_jsr()** function is used in a function without the **bank** setting (interrupt specification), an error will be output.
 If a variable set to 0 is specified for **imask**, the interrupt mask is set to 0.

void bset(unsigned char *addr, unsigned char bit_num) Manipulate bits in memory

Description: Sets 1 to the specified bit (**bit_num**) of the specified address (**addr**). The values specifiable for **bit_num** are 0 to 7.

Header: <machine.h> or <umachine.h>

Parameter: *addr Address
 bit_num Bit

Example: #include <machine.h>
 void func1(void)
 {
 bset((unsigned char *) (0xffffe3886), 0);
 }

After compilation:

```
MOVI20  #-116602,R14    ; H'FFFE3886
BSET.B  #0,@(0,R14)
```

Remarks: This function is only valid when **cpu= sh2a | sh2afpu** is specified.

void bclr(unsigned char *addr, unsigned char bit_num)**Manipulate bits in memory**

Description: Sets 0 to the specified bit (`bit_num`) of the specified address (`addr`). The values specifiable for `bit_num` are 0 to 7.

Header: <machine.h> or <umachine.h>

Parameter: *addr Address
 bit_num Bit

Example:

```
#include <machine.h>
void func1(void)
{
    bclr((unsigned char *) (0xffffe3886), 0);
}
```

After compilation:

```
MOVI20 #-116602,R14 ; H'FFFE3886
BCLR.B #0,@(0,R14)
```

Remarks: This function is only valid when `cpu= sh2a | sh2afpu` is specified.

void bcopy(unsigned char *from_addr, unsigned char from_bit_num, unsigned char *to_addr, unsigned char to_bit_num) **Manipulate bits in memory**

Description: Sets the value of bit [1] (from_bit_num) of address [1] (from_addr) to bit T and bit [2] (to_bit_num) of address [2] (to_addr). The values specifiable for **from_bit_num** and **to_bit_num** are 0 to 7.

Header: <machine.h> or <umachine.h>

Parameter:

*from_addr	Address [1] (origin)
from_bit_num	Bit [1] (origin)
*to_addr	Address [2] (destination)
to_bit_num	Bit [2] (destination)

Example: To copy the values of different bits at different addresses:

```
#include <machine.h>
void func1(void)
{
    bcopy((unsigned char *) (0xfffe3886),
          0,
          (unsigned char *) (0xfffd3886),
          1);
}
```

After compilation:

```
MOVI20    #-116602,R14    ; H'FFFE3886
BLD.B     #0,@(0,R14)
MOVI20    #-182138,R14   ; H'FFFD3886
BST.B     #1,@(0,R14)
RTS/N
```

To copy the values of different bits at the same address:

```
#include <machine.h>
void func1(void)
{
    bcopy((unsigned char *) (0xfffe3886),
          0,
          (unsigned char *) (0xfffe3886),
          1);
}
```

After compilation:

```
MOVI20    #-116602,R14    ; H'FFFE3886
BLD.B     #0,@(0,R14)
MOVI20    #-182138,R14   ; H'FFFD3886
BST.B     #1,@(0,R14)
RTS/N
```

Remarks: This function is only valid when **cpu= sh2a | sh2afpu** is specified.

void bnotcopy(unsigned char *from_addr, unsigned char from_bit_num, unsigned char *to_addr, unsigned char to_bit_num) **Manipulate bits in memory**

Description: Sets the inverted value of bit [1] (from_bit_num) of address [1] (from_addr) to bit T and bit [2] (to_bit_num) of address [2] (to_addr). The values specifiable for **from_bit_num** and **to_bit_num** are 0 to 7.

Header: <machine.h> or <umachine.h>

Parameter:

*from_addr	Address [1] (origin)
from_bit_num	Bit [1] (origin)
*to_addr	Address [2] (destination)
to_bit_num	Bit [2] (destination)

Example: To copy the inverted values of different bits at different addresses:

```
#include <machine.h>
void func1(void)
{
    bnotcopy ((unsigned char *) (0xffffe3886),
              0,
              (unsigned char *) (0xffffd3886),
              1);
}
```

After compilation:

```
MOVI20    #-116602,R14    ; H'FFFE3886
BLDNOT.B  #0,@(0,R14)
MOVI20    #-182138,R14   ; H'FFFD3886
BST.B     #1,@(0,R14)
RTS/N
```

To copy the inverted values of specific bits:

```
#include <machine.h>
void func1(void)
{
    bnotcopy((unsigned char *) (0xffffe3886),
              1,
              (unsigned char *) (0xffffe3886),
              1);
}
```

After compilation:

```
MOVI20    #-116602,R14    ; H'FFFE3886
BLDNOT.B  #1,@(0,R14)
BST.B     #1,@(0,R14)
RTS/N
```

Remarks: This function is only valid when **cpu= sh2a | sh2afpu** is specified.

10.4 C/C++ Libraries

10.4.1 Standard C Libraries

Overview of Libraries

This section describes the specifications of the C library functions, which can be used generally in C/C++ programs. This section gives an overview of the library configuration, and describes the layout and the terms used in this library function description.

(1) Library Types

A library implements standard processing such as input/output and string manipulation in the form of C/C++ language functions. Libraries can be used by including standard include files for each unit of processing.

Standard include files contain declarations for the corresponding libraries and definitions of the macro names necessary to use them.

Table 10.37 shows the various library types and the corresponding standard include files.

Table 10.37 Library Types and Corresponding Standard Include Files

Library Type	Description	Standard Include Files
Program diagnostics	Outputs program diagnostic information.	<assert.h>
Character handling	Handles and checks characters.	<ctype.h>
Mathematics	Performs numerical calculations such as trigonometric functions.	<math.h> <mathf.h>
Non-local jumps	Supports transfer of control between functions.	<setjmp.h>
Variable arguments	Supports access to variable arguments for functions with such arguments.	<stdarg.h>
Input/output	Performs input/output handling.	<stdio.h>
General utilities	Performs C program standard processing such as storage area management.	<stdlib.h>
String handling	Performs string comparison, copying, etc.	<string.h>

In addition to the above standard include files, standard include files consisting solely of macro name definitions, shown in table 10.38, are provided to improve programming efficiency.

Table 10.38 Standard Include Files Comprising Macro Name Definitions

Standard Include File	Description
<stddef.h>	Defines macro names used by the standard include files.
<float.h>	Defines various limit values relating to the internal representation of floating-point numbers.
<limits.h>	Defines various limit values relating to compiler internal processing.
<errno.h>	Defines the value to set in errno when an error is generated in a library function.
<fixed.h>	Defines various limit values relating to the internal representation of fixed-point numbers.

(2) Organization of Library Part

The organization of the library part of this manual is described below.

Library functions are categorized for each standard include file, and descriptions are given for each standard include file. For each category, there is first a description relating to the macro names and function declarations defined in the standard include file (figure 10.4), followed by a description of each function (figure 10.5).

Figure 10.4 shows the standard include file description layout, and figure 10.5, the function description layout.

<standard include file name>

- Summarizes the overall function of this standard include file.
- Describes names defined or declared in this standard include file according to the name categories such as [Type], [Constant], [Variable], and [Function]. For macro names, (macro) is always attached beside the name category or name description.
- Adds description if implementation-defined specifications are included or notes common to the functions declared in this standard include file are given.

Figure 10.4 Layout of Standard Include File Description

Function name

Description: Describes the library function.

Header file: Shows the name of standard include file to be declared.

Return value: Normal: Shows the return value when the library function ends normally.

Abnormal: Shows the return value when the library function ends abnormally.

Parameters: Indicates the meanings of the parameters.

Example: Describes the calling procedure.

Error conditions:

Conditions for the occurrence of errors that cannot be determined from the return value in library function processing.

If such an error occurs, the value defined in each compiler for the error type is set in `errno*`.

Remarks: Details the library function specifications.

Implementation define:

The compiler processing method.

Figure 10.5 Layout of Function Description

Note: **errno** is a variable that stores the error type if an error occurs during execution of a library function. See section 10.4.1, descriptions for `<stddef.h>`, for details.

(3) Terms Used in Library Function Descriptions

(a) Stream input/output

In data input/output, it would lead to poor efficiency if each call of an input/output function, which handles a single character, drove the input/output device and the OS functions. To solve this problem, a storage area called a buffer is normally provided, and the data in the buffer is input or output at one time.

From the viewpoint of the program, on the other hand, it is more convenient to call input/output functions for each character.

Using the library functions, character-by-character input/output can be performed efficiently without awareness of the buffer status within the program by automatically performing buffer management.

Those library functions enable a programmer to write a program considering the input/output as a single data stream, making the programmer be able to implement data input/output efficiently without being aware of the detailed procedure. Such capability is called stream input/output.

(b) FILE structure and file pointer

The buffer, and other information, required for the stream input/output described above are stored in a single structure, defined by the name FILE in the <stdio.h> standard include file. In stream input/output, all files are handled as having a FILE structure data structure. Files of this kind are called stream files. A pointer to this FILE structure is called a file pointer, and is used to specify an input/output file.

The file pointer is defined as

```
FILE *fp;
```

When a file is opened by the **fopen** function, etc., the file pointer is returned. If the open processing fails, NULL is returned. Note that if a NULL pointer is specified in another stream input/output function, that function will end abnormally. When a file is opened, the file pointer value must be checked to see whether the open processing has been successful.

(c) Functions and macros

There are two library function implementation methods: functions and macros.

A function has the same interface as an ordinary user-written function, and is incorporated during linkage. A macro is defined using a **#define** statement in the standard include file relating to the function.

The following points must be noted concerning macros:

- (i) Macros are expanded automatically by the preprocessor, and therefore a macro expansion cannot be invalidated even if the user declares a function with the same name.
- (ii) If an expression with a side effect as a macro parameter (assignment expression, increment, decrement) is specified, its result is not guaranteed.

Example: Macro definition of MACRO that calculates the absolute value of a parameter, is as follows

If the following definition is made:

```
#define MACRO(a) (a) >= 0 ? (a) : -(a)
```

and if

```
X=MACRO(a++)
```

is in the program, the macro will be expanded as follows:

```
X = (a++) >= 0 ? (a++) : -(a++)
```

a will be incremented twice, and the resultant value will be different from the absolute value of the initial value of a.

(d) EOF

In functions such as **getc**, **getchar**, and **fgetc**, which input data from a file, EOF is the value returned at end-of-file. The name EOF is defined in the <stdio.h> standard include file.

(e) NULL

This is the value when a pointer is not pointing at anything. The name NULL is defined in the <stddef.h> standard include file.

(f) Null character

The end of a string literal in C is indicated by the characters `\0`. String parameters in library functions must also conform to this convention. The characters `\0` indicating the end of a string are called null characters.

(g) Return code

With some library functions, a return value is used to determine the result (such as whether the specified processing succeeded or failed). In this case, the return value is called as the return code.

(h) Text files and binary files

Many systems have special file formats to store data. To support this facility, library functions have two file formats: text files and binary files.

(i) Text files

A text file is used to store ordinary text, and consists of a collection of lines. In text file input, the new-line designator (`\n`) is input as a line separator. In output, output of the current line is terminated by outputting the new-line designator (`\n`). Text files are used to input/output files that store standard text for each system. With text files, characters input or output by a library function do not necessarily correspond to a physical stream of data in the file.

(ii) Binary files

A binary file is configured as a row of byte data. Data input or output by a library function corresponds to a physical list of data in the file.

(i) Standard input/output files

Files that can be used as standard by input/output library functions by default without preparations such as opening file are called standard input/output files. Standard input/output files comprise the standard input file (stdin), standard output file (stdout), and standard error output file (stderr).

(i) Standard input file (stdin)

Standard file to be input to a program.

(ii) Standard output file (stdout)

Standard file to be output from a program.

(iii) Standard error output file (stderr)

Standard file for storing output of error messages, etc., from a program.

(j) Floating-point numbers

Floating-point numbers are numbers represented by approximation of real-numbers. In a C source program, floating-point numbers are represented by decimal numbers, but inside the computer they are normally represented by binary numbers.

In the case of binary numbers, the floating-point representation is as follows:

$$2^n \times m \text{ (n: integer, m: binary fraction)}$$

Here, n is called the exponent of the floating-point number, and m is called the mantissa.

The number of bits to represent n and m is normally fixed so that a floating-point number can be represented using a specific data size.

Some terms relating to floating-point numbers are explained below.

(i) Radix

An integer value indicating the number of distinct digits in the number system used by a floating-point number (10 for decimal, 2 for binary, etc.). The radix is normally 2.

(ii) Rounding

Rounding is performed when an intermediate result of an operation of higher precision than a floating-point number is stored as a floating-point number. There is rounding up, rounding down, and half-adjust rounding (i.e., rounding up fractions over 1/2 and rounding down fractions under 1/2; or, in binary representation, rounding down 0 and rounding up 1).

(iii) Normalization

When a floating-point number is represented in the form $2^n \times m$, the same number can be represented in different ways.

Example: The following two expressions represent the same value.

$$2^5 \times 1.0_{(2)} \quad (2) \text{ indicates a binary number}$$

$$2^6 \times 0.1_{(2)}$$

Usually, a representation in which the leading digit is not 0 is used, in order to secure the number of valid digits. This is called a normalized floating-point number, and the operation that converts a floating-point number to this kind of representation is called normalization.

(iv) Guard bit

When saving an intermediate result of a floating-point operation, data one bit longer than the actual floating-point number is normally provided in order for rounding to be carried out. However, this alone does not permit an accurate result to be achieved in the event of digit dropping, etc. For this reason, the intermediate result is saved with an extra bit, called a guard bit.

(k) File access mode

This is a string that indicates the kind of processing to be carried out on a file when it is opened. There are 12 different strings, as shown in table 10.39.

Table 10.39 File Access Modes

Access Mode	Meaning
'r'	Open text file for reading
'w'	Open text file for writing
'a'	Open text file for addition
'rb'	Open binary file for reading
'wb'	Open binary file for writing
'ab'	Open binary file for addition
'r+'	Open text file for reading and updating
'w+'	Open text file for writing and updating
'a+'	Open text file for addition and updating
'r+b'	Open binary file for reading and updating
'w+b'	Open binary file for writing and updating
'a+b'	Open binary file for addition and updating

(l) Implementation definition

Definitions differ by compilers.

(m) Error indicator and end-of-file indicator

The following two data items are held for each stream file: (1) an error indicator that indicates whether or not an error has occurred during file input/output, and (2) an end-of-file indicator that indicates whether or not the input file has ended.

These data items can be referenced by the **ferror** function and the **feof** function, respectively.

With some functions that handle stream files, error occurrence and end-of-file information cannot be obtained from the return value alone. The error indicator and end-of-file indicator are useful for checking the file status after execution of such functions.

(n) File position indicator

Stream files that can be read or written at any position within the file, such as disk files, have an associated data item called a file position indicator that indicates the current read/write position within the file.

File position indicators are not used with stream files that do not permit the read/write position within the file to be changed, such as terminals.

(4) Notes on use of libraries

(a) The contents of macros defined in a library differ for each compiler.

When a library is used, the behavior is not guaranteed if the contents of these macros are redefined.

(b) With libraries, errors are not detected in all cases. The behavior is not guaranteed if library functions are called in a form other than those shown in the descriptions in the following sections.

<stddef.h>

Defines macro names used in common in the standard include file.

The following macro names are all implementation-defined.

Type	Definition Name	Description
Type (macro)	ptrdiff_t	Indicates the type of the result of subtracting two pointers.
	size_t	Indicates the type of the result of an operation using the sizeof operator.
Constant (macro)	NULL	Indicates the value when a pointer is not pointing at anything. This value is such that the result of a comparison with 0 using the equality operator (==) is true.
Variable (macro)	errno	If an error occurs during library function processing, the error code defined in the respective library is set in errno. By setting 0 in errno before calling a library function and checking the error code set in errno after the library function processing has ended, it is possible to check whether an error occurred during the library function processing.
Macro	offsetof (type, member)	Obtains the offset in bytes from the beginning of a structure to a structure member.

Implementation Define

Item	Compiler Specifications
Value of macro NULL	The pointer type value 0 is set to void.
Contents of macro ptrdiff_t	int type

<assert.h>

Adds diagnostics into programs.

Type	Definition Name	Description
Function (macro)	assert	Adds diagnostics into programs.

To invalidate the diagnostics defined by <assert.h>, define macro name NDEBUG with a **#define** statement (**#define NDEBUG**) before including <assert.h>.

Note: If a **#undef** statement is used for macro name assert, the result of subsequent assert calls is not guaranteed.

void assert (int expression)

Description: Adds diagnostics into programs.

Header file: <assert.h>

Parameters: expression Expression to be evaluated.

Example:

```
#include <assert.h>
int expression;
    assert (expression);
```

Remarks: When the expression is true, the assert macro terminates processing without returning a value. If the expression is false, it outputs diagnostic information to the standard error file in the form defined by the compiler, and then calls the **abort** function.

The diagnostic information includes the parameter's program text, source file name, and source line numbers.

Implementation define:

The following message is output when the expression is false in **assert (expression)**:

ASSERTION FAILED:ΔexpressionΔFILEΔ<file name>,lineΔ<line number>

<ctype.h>

Performs type determination and conversion for characters.

Type	Definition Name	Description
Function	isalnum	Tests for an alphabetic character or a decimal digit.
	isalpha	Tests for an alphabetic character.
	iscntrl	Tests for a control character.
	isdigit	Tests for a decimal digit.
	isgraph	Tests for a printing character except space.
	islower	Tests for a lowercase letter.
	isprint	Tests for a printing character, including space.
	ispunct	Tests for a special character.
	isspace	Tests for a space character.
	isupper	Tests for an uppercase letter.
	isxdigit	Tests for a hexadecimal digit.
	tolower	Converts an uppercase letter to lowercase.
	toupper	Converts a lowercase letter to uppercase.

In the above functions, if the input parameter value is not within the range that can be represented by the unsigned char type and is not EOF, the operation of the function is not guaranteed. Character types are listed in table 10.40.

Table 10.40 Character Types

Character Type	Description
Uppercase letter	Any of the following 26 characters 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z'
Lowercase letter	Any of the following 26 characters 'a', 'b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j', 'k', 'l', 'm', 'n', 'o', 'p', 'q', 'r', 's', 't', 'u', 'v', 'w', 'x', 'y', 'z'
Alphabetic character	Any uppercase or lowercase letter
Decimal digit	Any of the following 10 characters '0', '1', '2', '3', '4', '5', '6', '7', '8', '9'
Printing character	A character, including space (' ') that is displayed on the screen (corresponding to ASCII codes 0x20 to 0x7E)
Control character	Any character except a printing character
White-space character	Any of the following 6 characters Space (' '), form feed ('\f'), new-line ('\n'), carriage return ('\r'), horizontal tab ('\t'), vertical tab ('\v')
Hexadecimal digit	Any of the following 22 characters '0', '1', '2', '3', '4', '5', '6', '7', '8', '9', 'A', 'B', 'C', 'D', 'E', 'F', 'a', 'b', 'c', 'd', 'e', 'f'
Special character	Any printing character except space (' '), an alphabetic character, or a decimal digit

Implementation Define

Item	Compiler Specifications
The character set inspected by the isalnum function, isalpha function, iscntrl function, islower function, isprint function, and isupper functions	Character set represented by the unsigned char type. Table 10.41 shows the character set that results in a true return value.

Table 10.41 True Character

Function Name	True Characters
isalnum	'0' to '9', 'A' to 'Z', 'a' to 'z'
isalpha	'A' to 'Z', 'a' to 'z'
iscntrl	'\x00' to '\x1f', '\x7f'
islower	'a' to 'z'
isprint	'\x20' to '\x7E'
isupper	'A' to 'Z'

int isalnum (int c)

Description: Tests for an alphabetic character or a decimal digit.

Header file: <ctype.h>

Return values: If character **c** is an alphabetic character or a decimal digit: Nonzero
 If character **c** is not an alphabetic character or a decimal digit: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=isalnum(c);
```


int isalpha(int c)

Description: Tests for an alphabetic character.

Header file: <ctype.h>

Return values: If character **c** is an alphabetic character: Nonzero
If character **c** is not an alphabetic character: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=isalpha(c);
```

int iscntrl (int c)

Description: Tests for a control character.

Header file: <ctype.h>

Return values: If character **c** is a control character: Nonzero
If character **c** is not a control character: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=iscntrl (c);
```

int isdigit (int c)

Description: Tests for a decimal digit.

Header file: <ctype.h>

Return values: If character **c** is a decimal digit: Nonzero
If character **c** is not a decimal digit: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=isdigit(c);
```

int isgraph (int c)

Description: Tests for any printing character except space (' ').

Header file: <ctype.h>

Return values: If character **c** is a printing character except space: Nonzero
If character **c** is not a printing character except space: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=isgraph(c);
```

int islower (int c)

Description: Tests for a lowercase letter.

Header file: <ctype.h>

Return values: If character **c** is a lowercase letter: Nonzero
If character **c** is not a lowercase letter: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=islower(c);
```

int isprint (int c)

Description: Tests for a printing character, including space (' ').

Header file: <ctype.h>

Return values: If character **c** is a printing character, including space: Nonzero
If character **c** is not a printing character, including space: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=isprint(c);
```

int ispunct (int c)

Description: Tests for a special character.

Header file: <ctype.h>

Return values: If character **c** is a special character: Nonzero
If character **c** is not a special character: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=ispunct(c);
```

int isspace (int c)

Description: Tests for a white-space character.

Header file: <ctype.h>

Return values: If character **c** is a white-space character: Nonzero
If character **c** is not a white-space character: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=isspace(c);
```

int isupper (int c)

Description: Tests for an uppercase letter.

Header file: <ctype.h>

Return values: If character **c** is an uppercase letter: Nonzero
If character **c** is not an uppercase letter: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=isupper(c);
```

int isxdigit (int c)

Description: Tests for a hexadecimal digit.

Header file: <ctype.h>

Return values: If character **c** is a hexadecimal digit: Nonzero
If character **c** is not a hexadecimal digit: 0

Parameters: **c** Character to be tested

Example:

```
#include <ctype.h>
int c, ret;
ret=isxdigit(c);
```

int tolower (int c)

Description: Converts an uppercase letter to the corresponding lowercase letter.

Header file: <ctype.h>

Return values: If character **c** is an uppercase letter: Lowercase letter
corresponding to character **c**
If character **c** is not an uppercase letter: Character **c**

Parameters: **c** Character to be converted

Example:

```
#include <ctype.h>
int c, ret;
ret=tolower(c);
```

int toupper (int c)

Description: Converts a lowercase letter to the corresponding uppercase letter.

Header file: <ctype.h>

Return values: If character **c** is a lowercase letter: Uppercase letter
corresponding to character **c**
If character **c** is not a lowercase letter: Character **c**

Parameters: **c** Character to be converted

Example:

```
#include <ctype.h>
int c, ret;
ret=toupper(c);
```

<float.h>

Defines various limits relating to the internal representation of floating-point numbers.

The following macro names are all implementation-defined.

Type	Definition Name	Definition Value	Description
Constant (macro)	FLT_RADIX	2	Indicates the radix in exponent representation.
	FLT_ROUNDS	1	Indicates whether or not the result of an add operation is rounded off. The meaning of this macro definition is as follows: (1) When result of add operation is rounded off: Positive value (2) When result of add operation is rounded down: 0 (3) When nothing is specified: -1 The rounding-off and rounding-down methods are implementation-defined.
	FLT_GUARD	1	Indicates whether or not a guard bit is used in multiply operations. The meaning of this macro definition is as follows: (1) When guard bit is used: 1 (2) When guard bit is not used: 0
	FLT_NORMALIZE	1	Indicates whether or not floating-point values are normalized. The meaning of this macro definition is as follows: (1) When normalized: 1 (2) When not normalized: 0
	FLT_MAX	3.4028235677973364e+38F	Indicates the maximum value that can be represented as a float type floating-point value.
	DBL_MAX	1.7976931348623158e+308	Indicates the maximum value that can be represented as a double type floating-point value.
	LDBL_MAX	1.7976931348623158e+308	Indicates the maximum value that can be represented as a long double type floating-point value.
	FLT_MAX_EXP	127	Indicates the power-of-radix maximum value that can be represented as a float type floating-point value.
	DBL_MAX_EXP	1023	Indicates the power-of-radix maximum value that can be represented as a double type floating-point value.

Type	Definition Name	Definition Value	Description
Constant (macro)	LDBL_MAX_EXP	1023	Indicates the power-of-radix maximum value that can be represented as a long double type floating-point value.
	FLT_MAX_10_EXP	38	Indicates the power-of-10 maximum value that can be represented as a float type floating-point value.
	DBL_MAX_10_EXP	308	Indicates the power-of-10 maximum value that can be represented as a double type floating-point value.
	LDBL_MAX_10_EXP	308	Indicates the power-of-10 maximum value that can be represented as a long double type floating-point value.
	FLT_MIN	<ul style="list-style-type: none"> When <code>-cpu=sh4 sh4a</code> and <code>-denormalize=off</code> 1.1754943508222875 e-38F Other cases 1.4012984643248171 e-45F 	Indicates the minimum positive value that can be represented as a float type floating-point value.
	DBL_MIN	<ul style="list-style-type: none"> When <code>-cpu=sh4 sh4a</code> and <code>-denormalize=off</code> 2.2250738585072014 e-308 Other cases 4.9406564584124654 e-324 	Indicates the minimum positive value that can be represented as a double type floating-point value.
	LDBL_MIN	<ul style="list-style-type: none"> When <code>-cpu=sh4 sh4a</code> and <code>-denormalize=off</code> 2.2250738585072014 e-308 Other cases 4.9406564584124654 e-324 	Indicates the minimum positive value that can be represented as a long double type floating-point value.
	FLT_MIN_EXP	<ul style="list-style-type: none"> When <code>-cpu=sh4 sh4a</code> and <code>-denormalize=off</code> -126 Other cases -149 	Indicates the power-of-radix minimum value of a floating-point value that can be represented as a float type positive value.

Type	Definition Name	Definition Value	Description
Constant (macro)	DBL_MIN_EXP	<ul style="list-style-type: none"> When <code>-cpu=sh4 sh4a</code> and <code>-denormalize=off</code> -1022 Other cases -1074 	Indicates the power-of-radix minimum value of a floating-point value that can be represented as a double type positive value.
	LDBL_MIN_EXP	<ul style="list-style-type: none"> When <code>-cpu=sh4 sh4a</code> and <code>-denormalize=off</code> -1022 Other cases -1074 	Indicates the power-of-radix minimum value of a floating-point value that can be represented as a long double type positive value.
	FLT_MIN_10_EXP	<ul style="list-style-type: none"> When <code>-cpu=sh4 sh4a</code> and <code>-denormalize=off</code> -38 Other cases -44 	Indicates the power-of-10 minimum value of a floating-point value that can be represented as a float type positive value.
	DBL_MIN_10_EXP	<ul style="list-style-type: none"> When <code>-cpu=sh4 sh4a</code> and <code>-denormalize=off</code> -308 Other cases -323 	Indicates the power-of-10 minimum value of a floating-point value that can be represented as a double type positive value.
	LDBL_MIN_10_EXP	<ul style="list-style-type: none"> When <code>-cpu=sh4 sh4a</code> and <code>-denormalize=off</code> -308 Other cases -323 	Indicates the power-of-10 minimum value of a floating-point value that can be represented as a long double type positive value.
	FLT_DIG	6	Indicates the maximum number of digits in float type floating-point value decimal-precision.
	DBL_DIG	15	Indicates the maximum number of digits in double type floating-point value decimal-precision.
	LDBL_DIG	15	Indicates the maximum number of digits in long double type floating-point value decimal-precision.

Type	Definition Name	Definition Value	Description
Constant (macro)	FLT_MANT_DIG	24	Indicates the maximum number of mantissa digits when a float type floating-point value is represented in the radix.
	DBL_MANT_DIG	53	Indicates the maximum number of mantissa digits when a double type floating-point value is represented in the radix.
	LDBL_MANT_DIG	53	Indicates the maximum number of mantissa digits when a long double type floating-point value is represented in the radix.
	FLT_EXP_DIG	8	Indicates the maximum number of exponent digits when a float type floating-point value is represented in the radix.
	DBL_EXP_DIG	11	Indicates the maximum number of exponent digits when a double type floating-point value is represented in the radix.
	LDBL_EXP_DIG	11	Indicates the maximum number of exponent digits when a long double type floating-point value is represented in the radix.
	FLT_POS_EPS FLT_EPSILON	5.9604648328104311e -8F	Indicates the minimum floating-point value x for which $1.0 + x \neq 1.0$ in float type.
	DBL_POS_EPS DBL_EPSILON	1.1102230246251567e -16	Indicates the minimum floating-point value x for which $1.0 + x \neq 1.0$ in double type.
	LDBL_POS_EPS LDBL_EPSILON	1.1102230246251567e -16	Indicates the minimum floating-point value x for which $1.0 + x \neq 1.0$ in long double type.
	FLT_NEG_EPS	2.9802324164052156e -8F	Indicates the minimum floating-point value x for which $1.0 - x \neq 1.0$ in float type.
	DBL_NEG_EPS	5.5511151231257834e -17	Indicates the minimum floating-point value x for which $1.0 - x \neq 1.0$ in double type.
	LDBL_NEG_EPS	5.5511151231257834e -17	Indicates the minimum floating-point value x for which $1.0 - x \neq 1.0$ in long double type.
	FLT_POS_EPS_EX P	-23	Indicates the minimum integer n for which $1.0 + (\text{radix})^n \neq 1.0$ in float type.
DBL_POS_EPS_EX P	-52	Indicates the minimum integer n for which $1.0 + (\text{radix})^n \neq 1.0$ in double type.	

Type	Definition Name	Definition Value	Description
Constant (macro)	LDBL_POS_EPS_E XP	-52	Indicates the minimum integer n for which $1.0 + (\text{radix})^n \neq 1.0$ in long double type.
	FLT_NEG_EPS_EX P	-24	Indicates the minimum integer n for which $1.0 - (\text{radix})^n \neq 1.0$ in float type.
	DBL_NEG_EPS_EX P	-53	Indicates the minimum integer n for which $1.0 - (\text{radix})^n \neq 1.0$ in double type.
	LDBL_NEG_EPS_E XP	-53	Indicates the minimum integer n for which $1.0 - (\text{radix})^n \neq 1.0$ in long double type.

<limits.h>

Defines various limits relating to the internal representation of integer type data.

The following macro names are all implementation-defined.

Type	Definition Name	Definition Value	Description
Constant (macro)	CHAR_BIT	8	Indicates the number of bits of which char type is composed.
	CHAR_MAX	127	Indicates the maximum value that a char type variable can have as a value.
	CHAR_MIN	-128	Indicates the minimum value that a char type variable can have as a value.
	SCHAR_MAX	127	Indicates the maximum value that a signed char type variable can have as a value.
	SCHAR_MIN	-128	Indicates the minimum value that a signed char type variable can have as a value.
	UCHAR_MAX	255U	Indicates the maximum value that an unsigned char type variable can have as a value.
	SHRT_MAX	32767	Indicates the maximum value that a short type variable can have as a value.
	SHRT_MIN	-32768	Indicates the minimum value that a short type variable can have as a value.
	USHRT_MAX	65535U	Indicates the maximum value that an unsigned short type variable can have as a value.
	INT_MAX	2147483647	Indicates the maximum value that an int type variable can have as a value.
	INT_MIN	-2147483647-1	Indicates the minimum value that an int type variable can have as a value.
	UINT_MAX	4294967295U	Indicates the maximum value that an unsigned int type variable can have as a value.
	LONG_MAX	2147483647L	Indicates the maximum value that a long type variable can have as a value.
	LONG_MIN	-2147483647L-1L	Indicates the minimum value that a long type variable can have as a value.
	ULONG_MAX	4294967295U	Indicates the maximum value that an unsigned long type variable can have as a value.

Type	Definition Name	Definition Value	Description
Constant (macro)	LLONG_MAX	922337203685477 5807LL	Indicates the maximum value that a long long type variable can have as a value.
	LLONG_MIN	-92233720368547 75807LL-1LL	Indicates the minimum value that a long long type variable can have as a value.
	ULLONG_MAX	184467440737095 51615ULL	Indicates the maximum value that an unsigned long long type variable can have as a value.

<errno.h>

Defines the value to set in **errno** when an error is generated in a library function.

The following macro names are all implementation-defined.

Type	Definition Name	Description
Variable (macro)	errno	int type variable. An error number is set when an error is generated in a library function.
Constant (macro)	ERANGE	Refer to section 12.3, Standard Library Error Messages.
	EDOM	Same as above
	ESTRN	Same as above
	PTRERR	Same as above
	ECBASE	Same as above
	ETLN	Same as above
	EEXP	Same as above
	EEXPN	Same as above
	EFLOATO	Same as above
	EFLOATU	Same as above
	EDBLO	Same as above
	EDBLU	Same as above
	ELDBLO	Same as above
	ELDBLU	Same as above
	NOTOPN	Same as above
	EBADF	Same as above
	ECSPEC	Same as above
	EFIXEDO	Same as above
	EFIXEDU	Same as above

Type	Definition Name	Description
Constant	EACCUMO	Same as above
(macro)	EACCUMU	Same as above
	ELFIXEDO	Same as above
	ELFIXEDU	Same as above
	ELACCUMO	Same as above
	ELACCUMU	Same as above
	EMALRESM	Same as above
	EMALFRSM	Same as above
	ETOKRESM	Same as above
	ETOKFRSM	Same as above
	EIOBRESM	Same as above
	EIOBFRSM	Same as above

<fixed.h>

Defines various limits relating to the internal representation of fixed-point numbers.

The following macro names are all implementation-defined.

Type	Definition Name	Definition Value	Description
Constant (macro)	FIXED_BIT	16	Indicates the number of bits in a <code>__fixed</code> type value.
	FIXED_MIN	(-0.5r-0.5r)	Indicates the minimum value that can be represented by a <code>__fixed</code> type variable.
	FIXED_MAX	0.999969482421875r	Indicates the maximum value that can be represented by a <code>__fixed</code> type variable.
	FIXED_EPSILON	0.000030517578125r	Indicates the difference between 0.0r and the minimum value that is greater than 0.0r and can be represented as a <code>__fixed</code> type value.
	LFIXED_BIT	32	Indicates the number of bits in a long <code>__fixed</code> type value.
	LFIXED_MIN	(-0.5R-0.5R)	Indicates the minimum value that can be represented by a long <code>__fixed</code> type variable.
	LFIXED_MAX	0.999999999534338712 6922607421875R	Indicates the maximum value that can be represented by a long <code>__fixed</code> type variable.
	LFIXED_EPSILON	0.00000000465661287 3077392578125R	Indicates the difference between 0.0R and the minimum value that is greater than 0.0R and can be represented as a long <code>__fixed</code> type value.
	ACCUM_BIT	24	Indicates the number of bits in an <code>__accum</code> type value.
	ACCUM_MIN	(-128.0a-128.0a)	Indicates the minimum value that can be represented by an <code>__accum</code> type variable.
ACCUM_MAX	255.999969482421875a	Indicates the maximum value that can be represented by an <code>__accum</code> type variable.	
ACCUM_EPSILON	0.000030517578125a	Indicates the difference between 0.0a and the minimum value that is greater than 0.0a and can be represented as an <code>__accum</code> type value.	

Type	Definition Name	Definition Value	Description
Constant (macro)	LACCUM_BIT	40	Indicates the number of bits in a long __accum type value.
	LACCUM_MIN	(-128.0A-128.0A)	Indicates the minimum value that can be represented by a long __accum type variable.
	LACCUM_MAX	255.99999999953433871 26922607421875A	Indicates the maximum value that can be represented by a long __accum type variable.
	LACCUM_EPSILON	0.0000000004656612873 077392578125A	Indicates the difference between 0.0A and the minimum value that is greater than 0.0A and can be represented as a long __accum type value.

<math.h>

Performs various mathematical operations.

The following macro names are all implementation-defined.

Type	Definition Name	Description
Constant (macro)	EDOM	Indicates the value to be set in errno if the value of an parameter input to a function is outside the range of values defined in the function.
	ERANGE	Indicates the value to be set in errno if the result of a function cannot be represented as a double type value, or if overflow or underflow occurs.
	HUGE_VAL	Indicates the value for the function return value if the result of a function overflows.
Function	acos	Computes the arc cosine of a floating-point number.
	asin	Computes the arc sine of a floating-point number.
	atan	Computes the arc tangent of a floating-point number.
	atan2	Computes the arc tangent of the result of a division of two floating-point numbers.
	cos	Computes the cosine of a floating-point radian value.
	sin	Computes the sine of a floating-point radian value.
	tan	Computes the tangent of a floating-point radian value.
	cosh	Computes the hyperbolic cosine of a floating-point number.
	sinh	Computes the hyperbolic sine of a floating-point number.
	tanh	Computes the hyperbolic tangent of a floating-point number.
	exp	Computes the exponential function of a floating-point number.
	frexp	Breaks a floating-point number into a [0.5, 1.0) value and a power of 2.
	ldexp	Multiplies a floating-point number by a power of 2.
	log	Computes the natural logarithm of a floating-point number.
	log10	Computes the base-ten logarithm of a floating-point number.
	modf	Breaks a floating-point number into integral and fractional parts.
	pow	Computes a power of a floating-point number.
	sqrt	Computes the positive square root of a floating-point number.
	ceil	Computes the smallest integral value not less than or equal to the given floating-point number.
	fabs	Computes the absolute value of a floating-point number.
floor	Computes the largest integral value not greater than or equal to the given floating-point number.	
fmod	Computes the floating-point remainder of division of two floating-point numbers.	

Operation in the event of an error is described below.

(1) Domain error

A domain error occurs if the value of a parameter input to a function is outside the domain over which the mathematical function is defined. In this case, the value of `EDOM` is set in **errno**. The function return value depends on the compiler.

(2) Range error

A range error occurs if the result of a function cannot be represented as a double type value. In this case, the value of `ERANGE` is set in **errno**. If the result overflows, the function returns the value of `HUGE_VAL`, with the same sign as the correct value of the function. If the result underflows, 0 is returned as the return value.

Notes

1. If there is a possibility of a domain error resulting from a `<math.h>` function call, it is dangerous to use the resultant value directly. The value of **errno** should always be checked before using the result in such cases.

Example:

```
      .  
      .  
      .  
1  x=asin(a);  
2  if (errno==EDOM)  
3      printf ("error\n");  
4  else  
5      printf ("result is : %lf\n",x);  
      .  
      .  
      .
```

In line 1, the arc sine value is computed using the **asin** function. If the value of parameter `a` is outside the domain of the **asin** function `[-1.0, 1.0]`, the `EDOM` value is set in **errno**. Line 2 determines whether a domain error has occurred. If a domain error has occurred, error is output in line 3. If there is no domain error, the arc sine value is output in line 5.

2. Whether or not a range error occurs depends on the internal representation format of floating-point number determined by the compiler. For example, if an internal representation format that allows infinity to be represented as a value is used, `<math.h>` library functions can be implemented without causing range errors.
3. In the following cases, **errno** will not be set even though an error has occurred in the function.
 - (1) **cpu=sh2afpu**, **cpu=sh4**, or **cpu=sh4a** is specified and **fabs** and **sqrt** functions are used.
 - (2) **cpu=sh2e** and **double=float** are specified and **fabs** function is used.

Implementation Define

Item	Compiler Specifications
Value returned by a mathematical function if an input parameter is out of the range	A not-a-number is returned. For details on the format of not-a-numbers, refer to section 10.1.3, Floating-Point Number Specifications.
Whether errno is set to the value of macro ERANGE if an underflow error occurs in a mathematical function	Not specified
Whether a range error occurs if the second argument in the fmod function is 0	A range error occurs.

double acos (double d)

Description: Computes the arc cosine of a floating-point number.

Header file: <math.h>

Return values: Normal: Arc cosine of **d**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: **d** Floating-point number for which arc cosine is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=acos(d);
```

Error conditions: A domain error occurs for a value of **d** not in the range $[-1.0, +1.0]$.

Remarks: The **acos** function returns the arc cosine in the range $[0, \pi]$ by the radian.

double asin (double d)

Description: Computes the arc sine of a floating-point number.

Header file: <math.h>

Return values: Normal: Arc sine of **d**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: **d** Floating-point number for which arc sine is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=asin(d);
```

Error conditions: A domain error occurs for a value of **d** not in the range $[-1.0, +1.0]$.

Remarks: The **asin** function returns the arc sine in the range $[-\pi/2, +\pi/2]$ by the radian.

double atan (double d)

Description: Computes the arc tangent of a floating-point number.

Header file: <math.h>

Return values: Arc tangent of **d**

Parameters: **d** Floating-point number for which arc tangent is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=atan(d);
```

Remarks: The **atan** function returns the arc tangent in the range $(-\pi/2, +\pi/2)$ by the radian.

double atan2 (double y, double x)

Description: Computes the arc tangent of the division of two floating-point numbers.

Header file: <math.h>

Return values: Normal: Arc tangent value when **y** is divided by **x**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: **x** Divisor
y Dividend

Example:

```
#include <math.h>
double x, y, ret;
ret=atan2(y, x);
```

Error conditions: A domain error occurs if the values of both **x** and **y** are 0.0.

Remarks: The **atan2** function returns the arc tangent in the range $(-\pi, +\pi]$ by the radian. The meaning of the **atan2** function is illustrated in figure 10.6. As shown in the figure, the result of the **atan2** function is the angle between the X-axis and a straight line passing through the origin and point (x, y). If $y = 0.0$ and **x** is negative, the result is π . If $x = 0.0$, the result is $\pm\pi/2$, depending on whether **y** is positive or negative. Depending on the MCU setting, however, this may lead to a zero division exception.

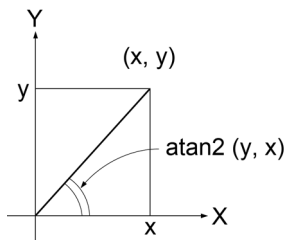


Figure 10.6 Meaning of atan2 Function

double cos (double d)

Description: Computes the cosine of a floating-point radian value.

Header file: <math.h>

Return values: Cosine of **d**

Parameters: **d** Radian value for which cosine is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=cos(d);
```

double sin (double d)

Description: Computes the sine of a floating-point radian value.

Header file: <math.h>

Return values: Sine of **d**

Parameters: **d** Radian value for which sine is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=sin(d);
```


double tan (double d)

Description: Computes the tangent of a floating-point radian value.

Header file: <math.h>

Return values: Tangent of **d**

Parameters: **d** Radian value for which tangent is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=tan(d);
```

double cosh (double d)

Description: Computes the hyperbolic cosine of a floating-point number.

Header file: <math.h>

Return values: Hyperbolic cosine of **d**

Parameters: **d** Floating-point number for which hyperbolic cosine is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=cosh(d);
```

double sinh (double d)

Description: Computes the hyperbolic sine of a floating-point number.

Header file: <math.h>

Return values: Hyperbolic sine of **d**

Parameters: **d** Floating-point number for which hyperbolic sine is to be computed

Example: `#include <math.h>`
 `double d, ret;`
 `ret=sinh(d);`

double tanh (double d)

Description: Computes the hyperbolic tangent of a floating-point number.

Header file: <math.h>

Return values: Hyperbolic tangent of **d**

Parameters: **d** Floating-point number for which hyperbolic tangent is to be computed

Example: `#include <math.h>`
 `double d, ret;`
 `ret=tanh(d);`

double exp (double d)

Description: Computes the exponential function of a floating-point number.

Header file: <math.h>

Return values: Exponential value of **d**

Parameters: **d** Floating-point number for which exponential function is to be computed

Example: `#include <math.h>`
 `double d, ret;`
 `ret=exp(d);`

double frexp (double value, double int *e)

Description: Breaks a floating-point number into a [0.5, 1.0) value and a power of 2.

Header file: <math.h>

Return values: If value is 0.0: 0.0
If value is not 0.0: Value of **ret** defined by $\text{ret} * 2^{\text{value pointed to by } e} = \text{value}$

Parameters: **value** Floating-point number to be broken into a [0.5, 1.0) value
and a power of 2
e Pointer to storage area that holds power-of-2 value

Example:

```
#include <math.h>
double ret, value;
int *e;
    ret=frexp(value, e);
```

Remarks: The **frexp** function breaks **value** into a [0.5, 1.0) value and a power of 2. It stores the resultant power-of-2 value in the area pointed to by **e**.

The **frexp** function returns the return value **ret** in the range [0.5, 1.0) or as 0.0.

If value is 0.0, the contents of the int storage area pointed to by **e** and the value of **ret** are both 0.0.

double ldexp (double e, int f)

Description: Multiplies a floating-point number by a power of 2.

Header file: <math.h>

Return values: Result of $e * 2^f$ operation

Parameters: e Floating-point number to be multiplied by a power of 2
f Power-of-2 value

Example:

```
#include <math.h>
double ret, e;
int f;
ret=ldexp(e, f);
```

double log (double d)

Description: Computes the natural logarithm of a floating-point number.

Header file: <math.h>

Return values: Normal: Natural logarithm of **d**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: d Floating-point number for which natural logarithm is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=log(d);
```

Error conditions:

A domain error occurs if **d** is negative.

A range error occurs if **d** is 0.0.

double log10 (double d)

Description: Computes the base-ten logarithm of a floating-point number.

Header file: <math.h>

Return values: Normal: Base-ten logarithm of **d**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: **d** Floating-point number for which base-ten logarithm is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=log10(d);
```

Error conditions:
A domain error occurs if **d** is negative.
A range error occurs if **d** is 0.0.

double modf (double a, double*b)

Description: Breaks a floating-point number into integral and fractional parts.

Header file: <math.h>

Return values: Fractional part of **a**

Parameters: **a** Floating-point number to be broken into integral and fractional parts
b Pointer indicating storage area that stores integral part

Example:

```
#include <math.h>
double a, *b, ret;
ret=modf(a, b);
```

double pow (double x, double y)

Description: Computes a power of floating-point number.

Header file: <math.h>

Return values: Normal: Value of **x** raised to the power **y**
 Abnormal: In case of domain error: Returns not-a-number.

Parameters: **x** Value to be raised to a power
y Power value

Example:

```
#include <math.h>
double x, y, ret;
ret=pow(x, y);
```

Error conditions:

A domain error occurs if **x** is 0.0 and **y** is 0.0 or less, or if **x** is negative and **y** is not an integer.

double sqrt (double d)

Description: Computes the positive square root of a floating-point number.

Header file: <math.h>

Return values: Normal: Positive square root of **d**
 Abnormal: In case of domain error: Returns not-a-number.

Parameters: **d** Floating-point number for which positive square root is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=sqrt(d);
```

Error conditions:

A domain error occurs if **d** is negative.

double ceil (double d)

Description: Returns the smallest integral value not less than or equal to the given floating-point number.

Header file: <math.h>

Return values: Smallest integral value not less than or equal to **d**

Parameters: **d** Floating-point number for which smallest integral value not less than that number is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=ceil(d);
```

Remarks: The **ceil** function returns the smallest integral value not less than or equal to **d**, expressed as a double. Therefore, if **d** is negative, the value after truncation of the fractional part is returned.

double fabs (double d)

Description: Computes the absolute value of a floating-point number.

Header file: <math.h>

Return values: Absolute value of **d**

Parameters: **d** Floating-point number for which absolute value is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=fabs(d);
```

double floor (double d)

Description: Returns the largest integral value not greater than or equal to the given floating-point number.

Header file: <math.h>

Return values: Largest integral value not greater than or equal to **d**

Parameters: **d** Floating-point number for which largest integral value not greater than that number is to be computed

Example:

```
#include <math.h>
double d, ret;
ret=floor(d);
```

Remarks: The **floor** function returns the largest integral value not greater than or equal to **d**, expressed as a double. Therefore, if **d** is negative, the value after rounding-up of the fractional part is returned.

double fmod (double x, double y)

Description: Computes the floating-point remainder of division of two floating-point numbers.

Header file: <math.h>

Return values: When **y** is 0.0: **x**
When **y** is not 0.0: Remainder of division of **x** by **y**

Parameters: **x** Dividend
y Divisor

Example:

```
#include <math.h>
double x, y, ret;
ret=fmod(x, y);
```

Remarks: In the **fmod** function, the relationship between parameters **x** and **y** and return value **ret** is as follows:

$$x = y * I + \text{ret} \text{ (where } I \text{ is an integer)}$$

The sign of return value **ret** is the same as the sign of **x**.

If the quotient of x/y cannot be expressed, the value of the result is not guaranteed.

When **y** is 0.0, depending on the MCU setting, however, this may lead to a zero division exception.

<mathf.h>

Performs various mathematical operations.

<mathf.h> declares mathematical functions and defines macros in single-precision format. The mathematical functions and macros used here do not follow the ANSI specifications. Each function receives a float-type parameter and returns a float-type value.

The following constants (macros) are all implementation-defined.

Type	Definition Name	Description
Constant (macro)	EDOM	Indicates the value to be set in errno if the value of an parameter input to a function is outside the range of values defined in the function.
	ERANGE	Indicates the value to be set in errno if the result of a function cannot be represented as a float type value, or if overflow or underflow occurs.
	HUGE_VALF	Indicates the value for the function return value if the result of a function overflows.
Function	acosf	Computes the arc cosine of a floating-point number.
	asinf	Computes the arc sine of a floating-point number.
	atanf	Computes the arc tangent of a floating-point number.
	atan2f	Computes the arc tangent of the result of a division of two floating-point numbers.
	cosf	Computes the cosine of a floating-point radian value.
	sinf	Computes the sine of a floating-point radian value.
	tanf	Computes the tangent of a floating-point radian value.
	coshf	Computes the hyperbolic cosine of a floating-point number.
	sinhf	Computes the hyperbolic sine of a floating-point number.
	tanhf	Computes the hyperbolic tangent of a floating-point number.
	expf	Computes the exponential function of a floating-point number.
	frexpf	Breaks a floating-point number into a [0.5f, 1.0f) value and a power of 2.
	ldexpf	Multiplies a floating-point number by a power of 2.
	logf	Computes the natural logarithm of a floating-point number.
	log10f	Computes the base-ten logarithm of a floating-point number.
	modff	Breaks a floating-point number into integral and fractional parts.
	powf	Computes a power of a floating-point number.
	sqrtf	Computes the positive square root of a floating-point number.
	ceilf	Computes the smallest integral value not less than or equal to the given floating-point number.
	fabsf	Computes the absolute value of a floating-point number.
floorf	Computes the largest integral value not greater than or equal to the given floating-point number.	
fmodf	Computes the floating-point remainder of division of two floating-point numbers.	

Operation in the event of an error is described below.

1. Domain error

A domain error occurs if the value of a parameter input to a function is outside the domain over which the mathematical function is defined. In this case, the value of EDOM is set in **errno**. The function return value depends on the compiler.

2. Range error

A range error occurs if the result of a function cannot be represented as a float type value. In this case, the value of ERANGE is set in **errno**. If the result overflows, the function returns the value of HUGE_VALF, with the same sign as the correct value of the function. If the result underflows, 0 is returned as the return value.

Notes

1. If there is a possibility of a domain error resulting from a `<mathf.h>` function call, it is dangerous to use the resultant value directly. The value of **errno** should always be checked before using the result in such cases.

Example:

```
.  
. .  
1  x=asinf(a);  
2  if (errno==EDOM)  
3  printf ("error\n");  
4  else  
5  printf ("result is : %f\n",x);  
. . .
```

In line 1, the arc sine value is computed using the **asinf** function. If the value of parameter *a* is outside the domain of the **asinf** function $[-1.0f, 1.0f]$, the EDOM value is set in **errno**. Line 2 determines whether a domain error has occurred. If a domain error has occurred, error is output in line 3. If there is no domain error, the arc sine value is output in line 5.

2. Whether or not a range error occurs depends on the internal representation format of floating-point number determined by the compiler. For example, if an internal representation format that allows infinity to be represented as a value is used, `<mathf.h>` library functions can be implemented without causing range errors.
3. In the following cases, **errno** will not be set by the **fabs** or **sqrt** function even though an error has occurred in the function.
 - (1) **cpu=sh2afpu**, **cpu=sh4**, or **cpu=sh4a** is specified and **fabsf** or **sqrtf** functions is used.
 - (2) **cpu=sh2e** is specified and **fabsf** function is used.

Implementation Define

Item	Compiler Specifications
Value returned by a mathematical function if an input parameter is out of the range	A not-a-number is returned. For details on the format of not-a-numbers, refer to section 10.1.3, Floating-Point Number Specifications.
Whether errno is set to the value of macro ERANGE if an underflow error occurs in a mathematical function	Not specified
Whether a range error occurs if the second argument in the fmodf function is 0	A range error occurs.

float acosf (float f)

Description: Computes the arc cosine of a floating-point number.

Header file: <mathf.h>

Return values: Normal: Arc cosine of **f**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: **f** Floating-point number for which arc cosine is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=acosf(f);
```

Error conditions: A domain error occurs for a value of **f** not in the range $[-1.0f, +1.0f]$.

Remarks: The **acosf** function returns the arc cosine in the range $[0, \pi]$ by the radian.

float asinf (float f)

Description: Computes the arc sine of a floating-point number.

Header file: <mathf.h>

Return values: Normal: Arc sine of **f**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: **f** Floating-point number for which arc sine is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=asinf(f);
```

Error conditions: A domain error occurs for a value of **f** not in the range $[-1.0f, +1.0f]$.

Remarks: The **asinf** function returns the arc sine in the range $[-\pi/2, +\pi/2]$ by the radian.

float atanf (float f)

Description: Computes the arc tangent of a floating-point number.

Header file: <mathf.h>

Return values: Arc tangent of **f**

Parameters: **f** Floating-point number for which arc tangent is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=atanf (f);
```

Remarks: The **atanf** function returns the arc tangent in the range $(-\pi/2, +\pi/2)$ by the radian.

float atan2f (float y, float x)

Description: Computes the arc tangent of the division of two floating-point numbers.

Header file: <mathf.h>

Return values: Normal: Arc tangent value when **y** is divided by **x**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: **x** Divisor
y Dividend

Example:

```
#include <mathf.h>
float x, y, ret;
ret=atan2f(y, x);
```

Error conditions: A domain error occurs if the values of both **x** and **y** are 0.0f

Remarks: The **atan2f** function returns the arc tangent in the range $(-\pi, +\pi]$ by the radian. The meaning of the **atan2f** function is illustrated in figure 10.7. As shown in the figure, the result of the **atan2f** function is the angle between the X-axis and a straight line passing through the origin and point (x, y). If $y = 0.0f$ and **x** is negative, the result is π .
If $x = 0.0f$, the result is $\pm\pi/2$, depending on whether **y** is positive or negative. Depending on the MCU setting, however, this may lead to a zero division exception.

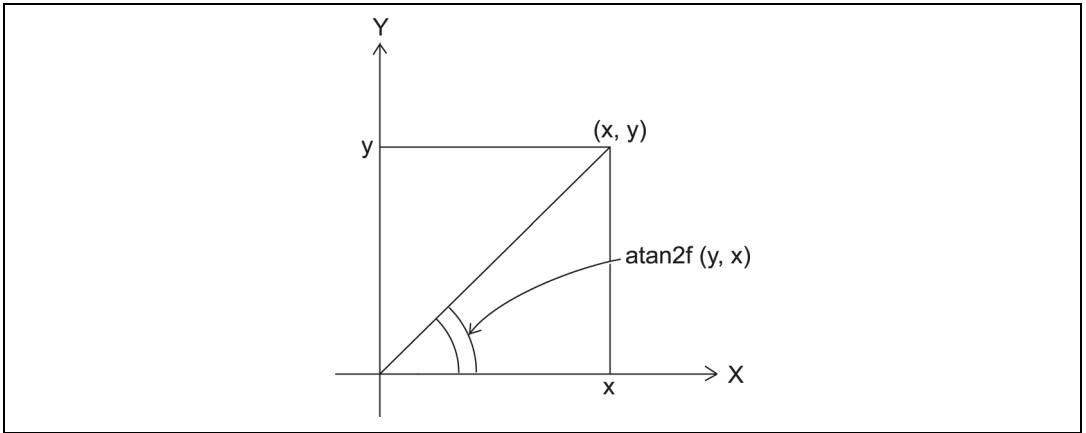


Figure 10.7 Meaning of atan2f Function

float cosf (float f)

Description: Computes the cosine of a floating-point radian value.

Header file: <mathf.h>

Return values: Cosine of **f**

Parameters: **f** Radian value for which cosine is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=cosf(f);
```

float sinf (float f)

Description: Computes the sine of a floating-point radian value.

Header file: <mathf.h>

Return values: Sine of **f**

Parameters: **f** Radian value for which sine is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=sinf(f);
```

float tanf (float f)

Description: Computes the tangent of a floating-point radian value.

Header file: <mathf.h>

Return values: Tangent of **f**

Parameters: **f** Radian value for which tangent is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=tanf(f);
```

float coshf (float f)

Description: Computes the hyperbolic cosine of a floating-point number.

Header file: <mathf.h>

Return values: Hyperbolic cosine of **f**

Parameters: **f** Floating-point number for which hyperbolic cosine is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=coshf(f);
```

float sinhf (float f)

Description: Computes the hyperbolic sine of a floating-point number.

Header file: <mathf.h>

Return values: Hyperbolic sine of **f**

Parameters: **f** Floating-point number for which hyperbolic sine is to be
computed

Example:

```
#include <mathf.h>
float f, ret;
ret=sinhf(f);
```

float tanhf (float f)

Description: Computes the hyperbolic tangent of a floating-point number.

Header file: <mathf.h>

Return values: Hyperbolic tangent of **f**

Parameters: **f** Floating-point number for which hyperbolic tangent is to be
computed

Example:

```
#include <mathf.h>
float f, ret;
ret=tanhf(f);
```

float expf (float f)

Description: Computes the exponential function of a floating-point number.

Header file: <mathf.h>

Return values: Exponential value of **f**

Parameters: **f** Floating-point number for which exponential function is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=expf(f);
```

float frexpf (float value, float int *e)

Description: Breaks a floating-point number into a [0.5f, 1.0f) value and a power of 2.

Header file: <mathf.h>

Return values: If value is 0.0f: 0.0f
If value is not 0.0f:
Value of **ret** defined by $ret * 2^{\text{value pointed to by } e} = \text{value}$

Parameters: **value** Floating-point number to be broken into a [0.5f, 1.0f) value and a power of 2
e Pointer to storage area that holds power-of-2 value

Example:

```
#include <mathf.h>
float ret, value;
int *e
ret=frexpf(value, e);
```

Remarks: The **frexpf** function breaks **value** into a [0.5f, 1.0f) value and a power of 2. It stores the resultant power-of-2 value in the area pointed to by **e**.

The **frexpf** function returns the return value **ret** in the range [0.5f, 1.0f) or as 0.0f.

If value is 0.0f, the contents of the int storage area pointed to by **e** and the value of **ret** are both 0.0f.

float ldexpf (float e, int f)

Description: Multiplies a floating-point number by a power of 2.

Header file: <mathf.h>

Return values: Result of $e * 2^f$ operation

Parameters: **e** Floating-point number to be multiplied by a power of 2
f Power-of-2 value

Example:

```
#include <mathf.h>
float ret, e;
int f;
ret=ldexpf(e, f);
```

float logf (float f)

Description: Computes the natural logarithm of a floating-point number.

Header file: <mathf.h>

Return values: Normal: Natural logarithm of **f**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: **f** Floating-point number for which natural logarithm is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=logf(f);
```

Error conditions:

A domain error occurs if **f** is negative.

A range error occurs if **f** is 0.0f.

float log10f (float f)

Description: Computes the base-ten logarithm of a floating-point number.

Header file: <mathf.h>

Return values: Normal: Base-ten logarithm of **f**
Abnormal: In case of domain error: Returns not-a-number.

Parameters: **f** Floating-point number for which base-ten logarithm is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=log10f(f);
```

Error conditions:
A domain error occurs if **f** is negative.
A range error occurs if **f** is 0.0f.

float modff (float a, float *b)

Description: Breaks a floating-point number into integral and fractional parts.

Header file: <mathf.h>

Return values: Fractional part of **a**

Parameters: **a** Floating-point number to be broken into integral and fractional parts
b Pointer indicating storage area that stores integral part

Example:

```
#include <mathf.h>
float a, *b, ret;
ret=modff(a, b);
```

float powf (float x, float y)

Description: Computes a power of a floating-point number.

Header file: <mathf.h>

Return values: Normal: Value of **x** raised to the power **y**
 Abnormal: In case of domain error: Returns not-a-number.

Parameters: **x** Value to be raised to a power
y Power value

Example:

```
#include <mathf.h>
float x, y, ret;
ret=powf(x, y);
```

Error conditions:
 A domain error occurs if **x** is 0.0f and **y** is 0.0f or less, or if **x** is negative and **y** is not an integer.

float sqrtf (float f)

Description: Computes the positive square root of a floating-point number.

Header file: <mathf.h>

Return values: Normal: Positive square root of **f**
 Abnormal: In case of domain error: Returns not-a-number.

Parameters: **f** Floating-point number for which positive square root is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=sqrtf(x, y);
```

Error conditions:
 A domain error occurs if **f** is negative.

float ceilf (float f)

Description: Returns the smallest integral value not less than or equal to the given floating-point number.

Header file: <mathf.h>

Return values: Smallest integral value not less than or equal to **f**

Parameters: **f** Floating-point number for which smallest integral value not less than that number is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=ceilf(f);
```

Remarks: The **ceilf** function returns the smallest integral value not less than or equal to **f**, expressed as a float. Therefore, if **f** is negative, the value after truncation of the fractional part is returned.

float fabsf (float f)

Description: Computes the absolute value of a floating-point number.

Header file: <mathf.h>

Return values: Absolute value of **f**

Parameters: **f** Floating-point number for which absolute value is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=fabsf(f);
```

float floorf (float f)

Description: Returns the largest integral value not greater than or equal to the given floating-point number.

Header file: <mathf.h>

Return values: Largest integral value not greater than or equal to **f**

Parameters: **f** Floating-point number for which largest integral value not greater than that number is to be computed

Example:

```
#include <mathf.h>
float f, ret;
ret=floorf(f);
```

Remarks: The **floorf** function returns the largest integral value not greater than or equal to **f**, expressed as a float. Therefore, if **f** is negative, the value after rounding-up of the fractional part is returned.

float fmodf (float x, float y)

Description: Computes the floating-point remainder of division of two floating-point numbers.

Header file: <mathf.h>

Return values: When **y** is 0.0f: **x**
When **y** is not 0.0f: Remainder of division of **x** by **y**

Parameters: **x** Dividend
y Divisor

Example:

```
#include <mathf.h>
float x, y, ret;
ret=fmodf(x, y);
```

Remarks: In the **fmodf** function, the relationship between parameters **x** and **y** and return value **ret** is as follows:

$$x = y * i + \text{ret} \text{ (where } i \text{ is an integer)}$$

The sign of return value **ret** is the same as the sign of **x**.

If the quotient of **x/y** cannot be expressed, the value of the result is not guaranteed.

When **y** is 0.0, depending on the MCU setting, however, this may lead to a zero division exception.

<setjmp.h>

Supports transfer of control between functions.

The following macros are implementation-defined.

Type	Definition Name	Description
Type (macro)	jmp_buf	Indicates the type name corresponding to a storage area for storing information that enables transfer of control between functions.
Function	setjmp	Saves the executing environment defined by jmp_buf of the currently executing function in the specified storage area.
	longjmp	Restores the function executing environment saved by the setjmp function, and transfers control to the program location at which the setjmp function was called.

The **setjmp** function saves the executing environment of the current function. The location in the program that called the **setjmp** function can subsequently be returned to by calling the **longjmp** function. An example of how transfer of control between functions is supported using the **setjmp** and **longjmp** functions is shown below.

Example:

```
1  #include <stdio.h>
2  #include <setjmp.h>
3  jmp_buf env;
4  void sub( );
5  void main( )
6  {
7
8      if (setjmp(env)!=0){
9          printf("return from longjmp\n");
10         exit(0);
11     }
12     sub( );
13 }
14
15 void sub( )
16 {
17     printf("subroutine is running \n");
18     longjmp(env, 1);
19 }
```

Explanation

The **setjmp** function is called in line 8. At this time, the environment in which the **setjmp** function was called is saved in **jmp_buf** type variable **env**. The return value in this case is 0, and therefore function **sub** is called next.

The environment saved in variable **env** is restored by the **longjmp** function called within function **sub**. As a result, the program behaves just as if a return had been made from the **setjmp** function in line 8. However, the return value at this time is 1 specified by the second parameter of the **longjmp** function. As a result, execution proceeds from line 9.

int setjmp (jmp_buf env)

Description: Saves the executing environment of the currently executing function in the specified storage area.

Header file: <setjmp.h>

Return values: When **setjmp** function is called: 0
On return from **longjmp** function: Nonzero

Parameters: env Pointer to storage area in which executing environment is to be saved

```
Example: #include <setjmp.h>
         int ret;
         jmp_buf env;
         ret=setjmp (env);
```

Remarks: The executing environment saved by the **setjmp** function is used by the **longjmp** function. The return value is 0 when the function is called as the **setjmp** function, but the return value on return from the **longjmp** function is the value of the second parameter specified by the **longjmp** function.

If the **setjmp** function is called from a complex expression, part of the current executing environment, such as the intermediate result of expression evaluation, may be lost. The **setjmp** function should only be used in the form of a comparison between the result of the **setjmp** function and a constant expression, and should not be called within a complex expression.

Do not use a pointer when calling the setjmp function.

void longjmp (jmp_buf env, int ret)

Description: Restores the function executing environment saved by the **setjmp** function, and transfers control to the program location at which the **setjmp** function was called.

Header file: <setjmp.h>

Parameters: env Pointer to storage area in which executing environment was saved
ret Return code to **setjmp** function

Example:

```
#include <setjmp.h>
int ret;
jmp_buf env;
longjmp(env, ret);
```

Remarks: From the storage area specified by the first parameter **env**, the **longjmp** function restores the function executing environment saved by the most recent invocation of the **setjmp** function in the same program, and transfers control to the program location at which that **setjmp** function was called. The value of the second parameter **ret** of the **longjmp** function is returned as the **setjmp** function return value. However, if **ret** is 0, the value 1 is returned to the **setjmp** function as a return value.

If the **setjmp** function has not been called, or if the function that called the **setjmp** function has already executed a return statement, the operation of the **longjmp** function is not guaranteed.

<stdarg.h>

Enables referencing of variable arguments for functions with such arguments.

The following macros are implementation-defined.

Type	Definition Name	Description
Type (macro)	va_list	Indicates the types of variables used in common by the va_start, va_arg, and va_end macros in order to reference variable parameters.
Function (macro)	va_start	Executes initialization processing for performing variable parameter referencing.
	va_arg	Enables referencing of the argument following the argument currently being referenced for a function with variable parameters.
	va_end	Terminates referencing of the arguments of a function with variable parameters.

An example of a program using the macros defined by this standard include file is shown below.

Example:

```
1  #include <stdio.h>
2  #include <stdarg.h>
3
4  extern void prlist(int count, ...);
5
6  void main( )
7  {
8      prlist(1, 1);
9      prlist(3, 4, 5, 6);
10     prlist(5, 1, 2, 3, 4, 5);
11 }
12
13 void prlist(int count, ...)
14 {
15     va_list ap;
16     int i;
17
18     va_start(ap, count);
19     for(i=0; i<count; i++)
20         printf("%d", va_arg(ap, int));
21     putchar('\n');
22     va_end(ap);
23 }
```

Explanation

In this example, the number of data items to be output is specified in the first parameter, and function `prlist` is implemented, outputting that number of subsequent parameters.

In line 18, the variable parameter reference is initialized by `va_start`. Each time an parameter is output, the next parameter is referenced by the `va_arg` macro (line 20). In the `va_arg` macro, the type name of the parameter (in this case, `int` type) is specified in the second parameter.

When parameter referencing ends, the `va_end` macro is called (line 22).

void va_start (va_list ap, parmN)

Description: Executes initialization processing for referencing variable parameters.

Header file: <stdarg.h>

Parameters: ap Variable for accessing variable parameters
parmN Identifier of rightmost argument

Example:

```
#include <stdarg.h>
void func(int count, ...)
{
    va_list ap;
    va_start(ap, count);
}
```

Remarks: The **va_start** macro initializes **ap** for subsequent use by the **va_arg** and **va_end** macros.

The parameter **parmN** is the identifier of the rightmost parameter in the parameter list in the external function definition (the one just before the , ...).

To reference a function with no variable name, the **va_start** macro call must be executed first of all.

type **va_arg** (**va_list ap**, **type**)

Description: Allows a reference to the parameter after the parameter currently being referred to in the function with a variable number of parameters.

Header file: <stdarg.h>

Return values: Parameter value

Parameters: **ap** Variable for accessing variable parameters

type Type of parameter to be accessed

Example:

```
#include <stdarg.h>
va_list ap;
int ret;
ret=va_arg(ap, type);
```

Remarks: Specify a variable of the **va_list** type to be initialized by the **va_start** macro as the first parameter. The value of **ap** is updated each time **va_arg** is used, and, as a result a sequence of variable parameters is returned by sequential calls of this macro.

Specify the type to refer to as the second parameter **type**.

The **ap** parameter must be the same as the **ap** initialized by **va_start**.

It will not be possible to refer to the parameters correctly when a type for which the size is changed by type conversion is specified, i.e., when char type, unsigned char type, short type, unsigned short type, or float type is specified as the type of the function parameter in **type**. If such a type is specified, correct operation is not guaranteed.

void va_end (va_list ap)

Description: Terminates referencing of the parameters of a function with variable arguments.

Header file: <stdarg.h>

Parameters: ap Variable for accessing variable parameters

Example:

```
#include <stdarg.h>
va_list ap;
va_end(ap);
```

Remarks: The **ap** parameter must be the same as the **ap** initialized by **va_start**. If the **va_end** macro is not called before the return from a function, the operation of that function is not guaranteed.

<stdio.h>

Performs processing relating to input/output of stream input/output file.

The following macros are all implementation-defined.

Type	Definition Name	Description
Constant (macro)	FILE	Indicates a structure type that stores various control information including a pointer to the buffer (required for stream input/output processing), an error indicator, and an end-of-file indicator.
	_IOFBF	Indicates full buffering of input/output as the buffer area usage method.
	_IOLBF	Indicates line buffering of input/output as the buffer area usage method.
	_IONBF	Indicates non-buffering of input/output as the buffer area usage method.
	BUFSIZ	Indicates the buffer size required for input/output processing.
	EOF	Indicates end-of-file, that is, no more input from a file.
	L_tmpnam*	Indicates the size of an array large enough to store a string literal of a temporary file name generated by the tmpnam function.
	SEEK_CUR	Indicates a shift of the current file read/write position to an offset from the current position.
	SEEK_END	Indicates a shift of the current file read/write position to an offset from the end-of-file position.
	SEEK_SET	Indicates a shift of the current file read/write position to an offset from the beginning of the file.
	SYS_OPEN*	Indicates the number of files for which simultaneous opening is guaranteed by the implementation.
	TMP_MAX*	Indicates the minimum number of unique file names that shall be generated by the tmpnam function.
	stderr	Indicates the file pointer for the standard error file.
	stdin	Indicates the file pointer for the standard input file.
	stdout	Indicates the file pointer for the standard output file.
Function	fclose	Closes a stream input/output file.
	fflush	Outputs stream input/output file buffer contents to the file.
	fopen	Opens a stream input/output file under the specified file name.
	freopen	Closes a currently open stream input/output file and reopens a new file under the specified file name.

Note: These macros are not defined in this implementation method.

Type	Definition Name	Description
Function	setbuf	Defines and sets a stream input/output buffer area on the user program side.
	setvbuf	Defines and sets a stream input/output buffer area on the user program side.
	fprintf	Outputs data to a stream input/output file according to a format.
	fscanf	Inputs data from a stream input/output file and converts it according to a format.
	printf	Converts data according to a format and outputs it to the standard output file (stdout).
	scanf	Inputs data from the standard input file (stdin) and converts it according to a format.
	sprintf	Converts data according to a format and outputs it to the specified area.
	sscanf	Inputs data from the specified storage area and converts it according to a format.
	vfprintf	Outputs a variable parameter list to the specified stream input/output file according to a format.
	vprintf	Outputs a variable parameter list to the standard output file (stdout) according to a format.
	vsprintf	Outputs a variable parameter list to the specified area according to a format.
	fgetc	Inputs one character from a stream input/output file.
	fgets	Inputs a string from a stream input/output file.
	fputc	Outputs one character to a stream input/output file.
	fputs	Outputs a string to a stream input/output file.
	getc	(macro) Inputs one character from a stream input/output file.
	getchar	(macro) Inputs one character from the standard input file.
	gets	Inputs a string from the standard input file.
	putc	(macro) Outputs one character to a stream input/output file.
	putchar	(macro) Outputs one character to the standard output file.
	puts	Outputs a string to the standard output file.
	ungetc	Returns one character to a stream input/output file.
	fread	Inputs data from a stream input/output file to the specified storage area.
	fwrite	Outputs data from a storage area to a stream input/output file.

Type	Definition Name	Description
Function	fseek	Shifts the current read/write position in a stream input/output file.
	ftell	Computes the current read/write position in a stream input/output file.
	rewind	Shifts the current read/write position in a stream input/output file to the beginning of the file.
	clearerr	Clears the error state of a stream input/output file.
	feof	Tests for the end of a stream input/output file.
	ferror	Tests for stream input/output file error state.
	perror	Outputs an error message corresponding to the error number to the standard error file (stderr).

Specification Defined by the Implementation

Item	Compiler Specifications
Whether the last line of the input text requires a line feed character indicating end	Not specified. Depends on the low-level interface routine specifications.
Whether the blank characters written immediately before the carriage return character are read	
Number of null characters added to data written in the binary file	
Initial value of file position specifier in the addition mode	
Is a file data lost following text file input?	
File buffering specifications	
Whether a file with file length 0 exists	
File name configuration rule	
Whether the same file is opened simultaneously	
Output format of the %p format conversion in the fprintf function	Hexadecimal representation.
Input data representation of the %p format conversion in the fscanf function. The meaning of conversion specifier ‘-’ in the fscanf function	Hexadecimal representation. If ‘-’ is not the first or last character or ‘-’ does not follow ‘A’, the compiler indicates the range from the previous character to the following character.
Value of errno specified by the fgetpos or ftell function	The fgetpos function is not supported. The ftell function does not specify the errno value. The errno value depends on the low-level interface routine specifications.
Output format of messages generated by the perror function	See (a) below for the output message format.
calloc, malloc, or realloc function operation when the size is 0.	The 0-byte area is allocated.

(a) The output format of **perror** function is

<string literal>:<error message for the error number specified in error>

(b) Table 10.42 shows the format when displaying the floating-point infinity and not-a-number in **printf** and **fprintf** functions.

Table 10.42 Display Format of Infinity and Not-a-Number

Value	Display Format
Positive infinity	++++++
Negative infinity	-----
Not-a-number	*****

An example of a program that performs a series of input/output processing operations for a stream input/output file is shown in the following.

Example

```
1  #include <stdio.h>
2
3  void main( )
4  {
5      int c;
6      FILE *ifp, *ofp;
7
8      if ((ifp=fopen("INPUT.DAT","r"))==NULL){
9          fprintf(stderr,"cannot open input file\n");
10         exit(1);
11     }
12     if ((ofp=fopen("OUTPUT.DAT","w"))==NULL){
13         fprintf(stderr,"cannot open output file\n");
14         exit(1);
15     }
16     while ((c=getc(ifp))!=EOF)
17         putc(c, ofp);
18     fclose(ifp);
19     fclose(ofp);
20 }
```

Explanation

This program copies the contents of file INPUT.DAT to file OUTPUT.DAT.

Input file INPUT.DAT is opened by the **fopen** function in line 8, and output file OUTPUT.DAT is opened by the **fopen** function in line 12. If opening fails, NULL is returned as the return value of the **fopen** function, an error message is output, and the program is terminated.

If the **fopen** function ends normally, the pointer to the data (FILE type) that stores information on the opened files is returned; these are set in variables **ifp** and **ofp**.

After successful opening, input/output is performed using these FILE type data.

When file processing ends, the files are closed with the **fclose** function.

int fclose (FILE *fp)

Description: Closes a stream input/output file.

Header file: <stdio.h>

Return values: Normal: 0

Abnormal: Nonzero

Parameters: fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
int ret;
ret=fclose(fp);
```

Remarks: The **fclose** function closes the stream input/output file indicated by file pointer **fp**.

If the output file of the stream input/output file is open and data that is not output remains in the buffer, that data is output to the file before it is closed.

If the input/output buffer was automatically allocated by the system, it is cancelled.

int fflush (FILE *fp)

Description: Outputs stream input/output file buffer contents to the file.

Header file: <stdio.h>

Return values: Normal: 0
Abnormal: Nonzero

Parameters: fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
int ret;
ret=fflush(fp);
```

Remarks: When an output file of the stream input/output file is open, the **fflush** function outputs the contents of the buffer that is not output for the stream input/output file specified by file pointer **fp** to the file. When an input file is open, the **ungetc** function specification is invalid.

FILE ***fopen** (const char ***fname**, const char ***mode**)

Description: Opens a stream input/output file under the specified file name.

Header file: <stdio.h>

Return values: Normal: File pointer indicating file information on opened file

Abnormal: NULL

Parameters: **fname** Pointer to string indicating file name
mode Pointer to string indicating file access mode

Example:

```
#include <stdio.h>
FILE *ret;
const char *fname, *mode;
ret=fopen(fname, mode);
```

Remarks: The **fopen** function opens the stream input/output file whose file name is the string pointed to by **fname**. If a file that does not exist is opened in write mode or addition mode, a new file is created wherever possible. When an existing file is opened in write mode, writing processing is performed from the beginning of the file, and previously written file contents are erased.

When a file is opened in addition mode, write processing is performed from the end-of-file position. When a file is opened in update mode, both input and output processing can be performed on the file. However, input cannot directly follow output without intervening execution of the **fflush**, **fseek**, or **rewind** function. Similarly, output cannot directly follow input without intervening execution of the **fflush**, **fseek**, or **rewind** function.

A string indicating the opening method may be added after the string indicating the file access mode.

The same file cannot be open for multiple tasks at the same time.

FILE *freopen (const char *fname, const char *mode, FILE *fp)

Description: Closes a currently open stream input/output file and reopens a new file under the specified file name.

Header file: <stdio.h>

Return values: Normal: fp
Abnormal: NULL

Parameters: fname Pointer to string indicating new file name
mode Pointer to string indicating file access mode
fp File pointer of currently open stream input/output file

Example:

```
#include <stdio.h>
const char *fname, *mode;
FILE *ret, *fp;
ret=freopen(fname, mode, fp);
```

Remarks: The **freopen** function first closes the stream input/output file indicated by file pointer **fp** (the following processing is carried out even if this close processing is unsuccessful). Next, the **freopen** function opens the file indicated by file name **fname** for stream input/output, reusing the FILE structure pointed to by **fp**.

The **freopen** function is useful when there is a limit on the number of files being opened at one time.

The **freopen** function normally returns the same value as **fp**, but returns NULL when an error occurs.

void setbuf (FILE *fp, char buf[BUFSIZ])

Description: Defines and sets a stream input/output buffer area by the user program.

Header file: <stdio.h>

Parameters: fp File pointer
buf Pointer to buffer area

Example:

```
#include <stdio.h>
FILE *fp;
char buf[BUFSIZ];
    setbuf(fp, buf);
```

Remarks: The **setbuf** function defines the storage area pointed to by **buf** so that it can be used as an input/output buffer area for the stream input/output file indicated by file pointer **fp**. As a result, input/output processing is performed using a buffer area of size BUFSIZ.

int setvbuf (FILE *fp, char *buf, int type, size_t size)

Description: Defines and sets a stream input/output buffer area by the user program.

Header file: <stdio.h>

Return values: Normal: 0
Abnormal: Nonzero

Parameters: fp File pointer
buf Pointer to buffer area
type Buffer management method
size Size of buffer area

Example:

```
#include <stdio.h>
FILE *fp;
char *buf;
int type, ret;
size_t size;
ret=setvbuf(fp, buf, type, size);
```

Remarks: The **setvbuf** function defines the storage area pointed to by **buf** so that it can be used as an input/output buffer area for the stream input/output file indicated by file pointer **fp**.

There are three ways of using this buffer area, as follows:

- (1) When **_IOFBF** is specified as **type** Input/output is fully buffered.
- (2) When **_IOLBF** is specified as **type** Input/output is line buffered. That is, input/output data is fetched from the buffer area when a new-line character is written, when the buffer area is full, or when input is requested.
- (3) When **_IONBF** is specified as **type** Input/output is unbuffered.
The **setvbuf** function usually returns 0. However, when an illegal value is specified for type or size, or when the request on how to use the buffer could not be accepted, a value other than 0 is returned.

The buffer area must not be released before the opened stream input/output file is closed. Also, the **setvbuf** function must be used between opening of the stream input/output file and execution of input/output processing,

int fprintf (FILE *fp, const char *control[, arg...])

Description: Outputs data to a stream input/output file according to the format.

Header file: <stdio.h>

Return values: Normal: Number of characters converted and output

Abnormal: Negative value

Parameters: fp File pointer
control Pointer to string indicating format
arg,... List of data to be output according to format

Example:

```
#include <stdio.h>
FILE *fp;
const char *control="%s";
int ret;
char buffer[]="Hello World\n"
ret=fprintf(fp, control, buffer);
```

Remarks: The **fprintf** function converts and edits argument **arg** according to the string that indicates the format pointed to by **control**, and outputs the result to the stream input/output file indicated by file pointer **fp**.

The **fprintf** function returns the number of characters converted and output when the function is terminated successfully, or a negative value if an error occurs.

The format specifications are shown below.

(1) Overview of formats

The string literal that represents the format is made up of two kinds of string.

(a) Ordinary characters

A character other than a conversion specification shown in (b) is output unchanged.

(b) Conversion specifications

A conversion specification is a string beginning with % that specifies the conversion method for the following argument. The conversion specifications format conforms to the following rules:

$$\% \text{ [Flag ...] } \left\{ \begin{array}{l} [*] \\ \text{[Field width]} \end{array} \right\} \left[\begin{array}{l} \cdot \\ - \end{array} \left\{ \begin{array}{l} [*] \\ \text{[Precision]} \end{array} \right\} \right] \text{[Parameter size specification] Conversion string}$$

When there is no parameter to be actually output for this conversion specification, the behavior is not guaranteed. Also, when the number of parameters to be actually output is greater than the conversion specification, the excess parameters are ignored.

(2) Description of conversion specifications

(a) Flags

Flags specify modifications to the data to be output, such as addition of a sign. The types of flag that can be specified, and their meanings, are shown in table 10.43.

Table 10.43 Flag Types and Their Meanings

Type	Meaning
-	If the number of converted data characters is less than the field width, the data will be output left-justified within the field.
+	A plus or minus sign will be prefixed to the result of a signed conversion.
space	If the first character of a signed conversion result is not a sign, a space will be prefixed to the result. If the space and + flags are both specified, the space flag will be ignored.
#	The converted data is to be modified according to the conversion types described in table 10.45. <ol style="list-style-type: none">(1) For c, d, i, s, and u conversions This flag is ignored.(2) For o conversion The converted data is prefixed with 0.(3) For x or X conversion The converted data is prefixed with 0x (or 0X)(4) For e, E, f, g, and G conversions A decimal point is output even if the converted data has no fractional part. With g and G conversions, the 0 suffixed to the converted data cannot be removed.

(b) Field width

The number of characters in the converted data to be output is specified as a decimal number.

If the number of converted data characters is less than the field width, the data is prefixed with spaces up to the field width. (However, if '!' is specified as a flag, spaces are suffixed to the data.)

If the number of converted data characters exceeds the field width, the field width is extended to allow the converted result to be output.

If the field width specification begins with 0, 0 characters, not spaces, are prefixed to the output data.

(c) Precision

The precision of the converted data is specified according to the type of conversion, as described in table 10.45.

The precision is specified in the form of a period (.) followed by a decimal integer. If the decimal integer is omitted, 0 is assumed to be specified.

If the specified precision is incompatible with the field width specification, the field width specification is ignored.

The precision specification has the following meanings according to the conversion type.

(1) For d, i, o, u, x, and X conversions

The minimum number of digits in the converted data is specified.

(2) For e, E, and f conversions

The number of digits after the decimal point in the converted data is specified.

(3) For g and G conversions

The maximum number of significant digits in the converted data is specified.

(4) For s conversion

The maximum number of printed digits is specified.

(d) Parameter size specification

For d, i, o, u, x, X, e, E, f, g, and G conversions (see table 10.45), specifies the size (short type, long type, long long, or long double type) of the data to be converted. In other conversions, this specification is ignored. Table 10.44 shows the types of size specification and their meanings.

Table 10.44 Parameter Size Specification Types and Meanings

Type	Meaning
h	For d, i, o, u, x, and X conversions, specifies that the data to be converted is of short type or unsigned short type.
l	For d, i, o, u, x, and X conversions, specifies that the data to be converted is of long type, unsigned long type, or double type.
L	For e, E, f, g, and G conversions, specifies that the data to be converted is of long double type.
ll	For d, i, o, u, x, and X conversions, specifies that the data to be converted is of long long type or unsigned long long type. For n conversion, specifies that the data to be converted is of pointer type to long long type.

(e) Conversion specifier

Specifies the format into which the data is to be converted.

If the data to be converted is structure or array type, or is a pointer pointing to those types, the behavior is not guaranteed except when a character array is converted by s conversion or when a pointer is converted by p conversion. Table 10.45 shows the conversion specifier and conversion methods. If a letter which is not shown in this table is specified as the conversion specifier, the behavior is not guaranteed. The behavior, if the other character is specified, depends on the compiler.

Table 10.45 Conversion Specifiers and Conversion Methods

Conversion Specifier	Conversion Type	Conversion Method	Data Type Subject to Conversion	Notes on Precision
d	d conversion	int type data is converted to a signed decimal string. d conversion and i conversion have the same specification.	int type	The precision specification indicates the minimum number of characters output. If the number of converted data characters is less than the field width, the string is prefixed with zeros. If the precision is omitted, 1 is assumed. If conversion and output of data with a value of 0 is attempted with 0 specified as the precision, nothing will be output.
i	i conversion		int type	
o	o conversion	int type data is converted to an unsigned octal string.	int type	
u	u conversion	int type data is converted to an unsigned decimal string.	int type	
x	x conversion	int type data is converted to unsigned hexadecimal. a, b, c, d, e, and f are used as hexadecimal characters.	int type	
X	X conversion	int type data is converted to unsigned hexadecimal. A, B, C, D, E, and F are used as hexadecimal characters.	int type	
f	f conversion	double type data is converted to a decimal string with the format [-] ddd.ddd.	double type	The precision specification indicates the number of digits after the decimal point. When there are characters after the decimal point, at least one digit is output before the decimal point. When the precision is omitted, 6 is assumed. When 0 is specified as the precision, the decimal point and subsequent characters are not output. The output data is rounded.
e	e conversion	double type data is converted to a decimal string with the format [-] d.ddd±dd. At least two digits are output as the exponent.	double type	The precision specification indicates the number of digits after the decimal point. The format is such that one digit is output before the decimal point in the converted characters, and a number of digits equal to the precision are output after the decimal point. When the precision is omitted, 6 is assumed. When 0 is specified as the precision, characters after the decimal point are not output. The output data is rounded.
E	E conversion	double type data is converted to a decimal string with the format [-] d.dddE±dd. At least two digits are output as the exponent.	double type	
g	g conversion	Whether f conversion format output or e conversion (or E conversion) format output is performed is determined by the value to be converted and the precision value that specifies the number of significant digits. Then double type data is output. If the exponent of the converted data is less than -4, or larger than the precision that indicates the number of significant digits, conversion to e (or E) format is performed.	double type	The precision specification indicates the maximum number of significant digits in the converted data.
G	(or G conversion)		double type	

Table 10.45 Conversion Specifiers and Conversion Methods (cont)

Conversion Specifier	Conversion Type	Conversion Method	Data Type Subject to Conversion	Notes on Precision
c	c conversion	int type data is converted to unsigned char data, with conversion to the character corresponding to that data.	int type	The precision specification is invalid.
s	s conversion	The string pointed to by pointer to char type are output up to the null character or up to the number of characters specified by the precision. (Null characters are not output. Space, horizontal tab, and new line characters are not included in the converted characters.)	Pointer to char type	The precision specification indicates the number of characters to be output. If the precision is omitted, characters are output up to, but not including, the null character in the string pointed to by the data. (Null characters are not output. Space, horizontal tab, and new line characters are not included in the converted characters.)
p	p conversion	Assuming data as a pointer, conversion is performed to a string of compiler-defined printable characters.	Pointer to void type	The precision specification is invalid.
n	No conversion is performed.	Data is regarded as pointer to int type, and the number of characters output so far is set in the storage area pointed to by that data.	Pointer to int type	
%	No conversion is performed.	% is output.	None	

(f) * specification for field width or precision

* can be specified as the field width or precision specification value. In this case, the value of the parameter corresponding to the conversion specification is used as the field width or precision specification value. When this parameter has a negative field width, flag '-' is interpreted as being specified for the positive field width. When the parameter has a negative precision, the precision is interpreted as being omitted.

int fscanf (FILE *fp, const char *control[, ptr...])

Description: Inputs data from a stream input/output file and converts it according to a format.

Header file: <stdio.h>

Return values: Normal: Number of data items successfully input and converted

Abnormal: Input data ends before input data conversion is performed: EOF

Parameters: fp File pointer
control Pointer to string indicating format
ptr,... Pointer to storage area that stores input data

Example:

```
#include <stdio.h>
FILE *fp;
const char *control="%d";
int ret,buffer[10];
    ret=fscanf(fp, control, buffer);
```

Remarks: The **fscanf** function inputs data from the stream input/output file indicated by file pointer **fp**, converts and edits it according to the string indicating the format pointed to by **control**, and stores the result in the storage area pointed to by **ptr**.

The format specifications for inputting data are shown below.

(1) Overview of formats

The string that represents the format is made up of the following three kinds of string.

(a) Space characters

If a space (' '), horizontal tab ('\t'), or new-line character ('\n') is specified, processing is performed to skip to the next non-white-space character in the input data.

(b) Ordinary characters

If a character that is neither one of the space characters listed in (a) nor % is specified, one input data character is input. The input character must match a character specified in the string that represents the format.

(c) Conversion specification

A conversion specification is a string beginning with % that specifies the method of converting the input data and storing it in the area pointed to by the following argument. The conversion specification format conforms to the following rules:

% [*] [Field width] [Converted data size] Conversion string

If there is no pointer to the storage area that stores input data for the conversion specification in the format, the behavior is not guaranteed. Also, when a pointer to a storage area that stores input data remains though the format is exhausted, that pointer is ignored.

(2) Description of conversion specification

(a) * specification

Suppresses storage of the input data in the storage area pointed to by the parameter.

(b) Field width

The maximum number of characters in the data to be input is specified as a decimal number.

(c) Converted data size

For d, i, o, u, x, X, e, E, and f conversions (see table 10.47), specifies the size (short type, long type, long long, or long double type) of the converted data. In other conversions, this specification is ignored.

Table 10.46 shows the types of size specification and their meanings.

Table 10.46 Converted Data Size Specification Types and Meanings

Type	Meaning
h	For d, i, o, u, x, and X conversions, specifies that the converted data is of short type.
l	For d, i, o, u, x, and X conversions, specifies that the converted data is of long type. For e, E, and f conversions, specifies that the converted data is of double type.
L	For e, E, and f conversions, specifies that the converted data is of long double type.
ll	For d, i, o, u, x, and X conversions, specifies that the converted data is of long long type.

(d) Conversion specifier

The input data is converted according to the type of conversion specified by the conversion specifier. However, processing is terminated when a white-space character is read, when a character for

which conversion is not permitted is read, or when the specified field width has been exceeded.

Table 10.47 Conversion Specifiers and Conversion Methods

Conversion Specifier	Conversion Type	Conversion Method	Data Type Subject to Conversion
d	d conversion	A decimal string is converted to integer type data.	Integer type
i	i conversion	A decimal string with a sign prefixed, or a decimal string with u (U) or l (L) suffixed is converted to integer type data. A string beginning with 0x (or 0X) is interpreted as hexadecimal, and the string is converted to int type data. A string beginning with 0 is interpreted as octal, and the string is converted to int type data.	Integer type
o	o conversion	An octal string is converted to integer type data.	Integer type
u	u conversion	An unsigned decimal string is converted to integer type data.	Integer type
x	x conversion	A hexadecimal string is converted to integer type data.	Integer type
X	X conversion	There is no difference in meaning between x conversion and X conversion.	
s	s conversion	Characters are converted as a single string until a space, horizontal tab, or new-line character is read. A null character is appended at the end of the string. (The string in which the converted data is set must be large enough to include the null character.)	Character type
c	c conversion	One character is input. The input character is not skipped even if it is a white-space character. To read only non-white-space characters, specify %1s. If the field width is specified, the number of characters equivalent to that specification are read. In this case, therefore, the storage area that stores the converted data needs the specified size.	char type
e	e conversion	A string indicating a floating-point number is converted to floating-point type data. There is no difference in meaning between the e conversion and E conversion, or between the g conversion and G conversion.	Floating-point type
E	E conversion		
f	f conversion	The input format is a floating-point number that can be represented by the strtod function.	
g	g conversion		
G	G conversion		
p	p conversion	A string converted by p conversion of the printf function is converted to pointer type data.	Pointer to void type
n	No conversion is performed.	Data input is not performed; the number of data characters input so far is set.	Integer type
[[conversion	A sequence of characters is specified after [, followed by]. This character sequence defines a sequence of characters comprising a string. If the first character of the character sequence is not a circumflex (^), the input data is input as a single string until a character not in this character sequence is first read. If the first character is ^, the input data is input as a single string until a character which is in the character sequence following the ^ is first read. A null character is automatically appended at the end of the input string (so the string in which the converted data is set must be large enough to include the null character).	Character type
%	No conversion is performed.	% is read.	None

If the conversion specifier is a letter not shown in table 10.47, the behavior is not guaranteed. For the other characters, the behavior is implementation-defined.

int printf (const char *control[, arg...])

Description: Converts data according to a format and outputs it to the standard output file (stdout).

Header file: <stdio.h>

Return values: Normal: Number of characters converted and output

Abnormal: Negative value

Parameters: control Pointer to string indicating format
arg,... Data to be output according to format

Example:

```
#include <stdio.h>
const char *control="%s";
int ret;
char buffer[]="Hello World\n";
ret=printf(control, buffer);
```

Remarks: The **printf** function converts and edits parameter **arg** according to the string that indicates the format pointed to by **control**, and outputs the result to the standard output file (stdout).

For details of the format specifications, see the description of the **fprintf** function.

int scanf (const char *control[, ptr...])

Description: Inputs data from the standard input file (stdin) and converts it according to a format.

Header file: <stdio.h>

Return values: Normal: Number of data items successfully input and converted

Abnormal: EOF

Parameters: control Pointer to string indicating format
ptr,... Pointer to storage area that holds input and converted data

Example:

```
#include <stdio.h>
const char *control="%d";
int ret,buffer[10];
ret=scanf(control,buffer);
```

Remarks: The **scanf** function inputs data from the standard input file (stdin), converts and edits it according to the string indicating the format pointed to by **control**, and stores the result in the storage area pointed to by **ptr**.

The **scanf** function returns the number of data items successfully input and converted as the return value. EOF is returned if the standard input file ends before the first conversion.

For details of the format specifications, see the description of the **fscanf** function.

For %e conversion, specify l for double type, and specify L for long double type. The default type is float.

int sprintf (char *s, const char *control[, arg...])

Description: Converts data according to a format and outputs it to the specified area.

Header file: <stdio.h>

Return values: Number of characters converted

Parameters:	s	Pointer to storage area to which data is to be output
	control	Pointer to string indicating format
	arg,...	Data to be output according to format

Example:

```
#include <stdio.h>
char *s;
const char *control="%s";
int ret;
char buffer[]="Hello World\n";
ret=sprintf(s, control, buffer);
```

Remarks: The **sprintf** function converts and edits parameter **arg** according to the string that indicates the format pointed to by **control**, and outputs the result to the storage area pointed to by **s**.

A null character is appended at the end of the converted and output string. This null character is not included in the return value (number of characters output).

For details of the format specifications, see the description of the **fprintf** function.

int sscanf (const char *s, const char *control[, ptr...])

Description: Inputs data from the specified storage area and converts it according to a format.

Header file: <stdio.h>

Return values: Normal: Number of data items successfully input and converted

Abnormal: EOF

Parameters: s Storage area containing data to be input
control Pointer to string indicating format
ptr,... Pointer to storage area that holds input and converted data

Example:

```
#include <stdio.h>
const char *s, *control="%d";
int ret,buffer[10];
    ret=sscanf(s, control, buffer);
```

Remarks: The **sscanf** function inputs data from the storage area pointed to by **s**, converts and edits it according to the string indicating the format pointed to by **control**, and stores the result in the storage area pointed to by **ptr**.

The **sscanf** function returns the number of data items successfully input and converted. EOF is returned when the input data ends before the first conversion.

For details of the format specifications, see the description of the **fscanf** function.

int **fprintf** (FILE ***fp**, const char ***control**, va_list **arg**)

Description: Outputs a variable parameter list to the specified stream input/output file according to a format.

Header file: <stdio.h>

Return values: Normal: Number of characters converted and output
 Abnormal: Negative value

Parameters: **fp** File pointer
control Pointer to string indicating format
arg Argument list

Example:

```
#include <stdarg.h>
#include <stdio.h>
FILE *fp;
const char *control="%d";
int ret;

void prlist(int count ,...)
{
    va_list ap;
    int i;
    va_start(ap, count);
    for(i=0;i<count;i++)
        ret=fprintf(fp, control, ap);
    va_end(ap);
}
```

Remarks: The **fprintf** function sequentially converts and edits a variable parameter list according to the string that indicates the format pointed to by **control**, and outputs the result to the stream input/output file indicated by **fp**.

The **fprintf** function returns the number of data items converted and output, or a negative value when an error occurs.

Within the **fprintf** function, the **va_end** macro is not invoked.

For details of the format specifications, see the description of the **printf** function.

Parameter **arg**, indicating the argument list, must be initialized beforehand by the **va_start** macro (and the succeeding **va_arg** macro).

int vprintf (const char *control, va_list arg)

Description: Outputs a variable parameter list to the standard output file (stdout) according to a format.

Header file: <stdio.h>

Return values: Normal: Number of characters converted and output

Abnormal: Negative value

Parameters: control Pointer to string indicating format
arg Argument list

Example:

```
#include <stdarg.h>
#include <stdio.h>
FILE *fp;
const char *control="%d";
int ret;

void prlist(int count ,...)
{
    va_list ap;
    int i;
    va_start(ap, count);
    for(i=0;i<count;i++)
        ret=vprintf(control, ap);
    va_end(ap);
}
```

Remarks: The **vprintf** function sequentially converts and edits a variable parameter list according to the string that indicates the format pointed to by **control**, and outputs the result to the standard output file.

The **vprintf** function returns the number of data items converted and output, or a negative value if an error occurs.

Within the **vprintf** function, the **va_end** macro is not invoked.

For details of the format specifications, see the description of the **fprintf** function.

Parameter **arg**, indicating the argument list, must be initialized beforehand by the **va_start** macro (and the succeeding **va_arg** macro).

int vsprintf (char *s, const char *control, va_list arg)

Description: Outputs a variable parameter list to the specified storage area according to a format.

Header file: <stdio.h>

Return values: Normal: Number of characters converted

Abnormal: Negative value

Parameters:

s	Pointer to storage area to which data is to be output
control	Pointer to string indicating format
arg	Argument list

Example:

```
#include <stdarg.h>
#include <stdio.h>
char *s;
const char *control="%d";
int ret;

void prlist(int count ,...)
{
    va_list ap;
    int i;
    va_start(ap, count);
    for(i=0;i<count;i++) {
        ret=vsprintf(s,control,buffer);
        va_arg(ap,int)
        s += ret;
    }
}
```

Remarks: The **vsprintf** function sequentially converts and edits a variable parameter list according to the string that indicates the format pointed to by **control**, and outputs the result to the storage area pointed to by **s**.

A null character is appended at the end of the converted and output string. This null character is not included in the return value (number of characters output).

For details of the format specifications, see the description of the **fprintf** function.

Parameter **arg**, indicating the argument list, must be initialized beforehand by the **va_start** macro (and the succeeding **va_arg** macro).

int fgetc (FILE *fp)

Description: Inputs one character from a stream input/output file.

Header file: <stdio.h>

Return values: Normal: End-of-file: EOF
Otherwise: Input character

Abnormal: EOF

Parameters: fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
int ret;
ret=fgetc (fp) ;
```

Error conditions:

When a read error occurs, the error indicator for that file is set.

Remarks: The **fgetc** function inputs one character from the stream input/output file indicated by file pointer **fp**.

The **fgetc** function normally returns the input character, but returns EOF at end-of-file or when an error occurs. At end-of-file, the end-of-file indicator for that file is set.

char *fgets (char *s, int n, FILE *fp)

Description: Inputs a string from a stream input/output file.

Header file: <stdio.h>

Return values: Normal: End-of-file: NULL
Otherwise: **s**

Abnormal: NULL

Parameters: **s** Pointer to storage area to which string is input
n Number of bytes of storage area to which string is input
fp File pointer

Example:

```
#include <stdio.h>
char *s, *ret;
int n;
FILE *fp;
ret=fgets(s, n, fp);
```

Remarks: The **fgets** function inputs a string from the stream input/output file indicated by file pointer **fp** to the storage area pointed to by **s**.

The **fgets** function performs input up to the (n-1)th character or a new-line character, or until end-of-file, and appends a null character at the end of the input string.

The **fgets** function normally returns **s**, the pointer to the storage area to which the string is input, but returns NULL at end-of-file or if an error occurs.

The contents of the storage area pointed to by **s** do not change at end-of-file, but are not guaranteed when an error occurs.

int fputc (int c, FILE *fp)

Description: Outputs one character to a stream input/output file.

Header file: <stdio.h>

Return values: Normal: Output character

Abnormal: EOF

Parameters: **c** Character to be output

fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
int c, ret;
    ret=fputc(c, fp);
```

Error conditions:

When a write error occurs, the error indicator for that file is set.

Remarks: The **fputc** function outputs character **c** to the stream input/output file indicated by file pointer **fp**.

The **fputc** function normally returns **c**, the output character, but returns EOF when an error occurs.

int fputs (const char *s, FILE *fp)

Description: Outputs a string to a stream input/output file.

Header file: <stdio.h>

Return values: Normal: 0
Abnormal: Nonzero

Parameters: s Pointer to string to be output
fp File pointer

Example:

```
#include <stdio.h>
const char *s;
int ret;
FILE *fp;
ret=fputs(s, fp);
```

Remarks: The **fputs** function outputs the string up to the character preceding the null character pointed to by **s** to the stream input/output file indicated by file pointer **fp**. The null character indicating the end of the string is not output.

The **fputs** function normally returns zero, but returns nonzero when an error occurs.

int getc (FILE *fp)

Description: Inputs one character from a stream input/output file.

Header file: <stdio.h>

Return values: Normal: End-of-file: EOF
Otherwise: Input character

Abnormal: EOF

Parameters: fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
int ret;
ret=getc (fp);
```

Error conditions:

When a read error occurs, the error indicator for that file is set.

Remarks: The **getc** function inputs one character from the stream input/output file indicated by file pointer **fp**.

The **getc** function normally returns the input character, but returns EOF at end-of-file or if an error occurs. At end-of-file, the end-of-file indicator for that file is set.

int getchar (void)

Description: Inputs one character from the standard input file (stdin).

Header file: <stdio.h>

Return values: Normal: End-of-file: EOF
Otherwise: Input character

Abnormal: EOF

Example:

```
#include <stdio.h>
int ret;
ret=getchar();
```

Error conditions:

When a read error occurs, the error indicator for that file is set.

Remarks: The **getchar** function inputs one character from the standard input file (stdin).

The **getchar** function normally returns the input character, but returns EOF at end-of-file or if an error occurs. At end-of-file, the end-of-file indicator for that file is set.

char *gets (char *s)

Description: Inputs a string from the standard input file (stdin).

Header file: <stdio.h>

Return values: Normal: End-of-file: NULL
Otherwise: s

Abnormal: NULL

Parameters: s Pointer to storage area to which string is input

Example:

```
#include <stdio.h>
char *ret, *s;
ret=gets(s);
```

Remarks: The **gets** function inputs a string from the standard input file (stdin) to the storage area starting at **s**.

The **gets** function inputs characters up to end-of-file or until a new-line character is input, and appends a null character instead of a new-line character.

The **gets** function normally returns **s**, the pointer to the storage area to which the string is input, but returns NULL at the end of the standard input file or when an error occurs.

The contents of the storage area pointed to by **s** do not change at the end of the standard input file, but is not guaranteed when an error occurs.

int putc (int c, FILE *fp)

Description: Outputs one character to a stream input/output file.

Header file: <stdio.h>

Return values: Normal: Output character

Abnormal: EOF

Parameters: c Character to be output

fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
int c, ret;
    ret=putc(c, fp);
```

Error conditions:

When a write error occurs, the error indicator for that file is set.

Remarks: The **putc** function outputs character **c** to the stream input/output file indicated by file pointer **fp**.

The **putc** function normally returns **c**, the output character, but returns EOF when an error occurs.

int putchar (int c)

Description: Outputs one character to the standard output file (stdout).

Header file: <stdio.h>

Return values: Normal: Output character
Abnormal: EOF

Parameters: **c** Character to be output

Example:

```
#include <stdio.h>
int c, ret;
ret=putchar(c);
```

Error conditions: When a write error occurs, the error indicator for that file is set.

Remarks: The **putchar** function outputs character **c** to the standard output file (stdout).

The **putchar** function normally returns **c**, the output character, but returns EOF when an error occurs.

int puts (const char *s)

Description: Outputs a string to the standard output file (stdout).

Header file: <stdio.h>

Return values: Normal: 0
Abnormal: Nonzero

Parameters: s Pointer to string to be output

Example:

```
#include <stdio.h>
const char *s;
int ret;
ret=puts(s);
```

Remarks: The **puts** function outputs the string pointed to by **s** to the standard output file (stdout). The null character indicating the end of the string is not output, but a new-line character is output instead.

The **puts** function normally returns zero, but returns nonzero when an error occurs.

int ungetc (int c, FILE *fp)

Description: Returns one character to a stream input/output file.

Header file: <stdio.h>

Return values: Normal: Returned character

Abnormal: EOF

Parameters: c Character to be returned

fp File pointer

Example:

```
#include <stdio.h>
int c, ret;
FILE *fp;
    ret=ungetc(c, fp);
```

Remarks: The **ungetc** function returns character **c** to the stream input/output file indicated by file pointer **fp**. Unless the **fflush**, **fseek**, or **rewind** function is called, this returned character will be the next input data.

The **ungetc** function normally returns character **c**, but returns EOF if an error occurs.

The behavior is not guaranteed when the **ungetc** function is called more than once without intervening **fflush**, **fseek**, or **rewind** function execution. When the **ungetc** function is executed, the current file position indicator for that file is moved back one position; however, when this file position indicator has already been positioned at the beginning of the file, its value is not guaranteed.

size_t fread (void *ptr, size_t size, size_t n, FILE *fp)

Description: Inputs data from a stream input/output file to the specified storage area.

Header file: <stdio.h>

Return values: When **size** or **n** is 0: 0
When **size** and **n** are both nonzero: Number of successfully input members

Parameters:

ptr	Pointer to storage area to which data is input
size	Number of bytes in one member
n	Number of members to be input
fp	File pointer

Example:

```
#include <stdio.h>
void *ptr;
size_t size;
size_t n, ret;
FILE *fp;
    ret=fread(ptr, size, n, fp);
```

Remarks: The **fread** function inputs **n** members whose size is specified by **size**, from the stream input/output file indicated by file pointer **fp**, into the storage area pointed to by **ptr**. The file position indicator for the file is advanced by the number of bytes input.

The **fread** function returns the number of members successfully input, which is normally the same as the value of **n**. However, at end-of-file or when an error occurs, the number of members successfully input so far is returned, and then the return value will be less than **n**. The **ferror** and **feof** functions should be used to distinguish between end-of-file and error occurrence.

When the value of **size** or **n** is zero, zero is returned as the return value and the contents of the storage area pointed to by **ptr** are unchanged. When an error occurs, or when only a part of the members can be input, the file position indicator is not guaranteed.

size_t fwrite (const void *ptr, size_t size, size_t n, FILE *fp)

Description: Outputs data from a memory area to a stream input/output file.

Header file: <stdio.h>

Return values: Number of successfully output members

Parameters:	ptr	Pointer to storage area storing data to be output
	size	Number of bytes in one member
	n	Number of members to be input
	fp	File pointer

Example:

```
#include <stdio.h>
const void *ptr;
size_t size;
size_t n, ret;
FILE *fp;
    ret=fwrite(ptr, size, n, fp);
```

Remarks: The **fwrite** function outputs **n** members whose size is specified by **size**, from the storage area pointed to by **ptr**, to the stream input/output file indicated by file pointer **fp**. The file position indicator for the file is advanced by the number of bytes output.

The **fwrite** function returns the number of members successfully output, which is normally the same as the value of **n**. However, when an error occurs, the number of members successfully output so far is returned, and then the return value will be less than **n**.

When an error occurs, the file position indicator is not guaranteed.

int fseek (FILE *fp, long offset, int type)

Description: Shifts the current read/write position in a stream input/output file.

Header file: <stdio.h>

Return values: Normal: 0
 Abnormal: Nonzero

Parameters: fp File pointer
 offset Offset from position specified by type of offset
 type Type of offset

```
Example: #include <stdio.h>
FILE *fp;
long offset;
int type, ret;
ret=fseek(fp, offset, type);
```

Remarks: The **fseek** function shifts the current read/write position in the stream input/output file indicated by file pointer **fp** by **offset** bytes from the position specified by **type** (the type of offset).
 The types of offset are shown in table 10.48.
 The **fseek** function normally returns zero, but returns nonzero in response to an invalid request.

Table 10.48 Types of Offset

Offset Type	Meaning
SEEK_SET	Shifts to a position which is located offset bytes away from the beginning of the file. The value specified by offset must be zero or positive.
SEEK_CUR	Shifts to a position which is located offset bytes away from the current position in the file. The shift is toward the end of the file if the value specified by offset is positive, and toward the beginning of the file if negative.
SEEK_END	Shifts to a position which is located offset bytes forward from end-of-file. The value specified by offset must be zero or negative.

In the case of a text file, the type of offset must be SEEK_SET and **offset** must be zero or the value returned by the **ftell** function for that file. Note also that calling the **fseek** function cancels the effect of the **ungetc** function.

long ftell (FILE *fp)

Description: Obtains the current read/write position in a stream input/output file.

Header file: <stdio.h>

Return values: Current file position indicator position (text file)
Number of bytes from beginning of file to current position (binary file)

Parameters: fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
long ret;
ret=ftell(fp);
```

Remarks: The **ftell** function obtains the current read/write position in the stream input/output file indicated by file pointer **fp**.

For a binary file, the **ftell** function returns the number of bytes from the beginning of the file to the current position. For a text file, it returns, as the position of the file position indicator, an implementation-defined value that can be used by the **fseek** function.

When the **ftell** function is used twice for a text file, the difference in the return values will not necessarily represent the actual distance in the file.

void rewind (FILE *fp)

Description: Shifts the current read/write position in a stream input/output file to the beginning of the file.

Header file: <stdio.h>

Parameters: fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
rewind(fp);
```

Remarks: The **rewind** function shifts the current read/write position in the stream input/output file indicated by file pointer **fp**, to the beginning of the file.

The **rewind** function clears the end-of-file indicator and error indicator for the file.

Note that calling the **rewind** function cancels the effect of the **ungetc** function.

void clearerr (FILE *fp)

Description: Clears the error state of a stream input/output file.

Header file: <stdio.h>

Parameters: fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
clearerr(fp);
```

Remarks: The **clearerr** function clears the error indicator and end-of-file indicator for the stream input/output file indicated by file pointer **fp**.

int feof (FILE *fp)

Description: Tests for the end of a stream input/output file.

Header file: <stdio.h>

Return values: End-of-file: Nonzero
Otherwise: 0

Parameters: fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
int ret;
ret=feof (fp);
```

Remarks: The **feof** function tests for the end of the stream input/output file indicated by file pointer **fp**.

The **feof** function tests the end-of-file indicator for the specified stream input/output file, and if the indicator is set, returns nonzero to indicate that the file is at its end. If the end-of-file indicator is not set, the **feof** function returns zero to show that the file is not yet at its end.

int ferror (FILE *fp)

Description: Tests for stream input/output file error state.

Header file: <stdio.h>

Return values: If file is in error state: Nonzero
Otherwise: 0

Parameters: fp File pointer

Example:

```
#include <stdio.h>
FILE *fp;
int ret;
ret=ferror(fp);
```

Remarks: The **ferror** function tests whether the stream input/output file indicated by file pointer **fp** is in the error state.

The **ferror** function tests the error indicator for the specified stream input/output file, and if the indicator is set, returns nonzero to show that the file is in the error state. If the error indicator is not set, the **ferror** function returns zero to show that the file is not in the error state.

void perror (const char *s)

Description: Outputs an error message corresponding to the error number to the standard error file (stderr).

Header file: <stdio.h>

Parameters: s Pointer to error message

Example:

```
#include <stdio.h>
const char *s;
perror(s);
```

Remarks: The **perror** function maps **errno** to the error message indicated by **s**, and outputs the message to the standard error file (stderr).

If **s** is not NULL and the string pointed to by **s** is not the null character, the output format is as follows: the string pointed to by **s** followed by a colon and space, then the implementation-defined error message, and finally a new-line character.

<stdlib.h>

Defines standard functions for standard processing of C programs.

The following macros are implementation-defined.

Type	Definition Name	Description
Type (macro)	div_t	Indicates the type of structure of the value returned by the div function.
	ldiv_t	Indicates the type of structure of the value returned by the ldiv function.
	lldiv_t	Indicates the type of structure of the value returned by the lldiv function.
Constant (macro)	RAND_MAX	Indicates the maximum of pseudo-random integers generated by the rand function.
Function	atof	Converts a number-representing string to a double type floating-point number.
	atoi	Converts a decimal-representing string to an int type integer.
	atol	Converts a decimal-representing string to a long type integer.
	atoll	Converts a decimal-representing string to a long long type integer.
	atofixed	Converts a number-representing string to a long __fixed type fixed-point number.
	atolaccum	Converts a number-representing string to a long __accum type fixed-point number.
	strtod	Converts a number-representing string to a double type floating-point number.
	strtol	Converts a number-representing string to a long type integer.
	strtoul	Converts a number-representing string to an unsigned long type integer.
	strtoll	Converts a number-representing string to a long long type integer.
	strtoull	Converts a number-representing string to an unsigned long long type integer.
	strtolfixed	Converts a number-representing string to a long __fixed type fixed-point number.
	strtolaccum	Converts a number-representing string to a long __accum type fixed-point number.
	rand	Generates pseudo-random integers from 0 to RAND_MAX.
	srand	Sets an initial value of the pseudo-random number series generated by the rand function.

Type	Definition Name	Description
Function	calloc	Allocates storage areas and clears all bits in the allocated storage areas to 0.
	free	Releases specified storage area.
	malloc	Allocates a storage area.
	realloc	Changes the size of storage area to a specified value.
	calloc__X	Allocates X storage areas and clears all bits in the allocated X storage areas to 0.
	free__X	Releases specified X storage area.
	malloc__X	Allocates an __X storage area.
	realloc__X	Changes the size of X storage area to a specified value.
	calloc__Y	Allocates Y storage areas and clears all bits in the allocated Y storage areas to 0.
	free__Y	Releases specified Y storage area.
	malloc__Y	Allocates an Y storage area.
	realloc__Y	Changes the size of Y storage area to a specified value.
	bsearch	Performs binary search.
	qsort	Performs sorting.
	abs	Calculates the absolute value of an int type integer.
	div	Carries out division of int type integers and obtains the quotient and remainder.
	labs	Calculates the absolute value of a long type integer.
	ldiv	Carries out division of long type integers and obtains the quotient and remainder.
	llabs	Calculates the absolute value of a long long type integer.
	lldiv	Carries out division of long long type integers and obtains the quotient and remainder.

double atof (const char *nptr)

Description: Converts a number-representing string to a double type floating-point number.

Header file: <stdlib.h>

Return values: Converted data as a double type floating-point number

Parameters: nptr Pointer to a number-representing string to be converted

Example:

```
#include <stdlib.h>
const char *nptr;
double ret;
ret=atof(nptr);
```

Error conditions:

If the converted result overflows or underflows, ERANGE is set to **errno**.

Remarks: Data is converted up to the first character that does not fit the floating-point data type.

The **atof** function does not guarantee the return value, if an error such as an overflow occurs. When you want to acquire the guaranteed return value, use the **strtod** function.

int atoi (const char *nptr)

Description: Converts a decimal-representing string to an int type integer.

Header file: <stdlib.h>

Return values: Converted data as an int type integer

Parameters: nptr Pointer to a number-representing string to be converted

Example:

```
#include <stdlib.h>
const char *nptr;
int ret;
ret=atoi(nptr);
```

Error conditions:

If the converted result overflows, ERANGE is set to **errno**.

Remarks: Data is converted up to the first character that does not fit the decimal data type.

The **atoi** function does not guarantee the return value, if an error such as an overflow occurs. When you want to acquire the guaranteed return value, use the **strtol** function.

long atol (const char *nptr)

Description: Converts a decimal-representing string to a long type integer.

Header file: <stdlib.h>

Return values: Converted data as a long type integer

Parameters: nptr Pointer to a number-representing string to be converted

Example:

```
#include <stdlib.h>
const char *nptr;
long ret;
ret=atol(nptr);
```

Error conditions:

If the converted result overflows, ERANGE is set to **errno**.

Remarks: Data is converted up to the first character that does not fit the decimal data type.

The **atol** function does not guarantee the return value, if an error such as an overflow occurs. When you want to acquire the guaranteed return value, use the **strtol** function.

long long atoll (const char *nptr)

Description: Converts a decimal-representing string to a long long type integer.

Header file: <stdlib.h>

Return values: Converted data as a long long type integer

Parameters: nptr Pointer to a number-representing string to be converted

Example:

```
#include <stdlib.h>
const char *nptr;
long long ret;
ret=atoll(nptr);
```

Error conditions:

If the converted result overflows, ERANGE is set to **errno**.

Remarks: Data is converted up to the first character that does not fit the decimal data type.

The **atoll** function does not guarantee the return value, if an error such as an overflow occurs. When you want to acquire the guaranteed return value, use the **strtoll** function.

long __fixed atofixed (const char *nptr)

Description: Converts a number-representing string to a long __fixed type fixed-point number.

Header file: <stdlib.h>

Return values: Converted data as a long __fixed type fixed-point number

Parameters: nptr Pointer to a number-representing string to be converted

Example:

```
#include <stdlib.h>
const char *nptr;
long __fixed ret;
ret=atofixed(nptr);
```

Error conditions: If the converted result overflows or underflows, ERANGE is set to **errno**.

Remarks: The **atofixed** function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp,** and **dspe** are specified.

Data is converted up to the first character that does not fit the fixed-point data type.

The **atofixed** function does not guarantee the return value, if an error such as an overflow occurs. When you want to acquire the guaranteed return value, use the **strtof** function.

long __accum atolaccum (const char *nptr)

Description: Converts a number-representing string to a long __accum type fixed-point number.

Header file: <stdlib.h>

Return values: Converted data as a long __accum type fixed-point number

Parameters: nptr Pointer to a number-representing string to be converted

Example:

```
#include <stdlib.h>
const char *nptr;
long __accum ret;
ret=atolaccum(nptr);
```

Error conditions: If the converted result overflows or underflows, ERANGE is set to **errno**.

Remarks: The **atolaccum** function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp,** and **dspe** are specified.

Data is converted up to the first character that does not fit the fixed-point data type.

The **atolaccum** function does not guarantee the return value, if an error such as an overflow occurs. When you want to acquire the guaranteed return value, use the **strtolaccum** function.

double strtod (const char *nptr, char **endptr)

- Description:** Converts a string which represents a number to a double type floating-point number.
- Header file:** <stdlib.h>
- Return values:**
- | | |
|------------------|--|
| Normal: | If the string pointed by nptr begins with a character that does not represent a floating-point number: 0
If the string pointed by nptr begins with a character that represents a floating-point number: converted data as a double type floating-point number |
| Abnormal: | If the converted data overflows: HUGE_VAL with the same sign as that of the string before conversion
If the converted data underflows: 0 |
- Parameters:**
- | | |
|---------------|--|
| nptr | Pointer to a string representing a number to be converted |
| endptr | Pointer to the storage area containing a pointer to the first character that does not comprise a floating-point number |
- Example:**
- ```
#include <stdlib.h>
const char *nptr;
char **endptr;
double ret;
 ret=strtod(nptr, endptr);
```
- Error conditions:**
- If the converted result overflows or underflows, ERANGE is set to **errno**.
- Remarks:** According to the rules described in section 10.1.3 (4), Floating-Point Operation Specifications, the **strtod** function converts data, from the first digit or the decimal point up to the character immediately before the character that does not comprise a floating-point number, into a double type floating-point number. However, if neither an exponent nor a decimal point is found in the data to be converted, the compiler assumes that the decimal point comes next to the last digit in the string. In the area pointed by **endptr**, the function sets up a pointer to the first character that does not compose a floating-point number. If some characters that do not compose a floating-point number come before numerals, the value of **nptr** is set. If **endptr** is NULL, nothing is set.

**long strtol (const char \*nptr, char \*\*endptr, int base)**

Description: Converts a string which represents a number to a long type integer.

Header file: <stdlib.h>

Return values: Normal: If the string pointed by **nptr** begins with a character that does not represent an integer: 0  
 If the string pointed by **nptr** begins with a character that represents an integer: Converted data as a long type integer

Abnormal: If the converted data overflows: LONG\_MAX or LONG\_MIN depending on the sign of the string before conversion

Parameters: **nptr** Pointer to a string representing a number to be converted  
**endptr** Pointer to the storage area containing a pointer to the first character that does not comprise an integer  
**base** Radix of conversion (0 or 2 to 36)

Example:

```
#include <stdlib.h>
long ret;
const char *nptr;
char **endptr;
int base;
ret=strtol(nptr, endptr, base);
```

Error conditions:

If the converted result overflows, ERANGE is set to **errno**.

Remarks:

The **strtol** function converts data, from the first numeral up to the character before the first character that does not represent an integer, into a long type integer.

In the storage area pointed by **endptr**, the function sets up a pointer to the first character that does not represent an integer. If some characters that do not represent an integer come before the first numeral, the value of **nptr** is set in this area. If **endptr** is NULL, nothing is set in this area.

If the value of **base** is 0, the rules described in section 10.1.1 (4), Integers, are observed at conversion. If the value of **base** is 2 to 36, it indicates the radix of conversion, where a (or A) to z (or Z) in the string to be converted correspond to numbers 10 to 35. If a character that is not smaller than the **base** value is found

in the string to be converted, conversion stops immediately. A 0 after a sign is ignored at conversion. Similarly, 0x (or 0X) at base 16 is ignored.

### unsigned long strtoul (const char \*nptr, char \*\*endptr, int base)

Description: Converts a string which represents a number to an unsigned long type integer.

Header file: <stdlib.h>

Return values: Normal: If the string pointed by **nptr** begins with a character that does not represent an integer: 0  
If the string pointed by **nptr** begins with a character that represents an integer: Converted data as an unsigned long type integer

Abnormal: If the converted data overflows: ULONG\_MAX

Parameters: **nptr** Pointer to a string representing a number to be converted  
**endptr** Pointer to the storage area containing a pointer to the first character that does not comprise an integer  
**base** Radix of conversion (0 or 2 to 36)

Example: 

```
#include <stdlib.h>
unsigned long ret;
const char *nptr;
char **endptr;
int base;
ret=strtoul(nptr, endptr, base);
```

Error conditions:

If the converted result overflows, ERANGE is set to **errno**.

Remarks: The **strtoul** function converts data, from the first numeral up to the character before the first character that does not represent an integer, into an unsigned long type integer.

In the storage area pointed by **endptr**, the function sets up a pointer to the first character that does not represent an integer. If some characters that do not represent an integer come before the first numeral, the value of **nptr** is set in this area. If **endptr** is NULL, nothing is set in this area.

If the value of **base** is 0, the rules described in section 10.1.1 (4), Integers, are observed at conversion. If the value of **base** is 2 to 36, it indicates the radix of conversion, where a (or A) to z (or Z) in the string to be converted correspond to numbers 10 to 35. If a character that is not smaller than the **base** value is found in the string to be converted, conversion stops immediately. A 0 after a sign is ignored at conversion. Similarly, 0x (or 0X) at base 16 is ignored.

### **long long strtoll (const char \*nptr, char \*\*endptr, int base)**

**Description:** Converts a string which represents a number to a long long type integer.

**Header file:** <stdlib.h>

**Return values:** **Normal:** If the string pointed by **nptr** begins with a character that does not represent an integer: 0  
If the string pointed by **nptr** begins with a character that represents an integer: Converted data as a long long type integer

**Abnormal:** If the converted data overflows: LONGLONG\_MAX or LONGLONG\_MIN depending on the sign of the string before conversion

**Parameters:** **nptr** Pointer to a string representing a number to be converted  
**endptr** Pointer to the storage area containing a pointer to the first character that does not comprise an integer  
**base** Radix of conversion (0 or 2 to 36)

**Example:**

```
#include <stdlib.h>
long long ret;
const char *nptr;
char **endptr;
int base;
ret=strtoll(nptr,endptr,base);
```

**Error conditions:**

If the converted result overflows, ERANGE is set to **errno**.

**Remarks:** The **strtoll** function converts data, from the first numeral up to the character before the first character that does not represent an integer, into a long long type integer.



In the storage area pointed by **endptr**, the function sets up a pointer to the first character that does not represent an integer. If some characters that do not represent an integer come before the first numeral, the value of **nptr** is set in this area. If **endptr** is NULL, nothing is set in this area.

If the value of **base** is 0, the rules described in section 10.1.1 (4), Integers, are observed at conversion. If the value of **base** is 2 to 36, it indicates the radix of conversion, where a (or A) to z (or Z) in the string to be converted correspond to numbers 10 to 35. If a character that is not smaller than the **base** value is found in the string to be converted, conversion stops immediately. A 0 after a sign is ignored at conversion. Similarly, 0x (or 0X) at base 16 is ignored.

**unsigned long long strtoull (const char \*nptr, char \*\*endptr, int base)**

**Description:** Converts a string which represents a number to an unsigned long long type integer.

**Header file:** <stdlib.h>

**Return values:** **Normal:** If the string pointed by **nptr** begins with a character that does not represent an integer: 0  
If the string pointed by **nptr** begins with a character that represents an integer: Converted data as an unsigned long long type integer

**Abnormal:** If the converted data overflows: ULLONG\_MAX

**Parameters:** **nptr** Pointer to a string representing a number to be converted  
**endptr** Pointer to the storage area containing a pointer to the first character that does not comprise an integer  
**base** Radix of conversion (0 or 2 to 36)

**Example:**

```
#include <stdlib.h>
unsigned long long ret;
const char *nptr;
char **endptr;
int base;
ret=strtoull(nptr,endptr,base);
```

**Error conditions:** If the converted result overflows, ERANGE is set to **errno**.

**Remarks:** The **strtoull** function converts data, from the first numeral up to the character before the first character that does not represent an integer, into an unsigned long long type integer.

In the storage area pointed by **endptr**, the function sets up a pointer to the first character that does not represent an integer. If some characters that do not represent an integer come before the first numeral, the value of **nptr** is set in this area. If **endptr** is NULL, nothing is set in this area.

If the value of **base** is 0, the rules described in section 10.1.1 (4), Integers, are observed at conversion. If the value of **base** is 2 to 36, it indicates the radix of conversion, where a (or A) to z (or Z) in the string to be converted correspond to

numbers 10 to 35. If a character that is not smaller than the **base** value is found in the string to be converted, conversion stops immediately. A 0 after a sign is ignored at conversion. Similarly, 0x (or 0X) at base 16 is ignored.

### **long \_\_fixed strtolfixed (const char \*nptr, char \*\*endptr)**

**Description:** Converts a string which represents a number to a long \_\_fixed type fixed-point number.

**Header file:** <stdlib.h>

**Return values:** **Normal:** If the string pointed by **nptr** begins with a character that does not represent a fixed-point number: 0  
If the string pointed by **nptr** begins with a character that represents a fixed-point number: Converted data as a long \_\_fixed type fixed-point number

**Abnormal:** If the converted data overflows: LFIXED\_MAX or LFIXED\_MIN depending on the sign of the string before conversion  
If the converted data underflows: 0

**Parameters:** **nptr** Pointer to a string representing a number to be converted  
**endptr** Pointer to the storage area containing a pointer to the first character that does not comprise a fixed-point number

**Example:**

```
#include <stdlib.h>
const char *nptr;
char **endptr;
long __fixed ret;
ret=strtolfixed(nptr,endptr);
```

**Error conditions:** If the converted result overflows or underflows, ERANGE is set to **errno**.

**Remarks:** This function is only valid when **cpu=sh2dsp**, **sh3dsp**, **sh4aldsp**, and **dspe** are specified.

The **strtolfixed** function converts data, from the first digit or the decimal point up to the character immediately before the character that does not comprise a fixed-point number, into a long \_\_fixed type fixed-point number. However, if

neither an exponent nor a decimal point is found in the data to be converted, the compiler assumes that the decimal point comes next to the last digit in the string. In the area pointed by **endptr**, the function sets up a pointer to the first character that does not compose a fixed-point number. If some characters that do not compose a fixed-point number come before numerals, the value of **nptr** is set. If **endptr** is NULL, nothing is set.

### **long \_\_accum strtolaccum (const char \*nptr, char \*\*endptr)**

**Description:** Converts a string which represents a number to a long \_\_accum type fixed-point number.

**Header file:** <stdlib.h>

**Return values:** **Normal:** If the string pointed by **nptr** begins with a character that does not represent a fixed-point number: 0  
If the string pointed by **nptr** begins with a character that represents a fixed-point number: Converted data as a long \_\_accum type fixed-point number

**Abnormal:** If the converted data overflows: LACCUM\_MAX or LACCUM\_MIN depending on the sign of the string before conversion  
If the converted data underflows: 0

**Parameters:** **nptr** Pointer to a string representing a number to be converted  
**endptr** Pointer to the storage area containing a pointer to the first character that does not comprise a fixed-point number

**Example:**

```
#include <stdlib.h>
const char *nptr;
char **endptr;
long __accum ret;
ret=strtolaccum(nptr,endptr);
```

**Error conditions:** If the converted result overflows or underflows, ERANGE is set to **errno**.

Remarks: This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp,** and **dspe** are specified.

The **strtolaccum** function converts data, from the first digit or the decimal point up to the character immediately before the character that does not comprise a fixed-point number, into a long `__accum` type fixed-point number. However, if neither an exponent nor a decimal point is found in the data to be converted, the compiler assumes that the decimal point comes next to the last digit in the string. In the area pointed by **endptr**, the function sets up a pointer to the first character that does not compose a fixed-point number. If some characters that do not compose a fixed-point number come before numerals, the value of **nptr** is set. If **endptr** is NULL, nothing is set.

### **int rand (void)**

Description: Generates a pseudo-random integer from 0 to RAND\_MAX.

Header file: <stdlib.h>

Return values: Pseudo-random integer

Example: 

```
#include <stdlib.h>
int ret;
ret=rand();
```

### **void srand (unsigned int seed)**

Description: Sets an initial value of the pseudo-random number series generated by the **rand** function.

Header file: <stdlib.h>

Parameters: **seed** Initial value for pseudo-random number series generation

Example: 

```
#include <stdlib.h>
unsigned int seed;
srand(seed);
```

Remarks: The **srand** function sets up an initial value for pseudo-random number series generation of the **rand** function. If pseudo-random number series generation by

the **rand** function is repeated and if the same initial value is set up again by the **srand** function, the same pseudo-random number series is repeated.

If the **rand** function is called before the **srand** function, 1 is set as the initial value for the pseudo-random number generation.

### **void \*calloc (size\_t nelem, size\_t elsize)**

Description: Allocates a storage area and clears all bits in the allocated storage area to 0.

Header file: <stdlib.h>

Return values: Normal: Starting address of an allocated storage area

Abnormal: Storage allocation failed, or either of the parameter is 0: NULL

Parameters: nelem Number of elements  
elsize Number of bytes occupied by a single element

Example: 

```
#include <stdlib.h>
size_t nelem, elsize;
void *ret;
ret=calloc(nelem, elsize);
```

Remarks: The **calloc** function allocates as many storage units of size **elsize** as the number specified by **nelem**. The function also clears all the bits in the allocated storage area to 0.

### **void free (void \*ptr)**

Description: Releases specified storage area.

Header file: <stdlib.h>

Parameters: ptr            Address of storage area to release

Example: 

```
#include <stdlib.h>
void *ptr;
free(ptr);
```

Remarks: The **free** function releases the storage area pointed by **ptr**, to enable reallocation for use. If **ptr** is NULL, the function carries out nothing.

If the storage area attempted to release was not allocated by the **calloc**, **malloc**, or **realloc** function, or when the area has already been released by the **free** or **realloc** function, correct operation is not guaranteed. Operation result of reference to released storage area is also not guaranteed.

### **void \*malloc (size\_t size)**

Description: Allocates a storage area.

Header file: <stdlib.h>

Return values: Normal:        Starting address of allocated storage area

Abnormal:    Storage allocation failed, or **size** is 0: NULL

Parameters: size            Size in number of bytes of storage area to allocate

Example: 

```
#include <stdlib.h>
size_t size;
void *ret;
ret=malloc(size);
```

Remarks: The **malloc** function allocates a storage area of a specified number of bytes by **size**.

**void \*realloc (void \*ptr, size\_t size)**

Description: Changes the size of a storage area to a specified value.

Header file: <stdlib.h>

Return values: Normal: Starting address of storage area whose size has been changed

Abnormal: Storage area allocation has failed, or **size** is 0: NULL

Parameters: **ptr** Starting address of storage area to be changed  
**size** Size of storage area in number of bytes after the change

Example:

```
#include <stdlib.h>
size_t size;
void *ptr, *ret;
 ret=realloc(ptr, size);
```

Remarks: The **realloc** function changes the size of the storage area specified by **ptr** to the number of bytes specified by **size**. If the newly allocated storage area is smaller than the old one, the contents are left unchanged up to the size of the newly allocated area.

When **ptr** is not a pointer to the storage area allocated by the **calloc**, **malloc**, or **realloc** function or when **ptr** is a pointer to the storage area released by the **free** or **realloc** function, operation is not guaranteed.



**void \_\_X \*calloc\_\_X (size\_t nelem, size\_t elsize)**

Description: Allocates an X storage area and clears all bits in the allocated X storage area to 0.

Header file: <stdlib.h>

Return values: Normal: Starting address of an allocated X storage area  
Abnormal: X storage allocation failed, or either of the parameter is 0: NULL

Parameters: nelem Number of elements  
elsize Number of bytes occupied by a single element

Example: 

```
#include <stdlib.h>
size_t nelem, elsize;
void __X *ret;
ret=calloc__X(nelem,elsize);
```

Remarks: This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp,** and **dspc** are specified.  
The **calloc\_\_X** function allocates as many X storage units of size **elsize** as the number specified by **nelem**. The function also clears all the bits in the allocated X storage area to 0.

**void free\_\_X (void \_\_X \*ptr)**

Description: Releases specified X storage area.

Header file: <stdlib.h>

Parameters: ptr Address of X storage area to release

Example: 

```
#include <stdlib.h>
void __X *ptr;
free__X(ptr);
```

Remarks: This function is only valid when **cpu=sh2dsp**, **sh3dsp**, **sh4aldsp**, and **dspc** are specified.

The **free\_\_X** function releases the X storage area pointed by **ptr**, to enable reallocation for use. If **ptr** is NULL, the function carries out nothing.

If the X storage area attempted to release was not allocated by the **calloc\_\_X**, **malloc\_\_X**, or **realloc\_\_X** function, or when the area has already been released by the **free\_\_X** or **realloc\_\_X** function, operation is not guaranteed. Operation result of reference to a released X storage area is also not guaranteed.

**void \_\_X \*malloc\_\_X (size\_t size)**

Description:     Allocates X storage area.

Header file:     <stdlib.h>

Return values:   Normal:     Starting address of allocated X storage area  
                  Abnormal:   X storage allocation failed, or **size** is 0: NULL

Parameters:     size         Size in number of bytes of X storage area to allocate

Example:        

```
#include <stdlib.h>
size_t size;
void __X *ret;
 ret=malloc__X(size);
```

Remarks:       This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp,** and **dspe** are specified.

The **malloc\_\_X** function allocates an X storage area of a specified number of bytes by **size**.

**void \_\_X \*realloc\_\_X (void \_\_X \*ptr, size\_t size)**

Description: Changes the size of an X storage area to a specified value.

Header file: <stdlib.h>

Return values: Normal: Starting address of X storage area whose size has been changed

Abnormal: X storage area allocation has failed, or **size** is 0: NULL

Parameters: **ptr** Starting address of X storage area to be changed  
**size** Size of X storage area in number of bytes after the change

Example:

```
#include <stdlib.h>
size_t size;
void __X *ptr, *ret;
 ret=realloc__X(ptr,size);
```

Remarks: This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp**, and **dspe** are specified.

The **realloc\_\_X** function changes the size of the X storage area specified by **ptr** to the number of bytes specified by **size**. If the newly allocated X storage area is smaller than the old one, the contents are left unchanged up to the size of the newly allocated X area.

When **ptr** is not a pointer to the X storage area allocated by the **calloc\_\_X**, **malloc\_\_X**, or **realloc\_\_X** function or when **ptr** is a pointer to the X storage area released by the **free\_\_X** or **realloc\_\_X** function, operation is not guaranteed.

## **void \_\_Y \*calloc\_\_Y (size\_t nelem, size\_t elsize)**

Description:     Allocates a Y storage area and clears all bits in the allocated Y storage area to 0.

Header file:     <stdlib.h>

Return values:   Normal:       Starting address of an allocated Y storage area  
                  Abnormal:     Y storage allocation failed, or either of the parameter is 0: NULL

Parameters:     nelem         Number of elements  
                  elsize        Number of bytes occupied by a single element

Example:        

```
#include <stdlib.h>
size_t nelem, elsize;
void __Y *ret;
 ret=calloc__Y(nelem,elsize);
```

Remarks:       This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp,** and **dspc** are specified.  
                  The **calloc\_\_Y** function allocates as many Y storage units of size **elsize** as the number specified by **nelem**. The function also clears all the bits in the allocated Y storage area to 0.

**void free\_\_Y (void \_\_Y \*ptr)**

Description: Releases specified Y storage area.

Header file: <stdlib.h>

Parameters: ptr            Address of Y storage area to release

Example:            #include <stdlib.h>  
                     void \_\_Y \*ptr;  
                     free\_\_Y(ptr);

Remarks:           This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp**, and **dspc** are specified.

The **free\_\_Y** function releases the Y storage area pointed by **ptr**, to enable reallocation for use. If **ptr** is NULL, the function carries out nothing.

If the Y storage area attempted to release was not allocated by the **calloc\_\_Y**, **malloc\_\_Y**, or **realloc\_\_Y** function, or when the area has already been released by the **free\_\_Y** or **realloc\_\_Y** function, operation is not guaranteed. Operation result of reference to a released Y storage area is also not guaranteed.

## **void \_\_Y \*malloc\_\_Y (size\_t size)**

Description:     Allocates Y storage area.

Header file:     <stdlib.h>

Return values:   Normal:     Starting address of allocated Y storage area  
                  Abnormal:   Y storage allocation failed, or **size** is 0: NULL

Parameters:     size         Size in number of bytes of Y storage area to allocate

Example:        

```
#include <stdlib.h>
size_t size;
void __Y *ret;
 ret=malloc__Y(size);
```

Remarks:       This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp,** and **dspe** are specified.

The **malloc\_\_Y** function allocates the Y storage area of a specified number of bytes by **size**.

**void \_\_Y \*realloc\_\_Y (void \_\_Y \*ptr, size\_t size)**

Description: Changes the size of a Y storage area to a specified value.

Header file: <stdlib.h>

Return values: Normal: Starting address of Y storage area whose size has been changed

Abnormal: Y storage area allocation has failed, or **size** is 0: NULL

Parameters: **ptr** Starting address of Y storage area to be changed  
**size** Size of Y storage area in number of bytes after the change

Example:

```
#include <stdlib.h>
size_t size;
void __Y *ptr, *ret;
 ret=realloc__Y(ptr,size);
```

Remarks: This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp**, and **dspe** are specified.

The **realloc\_\_Y** function changes the size of the Y storage area specified by **ptr** to the number of bytes specified by **size**. If the newly allocated Y storage area is smaller than the old one, the contents are left unchanged up to the size of the newly allocated Y area.

When **ptr** is not a pointer to the Y storage area allocated by the **calloc\_\_Y**, **malloc\_\_Y**, or **realloc\_\_Y** function or when **ptr** is a pointer to the Y storage area released by the **free\_\_Y** or **realloc\_\_Y** function, operation is not guaranteed.



```
void *bsearch (const void *key, const void *base, size_t nmemb, size_t size,
 int (*compar)(const void *, const void *))
```

Description: Performs binary search.

Header file: <stdlib.h>

Return values: If a matching member is found: Pointer to the matching member  
If no matching member is found: NULL

|             |        |                                                |
|-------------|--------|------------------------------------------------|
| Parameters: | key    | Pointer to data to find                        |
|             | base   | Pointer to a table to be searched              |
|             | nmemb  | Number of members to be searched               |
|             | size   | Number of bytes of a member to be searched     |
|             | compar | Pointer to a function that performs comparison |

```
Example: #include <stdlib.h>
const void *key, *base;
size_t nmemb, size;
int (*compar)(const void *, const void *);
void *ret;
ret=bsearch(key, base, nmemb, size, compar);
```

Remarks: The **bsearch** function searches the table specified by **base** for a member that matches the data specified by **key**, by binary search method. The function that performs comparison should receive pointers **p1** (first parameter) and **p2** (second parameter) to two data items to compare, and return the result complying with the specification below.

If  $*p1 < *p2$ , return a negative value.

If  $*p1 == *p2$ , return 0.

If  $*p1 > *p2$ , return a positive value.

Members to be searched must be placed in the ascending order.

```
void qsort (const void *base, size_t nmemb, size_t size,
 int (*compar)(const void *, const void *))
```

Description: Performs sorting.

Header file: <stdlib.h>

Parameters:

|        |                                             |
|--------|---------------------------------------------|
| base   | Pointer to the table to be sorted           |
| nmemb  | Number of members to sort                   |
| size   | Number of bytes of a member to be sorted    |
| compar | Pointer to a function to perform comparison |

Example:

```
#include <stdlib.h>
const void *base;
size_t nmemb, size;
int (*compar)(const void *, const void *)
 qsort(base, nmemb, size, compar);
```

Remarks: The **qsort** function sorts out data on the table pointed to by **base**. The data arrangement order is specified by the pointer to a function to perform comparison. This comparison function should receive pointers **p1** (first parameter) and **p2** (second parameter) as two data items to be compared, and return the result complying with the specification below.

If  $*p1 < *p2$ , return a negative value.

If  $*p1 == *p2$ , return 0.

If  $*p1 > *p2$ , return a positive value.

### **int abs (int i)**

Description: Calculates the absolute value of an int type integer.

Header file: <stdlib.h>

Return values: Absolute value of i

Parameters: i Integer to calculate the absolute value of

Example: 

```
#include <stdlib.h>
int i, ret;
ret=abs(i);
```

Remarks: If the result cannot be expressed as an int type integer, correct operation is not guaranteed.

### **div\_t div (int numer, int denom)**

Description: Carries out division of int type integers and obtains the quotient and remainder.

Header file: <stdlib.h>

Return values: Quotient and remainder of division of **numer** by **denom**

Parameters: numer Dividend  
denom Divisor

Example: 

```
#include <stdlib.h>
int numer, denom;
div_t ret;
ret=div(numer, denom);
```

**long labs (long j)**

Description: Calculates the absolute value of a long type integer.

Header file: <stdlib.h>

Return values: Absolute value of **j**

Parameters: **j** Integer to calculate the absolute value of

Example: 

```
#include <stdlib.h>
long j;
long ret;
ret=labs(j);
```

Remarks: If the result cannot be expressed as a long type integer, correct operation is not guaranteed.

**ldiv\_t ldiv (long numer, long denom)**

Description: Carries out division of long type integer and obtains the quotient and remainder.

Header file: <stdlib.h>

Return values: Quotient and remainder of division of **numer** by **denom**

Parameters: **numer** Dividend  
**denom** Divisor

Example: 

```
#include <stdlib.h>
long numer, denom;
ldiv_t ret;
ret=ldiv(numer, denom);
```

### **long long labs (long long j)**

Description:     Calculates the absolute value of a long long type integer.

Header file:     <stdlib.h>

Return values:   Absolute value of **j**

Parameters:     **j**             Integer to calculate the absolute value of

Example:        

```
#include <stdlib.h>
long long j;
long long ret;
 ret=llabs(j);
```

Remarks:        If the result cannot be expressed as a long long type integer, correct operation is not guaranteed.

### **lldiv\_t lldiv (long long numer,long long denom)**

Description:     Carries out division of long long type integers and obtains the quotient and remainder.

Header file:     <stdlib.h>

Return values:   Quotient and remainder of division of **numer** by **denom**

Parameters:     **numer**         Dividend  
                  **denom**         Divisor

Example:        

```
#include <stdlib.h>
long long numer, denom;
lldiv_t ret;
 ret=lldiv(numer,denom);
```

**<string.h>**

Defines functions for manipulating character arrays.

| Type     | Definition Name | Description                                                                                                                                                      |
|----------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Function | memcpy          | Copies contents of a source storage area of a specified length to a destination storage area.                                                                    |
|          | memcpy__X__X    | Copies contents of a source X storage area of a specified length to a destination X storage area.                                                                |
|          | memcpy__X__Y    | Copies contents of a source Y storage area of a specified length to a destination X storage area.                                                                |
|          | memcpy__Y__X    | Copies contents of a source X storage area of a specified length to a destination Y storage area.                                                                |
|          | memcpy__Y__Y    | Copies contents of a source Y storage area of a specified length to a destination Y storage area.                                                                |
|          | strcpy          | Copies contents of a source string including the null character to a destination storage area.                                                                   |
|          | strncpy         | Copies a source string of a specified length to a destination storage area.                                                                                      |
|          | strcat          | Concatenates a string after another string.                                                                                                                      |
|          | strncat         | Concatenates a string of a specified length after another string.                                                                                                |
|          | memcmp          | Compares two storage areas specified.                                                                                                                            |
|          | strcmp          | Compares two strings specified.                                                                                                                                  |
|          | strncmp         | Compares two strings specified for a specified length.                                                                                                           |
|          | memchr          | Searches a specified storage area for the first occurrence of a specified character.                                                                             |
|          | strchr          | Searches a specified string for the first occurrence of a specified character.                                                                                   |
|          | strcspn         | Checks a specified string from the beginning and counts the number of consecutive characters at the beginning that are not included in another string specified. |
|          | strpbrk         | Searches a specified string for the first occurrence of any character that is included in another string specified.                                              |
|          | strrchr         | Searches a specified string for the last occurrence of a specified character.                                                                                    |
|          | strspn          | Checks a specified string from the beginning and counts the number of consecutive characters at the beginning that are included in another string specified.     |

| Type     | Definition Name | Description                                                                                                                                                                                                     |
|----------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Function | strstr          | Searches a specified string for the first occurrence of another string specified.                                                                                                                               |
|          | strtok          | Divides a specified string into some tokens.                                                                                                                                                                    |
|          | memset          | Sets a specified character for a specified number of times at the beginning of a specified storage area.                                                                                                        |
|          | strerror        | Sets error messages.                                                                                                                                                                                            |
|          | strlen          | Calculates the length of a string.                                                                                                                                                                              |
|          | memmove         | Copies the specified size of the contents of a source area to the destination storage area. If a part of the source storage area and a part of the destination storage area overlap, correct copy is performed. |

**Implementation-Defined**

| Item                                                         | Compiler Specifications                                 |
|--------------------------------------------------------------|---------------------------------------------------------|
| Error message returned by the <code>strerror</code> function | Refer to section 12.3, Standard Library Error Messages. |

When using functions defined in this standard include file, note the following.

- (1) On copying a string, if the destination area is smaller than the source area, correct operation is not guaranteed.

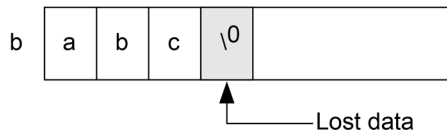
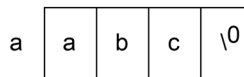
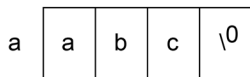
**Example**

```
char a[]="abc";
char b[3];
.
.
.
strcpy (b, a);
```

In the above example, size of array `a` (including the null character) is 4 bytes. Copying by **`strcpy`** overwrites data beyond the boundary of array `b`.

Before copy

After copy



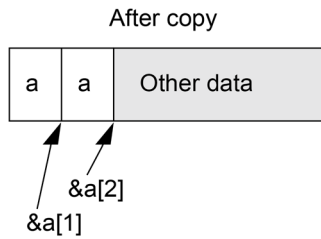
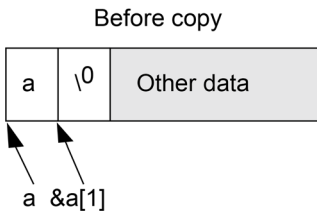


(2) On copying a string, if the source area overlaps the destination area, correct operation is not guaranteed.

Example

```
int a[]="a";
:
:
strcpy(&a[1], a);
:
```

In the above example, before the null character of the source is read, 'a' is written over the null character. Then the subsequent data after the source string is overwritten in succession.



Subsequent data is copied in succession.

**void \*memcpy (void \*s1, const void \*s2, size\_t n)**

Description: Copies contents of a copy source storage area of a specified length to a destination storage area.

Header file: <string.h>

Return values: **s1** value

Parameters: s1            Pointer to destination storage area  
 s2            Pointer to source storage area  
 n             Number of characters to be copied

Example: 

```
#include <string.h>
void *ret, *s1;
const void *s2;
size_t n;
ret=memcpy(s1, s2, n);
```

**void \_\_X \*memcpy\_\_X\_\_X (void \_\_X \*s1, const void \_\_X \*s2, size\_t n)**

Description: Copies contents of a copy source X storage area of a specified length to a destination X storage area.

Header file: <string.h>

Return values: **s1** value

Parameters: s1            Pointer to destination X storage area  
 s2            Pointer to source X storage area  
 n             Number of characters to be copied

Example: 

```
#include <string.h>
void __X *ret, *s1;
const void __X *s2;
size_t n;
ret=memcpy__X__X(s1, s2, n);
```

Remarks: This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp**, and **dspe** are specified.

**void \_\_X \*memcpy\_\_X\_\_Y (void \_\_X \*s1, const void \_\_Y \*s2, size\_t n)**

Description: Copies contents of a copy source Y storage area of a specified length to a destination X storage area.

Header file: <string.h>

Return values: **s1** value

Parameters: s1            Pointer to destination X storage area  
              s2            Pointer to source Y storage area  
              n             Number of characters to be copied

Example: 

```
#include <string.h>
void __X *ret, *s1;
const void __Y *s2;
size_t n;
ret=memcpy__X__Y(s1,s2,n);
```

Remarks: This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp**, and **dspe** are specified.

**void \_\_Y \*memcpy\_\_Y\_\_X (void \_\_Y \*s1, const void \_\_X \*s2, size\_t n)**

Description: Copies contents of a copy source X storage area of a specified length to a destination Y storage area.

Header file: <string.h>

Return values: **s1** value

Parameters: s1            Pointer to destination Y storage area  
              s2            Pointer to source X storage area  
              n             Number of characters to be copied

Example:        #include <string.h>  
                 void \_\_Y \*ret, \*s1;  
                 const void \_\_X \*s2;  
                 size\_t n;  
                 ret=memcpy\_\_Y\_\_X(s1, s2, n);

Remarks: This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp**, and **dspe** are specified.

**void \_\_Y \*memcpy\_\_Y\_\_Y (void \_\_Y \*s1, const void \_\_Y \*s2, size\_t n)**

Description: Copies contents of a copy source Y storage area of a specified length to a destination Y storage area.

Header file: <string.h>

Return values: **s1** value

Parameters: s1            Pointer to destination Y storage area  
              s2            Pointer to source Y storage area  
              n             Number of characters to be copied

Example: 

```
#include <string.h>
void __Y *ret, *s1;
const void __Y *s2;
size_t n;
ret=memcpy__Y__Y(s1,s2,n);
```

Remarks: This function is only valid when **cpu=sh2dsp, sh3dsp, sh4aldsp**, and **dspe** are specified.

**char \*strcpy (char \*s1, const char \*s2)**

Description: Copies contents of a source string including the null character to a destination storage area.

Header file: <string.h>

Return values: **s1** value

Parameters: s1            Pointer to destination storage area  
              s2            Pointer to source string

Example: 

```
#include <string.h>
char *s1, *ret;
const char *s2;
ret=strcpy(s1, s2);
```

**char \*strncpy (char \*s1, const char \*s2, size\_t n)**

Description: Copies a source string of a specified length to a destination storage area.

Header file: <string.h>

Return values: **s1** value

Parameters: s1            Pointer to destination storage area  
              s2            Pointer to source string  
              n             Number of characters to be copied

Example:        #include <string.h>  
                 char \*s1, \*ret;  
                 const char \*s2;  
                 size\_t n;  
                 ret=strncpy(s1, s2, n);

Remarks:        The **strncpy** function copies up to **n** characters from the beginning of the string pointed by **s2** to a storage area pointed by **s1**. If the length of the string specified by **s2** is shorter than **n** characters, the function elongates the string to the length by padding with null characters.

If the length of the string specified by **s2** is longer than **n** characters, the copied string in **s1** storage area ends with a character other than the null character.

**char \*strcat (char \*s1, const char \*s2)**

Description: Concatenates a string after another string.

Header file: <string.h>

Return values: **s1** value

Parameters: **s1** Pointer to the string after which another string is appended  
**s2** Pointer to the string to be added after the other string

Example: 

```
#include <string.h>
char *s1, *ret;
const char *s2;
ret=strcat(s1, s2);
```

Remarks: The **strcat** function concatenates the string specified by **s2** at the end of another string specified by **s1**. The null character indicating the end of the **s2** string is also copied. The null character at the end of the **s1** string is deleted.

**char \*strncat (char \*s1, const char \*s2, size\_t n)**

Description: Concatenates a string of a specified length after another string.

Header file: <string.h>

Return values: **s1** value

Parameters: **s1** Pointer to the string after which another string is appended  
**s2** Pointer to the string to be appended after the other string  
**n** Number of characters to concatenate

Example: 

```
#include <string.h>
char *s1, *ret;
const char *s2;
size_t n;
ret=strncat(s1, s2, n);
```

Remarks: The **strncat** function concatenates up to **n** characters from the beginning of the string specified by **s2** at the end of another string specified by **s1**. The null character at the end of the **s1** string is replaced by the first character of the **s2** string. A null character is appended to the end of the concatenated string.

**int memcmp (const void \*s1, const void \*s2, size\_t n)**

Description: Compares two storage areas specified.

Header file: <string.h>

Return values: If storage area pointed by **s1** > storage area pointed by **s2**: Positive value  
If storage area pointed by **s1** == storage area pointed by **s2**: 0  
If storage area pointed by **s1** < storage area pointed by **s2**: Negative value

Parameters: **s1** Pointer to the reference storage area to be compared  
**s2** Pointer to the storage area to compare to the reference  
**n** Number of characters to compare

Example:

```
#include <string.h>
const void *s1, *s2;
size_t n;
int ret;
 ret=memcmp(s1, s2, n);
```

Remarks: The **memcmp** function compares the contents of the first **n** characters in the storage areas pointed by **s1** and **s2**. The rule of comparison are implementation-defined.



## **int strcmp (const char \*s1, const char \*s2)**

Description: Compares two strings specified.

Header file: <string.h>

Return values: If string pointed by **s1** > string pointed by **s2**: Positive value  
If string pointed by **s1** == string pointed by **s2**: 0  
If string pointed by **s1** < string pointed by **s2**: Negative value

Parameters: s1            Pointer to the reference string to be compared  
s2            Pointer to the string to compare to the reference

Example: 

```
#include <string.h>
const char *s1, *s2;
int ret;
ret=strcmp(s1, s2);
```

Remarks: The **strcmp** function compares the contents of the strings pointed by **s1** and **s2**, and sets up the comparison result as a return value. The rule of comparison are implementation-defined.

**int strcmp (const char \*s1, const char \*s2, size\_t n)**

Description: Compares two strings specified up to a specified length.

Header file: <string.h>

Return values: If string pointed by **s1** > string pointed by **s2**: Positive value  
If string pointed by **s1** == string pointed by **s2**: 0  
If string pointed by **s1** < string pointed by **s2**: Negative value

Parameters: **s1** Pointer to the reference string to be compared  
**s2** Pointer to the string to compare to the reference  
**n** Maximum number of characters to compare

Example:

```
#include <string.h>
const char *s1, *s2;
size_t n;
int ret;
 ret=strcmp(s1, s2, n);
```

Remarks: The **strcmp** function compares the contents of the strings pointed by **s1** and **s2**, up to **n** characters. The rule of comparison are implementation-defined.

## **void \*memchr (const void \*s, int c, size\_t n)**

Description: Searches a specified storage area for the first occurrence of a specified character.

Header file: <string.h>

Return values: If the character is found: Pointer to the found character  
If the character is not found: NULL

Parameters: **s** Pointer to the storage area to be searched  
**c** Character to search for  
**n** Number of characters to search

Example:

```
#include <string.h>
const void *s;
int c;
size_t n;
void *ret;
 ret=memchr(s, c, n);
```

Remarks: The **memchr** function searches the storage area specified by **s** from the beginning up to **n** characters, looking for the first occurrence of the character specified as **c**. If the **c** character is found, the function returns the pointer to the found character.

**char \*strchr (const char \*s, int c)**

Description: Searches a specified string for the first occurrence of a specified character.

Header file: <string.h>

Return values: If the character is found: Pointer to the found character  
If the character is not found: NULL

Parameters: s                Pointer to the string to search  
c                Character to search for

Example: 

```
#include <string.h>
const char *s;
int c;
char *ret;
ret=strchr(s, c);
```

Remarks: The **strchr** function searches the string specified by **s** looking for the first occurrence of the character specified as **c**. If the **c** character is found, the function returns the pointer to the found character.

The null character at the end of the **s** string is included in the search object.

## **size\_t strcspn (const char \*s1, const char \*s2)**

**Description:** Checks a specified string from the beginning and counts the number of consecutive characters at the beginning that are not included in another string specified.

**Header file:** <string.h>

**Return values:** Number of characters at the beginning of the **s1** string that are not included in the **s2** string

**Parameters:** **s1**            Pointer to the string to be checked  
**s2**            Pointer to the string used to check **s1**

**Example:**

```
#include <string.h>
const char *s1, *s2;
size_t ret;
ret=strcspn(s1, s2);
```

**Remarks:** The **strcspn** function checks from the beginning of the string specified by **s1**, and counts the number of consecutive characters that are not included in another string specified by **s2**, and returns that length.

The null character at the end of the **s2** string is not taken as a part of the **s2** string.

**char \*strpbrk (const char \*s1, const char \*s2)**

Description: Searches a specified string for the first occurrence of the character that is included in another string specified.

Header file: <string.h>

Return values: If the character is found: Pointer to the found character  
If the character is not found: NULL

Parameters: s1            Pointer to the string to search  
s2            Pointer to the string that indicates the characters to search **s1** for

Example: 

```
#include <string.h>
const char *s1, *s2;
char *ret;
 ret=strpbrk(s1, s2);
```

Remarks: The **strpbrk** function searches the string specified by **s1** looking for the first occurrence of any character included in the string specified by **s2**. If the searched character is found, the function returns the pointer to the first occurrence.

### **char \*strrchr (const char \*s, int c)**

Description: Searches a specified string for the last occurrence of a specified character.

Header file: <string.h>

Return values: If the character is found: Pointer to the found character  
If the character is not found: NULL

Parameters: s                Pointer to the string to be searched  
              c                Character to search for

Example: 

```
#include <string.h>
const char *s;
int c;
char *ret;
ret=strrchr(s, c);
```

Remarks: The **strrchr** function searches the string specified by **s** looking for the last occurrence of the character specified by **c**. If the **c** character is found, the function returns the pointer to the last occurrence of that character.

The null character at the end of the **s** string is included in the search objective.

**size\_t strspn (const char \*s1, const char \*s2)**

**Description:** Checks a specified string from the beginning and counts the number of consecutive characters at the beginning that are included in another string specified.

**Header file:** <string.h>

**Return values:** Number of characters at the beginning of the **s1** string that are included in the **s2** string

**Parameters:** s1            Pointer to the string to be checked  
s2            Pointer to the string used to check **s1**

**Example:**

```
#include <string.h>
const char *s1, *s2;
size_t ret;
ret=strspn(s1, s2);
```

**Remarks:** The **strspn** function checks from the beginning of the string specified by **s1**, and counts the number of consecutive characters that are included in another string specified by **s2**, and returns that length.



### **char \*strstr (const char \*s1, const char \*s2)**

Description: Searches a specified string for the first occurrence of another string specified.

Header file: <string.h>

Return values: If the string is found: Pointer to the found string  
If the string is not found: NULL

Parameters: s1            Pointer to the string to be searched  
              s2            Pointer to the string to search for

Example:        

```
#include <string.h>
const char *s1, *s2;
char *ret;
 ret=strstr(s1, s2);
```

Remarks:        The **strstr** function searches the string specified by **s1** looking for the first occurrence of another string specified by **s2**, and returns the pointer to the first occurrence.

**char \*strtok (char \*s1, const char \*s2)**

Description: Divides a specified string into some tokens.

Header file: <string.h>

Return values: If division into tokens is successful: Pointer to the first token divided  
If division into tokens is unsuccessful: NULL

Parameters: s1 Pointer to the string to divide into some tokens  
s2 Pointer to the string representing string dividing characters

Example: 

```
#include <string.h>
char *s1, *ret;
const char *s2;
ret=strtok(s1, s2);
```

Remarks: The **strtok** function should be repeatedly called to divide a string.

(1) First call

The string pointed by **s1** is divided at a character included in the string pointed by **s2**. If a token has been separated, the function returns a pointer to the beginning of that token. Otherwise, the function returns NULL.

(2) Second and subsequent calls

Starting from the next character separated before as the token, the function repeats division at a character included in the string pointed by **s2**. If a token has been separated, the function returns a pointer to the beginning of that token. Otherwise, the function returns NULL.

At the second and subsequent calls, specify NULL as the first parameter.

The string pointed by **s2** can be changed at each call.

The null character is appended to the end of a separated token.

An example of use of the **strtok** function is shown below.

**Example**

```
1 #include <string.h>
2 static char s1[]="a@b, @c/@d";
3 char *ret;
4
5 ret = strtok(s1, "@");
6 ret = strtok(NULL, ",@");
7 ret = strtok(NULL, "/"@"");
8 ret = strtok(NULL, "@");
```

**Explanation:**

The above example program uses the **strtok** function to divide string "a@b, @c/@d" into tokens a, b, c, and d.

The second line specifies string "a@b, @c/@d" as an initial value for string **s1**.

The fifth line calls the **strtok** function to divide tokens using '@' as the delimiter. As a result, a pointer to character 'a' is returned, and the null character is embedded at '@,' the first delimiter after character 'a.' Thus string 'a' has been separated.

Specify NULL for the first parameter to consecutively separate tokens from the same string, and repeat calling the **strtok** function.

Consequently, the function separates strings 'b,' 'c,' and 'd.'

**void \*memset (void \*s, int c, size\_t n)**

Description: Sets a specified character for a specified number of times at the beginning of a specified storage area.

Header file: <string.h>

Return values: Value of **s**

Parameters: **s** Pointer to storage area to set characters in  
**c** Character to be set  
**n** Number of characters to be set

Example: 

```
#include <string.h>
void *s, *ret;
int c;
size_t n;
ret=memset(s, c, n);
```

Remarks: The **memset** function sets the character specified by **c** for a number of times specified by **n** to the storage area specified by **s**.

### **char \*strerror (int s)**

Description: Returns an error message corresponding to a specified error number.

Header file: <string.h>

Return values: Pointer to the error message (string) corresponding to the specified error number

Parameters: s                    Error number

Example: 

```
#include <string.h>
char *ret;
int s;
ret=strerror(s);
```

Remarks: The **strerror** function receives an error number specified by **s** and returns an error message corresponding to the number. Contents of error messages are implementation-defined.

If the returned error message is modified, correct operation is not guaranteed.

### **size\_t strlen (const char \*s)**

Description: Calculates the length of a string.

Header file: <string.h>

Return values: Number of characters of the string

Parameters: s                    Pointer to the string to check the length of

Example: 

```
#include <string.h>
const char *s;
size_t ret;
ret=strlen(s);
```

Remarks: The null character at the end of the **s** string is excluded from the string length.

**void \*memmove (void \*s1, const void \*s2, size\_t n)**

**Description:** Copies the specified size of the contents of a source area to the destination storage area. If part of the source storage area and the destination storage area overlaps, data is copied to the destination storage area before the overlapped source storage area is overwritten. Therefore, correct copy is enabled.

**Header file:** <string.h>

**Return values:** Value of **s1**

**Parameters:**

|    |                                         |
|----|-----------------------------------------|
| s1 | Pointer to the destination storage area |
| s2 | Pointer to the source storage area      |
| n  | Number of characters to be copied       |

**Example:**

```
#include <string.h>
void *ret, *s1
const void *s2;
size_t n;
 ret=memmove(s1, s2, n);
```

## 10.4.2 EC++ Class Libraries

### (1) Overview of Libraries

This section describes the specifications of the EC++ class libraries, which can be used as standard libraries in C++ programs. This section gives an overview of the library configuration, and describes the layout and the terms used in this library function description.

- Library Types

Table 10.49 shows the various library types and the corresponding standard include files.

**Table 10.49 Library Types and Corresponding Standard Include Files**

| Library Type               | Description                                 | Standard Include Files                                          |
|----------------------------|---------------------------------------------|-----------------------------------------------------------------|
| Stream input/output class  | Performs input/output processing.           | <ios>, <streambuf>, <istream>, <ostream>, <iostream>, <iomanip> |
| Memory management          | Performs memory allocation and deallocation | <new>                                                           |
| Complex number calculation | Performs complex number calculation         | <complex>                                                       |
| String manipulation        | Performs string manipulation                | <string>                                                        |

### (2) Stream Input/Output Class Library

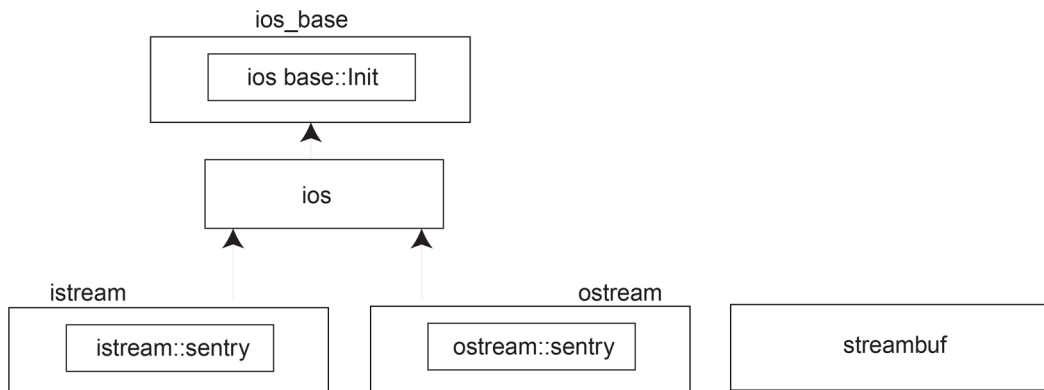
The header files for stream input/output class libraries are as follows.

1. <ios>  
Defines data members and function members that specify input/output formats and manage the input/output states. The <ios> header file also defines the Init and ios\_base classes.
2. <streambuf>  
Defines functions for the stream buffer.
3. <istream>  
Defines input functions from the input stream.
4. <ostream>  
Defines output functions to the output stream.
5. <iostream>  
Defines input/output functions.

## 6. &lt;iomanip&gt;

Defines manipulators with parameters.

The following shows the inheritance relation of the above classes. An arrow (->) indicates that a derived class refers to a base class. The streambuf class has no inheritance relation.



The following types are used by stream input/output class libraries.

| Type | Definition Name | Description             |
|------|-----------------|-------------------------|
| Type | streamoff       | Defined as long type.   |
|      | streamsize      | Defined as size_t type. |
|      | int_type        | Defined as int type.    |
|      | pos_type        | Defined as long type.   |
|      | off_type        | Defined as long type.   |



**(a) ios\_base::Init Class**

| Type     | Definition Name | Description                                                                                                                           |
|----------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Variable | init_cnt        | Static data member that counts the number of stream input/output objects. The data must be initialized to 0 by a low-level interface. |
| Function | Init ()         | Constructor                                                                                                                           |
|          | ~ Init ()       | Destructor                                                                                                                            |

1. ios\_base::Init::Init ()  
 Constructor of class Init.  
 Increments init\_cnt.
2. ios\_base::Init::~Init ()  
 Destructor of class Init.  
 Decrements init\_cnt.

**(b) ios\_base Class**

| Type     | Definition Name                                      | Description                                                |
|----------|------------------------------------------------------|------------------------------------------------------------|
| Type     | fmtflags                                             | Type that indicates the format control information         |
|          | iostate                                              | Type that indicates the stream buffer input/output state   |
|          | openmode                                             | Type that indicates the open mode of the file              |
|          | seekdir                                              | Type that indicates the seek state of the stream buffer    |
| Variable | fmtfl                                                | Format flag                                                |
|          | wide                                                 | Field width                                                |
|          | prec                                                 | Precision (number of decimal point digits) at output       |
|          | fillch                                               | Fill character                                             |
| Function | void _ec2p_init_base()                               | Initializes the base class                                 |
|          | void _ec2p_copy_base(<br>ios_base& ios_base_dt)      | Copies ios_base_dt                                         |
|          | ios_base()                                           | Constructor                                                |
|          | ~ios_base()                                          | Destructor                                                 |
|          | fmtflags flags() const                               | References the format flag (fmtfl)                         |
|          | fmtflags flags(fmtflags fmtflg)                      | Sets fmtflg&format flag (fmtfl) to the format flag (fmtfl) |
|          | fmtflags setf(fmtflags fmtflg)                       | Sets fmtflg to format flag (fmtfl)                         |
|          | fmtflags setf(<br>fmtflags fmtflg,<br>fmtflags mask) | Sets mask&fmtflg to the format flag (fmtfl)                |
|          | void unsetf(fmtflags mask)                           | Sets ~mask &format flag (fmtfl) to the format flag (fmtfl) |
|          | char fill() const                                    | Reads the fill character (fillch)                          |
|          | char fill(char ch)                                   | Sets ch as the fill character (fillch)                     |
|          | int precision() const                                | Reads the precision (prec)                                 |
|          | streamsize precision(<br>streamsize preci)           | Sets preci as precision (prec)                             |
|          | streamsize width() const                             | Reads the field width (wide)                               |
|          | streamsize width(streamsize wd)                      | Sets wd as field width (wide)                              |

## 1. ios\_base::fmtflags

Defines the format control information relating to input/output processing.

The definition for each bit mask of **fmtflags** is as follows.

```
const ios_base::fmtflags ios_base::boolalpha = 0x0000;
const ios_base::fmtflags ios_base::skipws = 0x0001;
const ios_base::fmtflags ios_base::unitbuf = 0x0002;
const ios_base::fmtflags ios_base::uppercase = 0x0004;
const ios_base::fmtflags ios_base::showbase = 0x0008;
const ios_base::fmtflags ios_base::showpoint = 0x0010;
const ios_base::fmtflags ios_base::showpos = 0x0020;
const ios_base::fmtflags ios_base::left = 0x0040;
const ios_base::fmtflags ios_base::right = 0x0080;
const ios_base::fmtflags ios_base::internal = 0x0100;
const ios_base::fmtflags ios_base::adjustfield = 0x01c0;
const ios_base::fmtflags ios_base::dec = 0x0200;
const ios_base::fmtflags ios_base::oct = 0x0400;
const ios_base::fmtflags ios_base::hex = 0x0800;
const ios_base::fmtflags ios_base::basefield = 0x0e00;
const ios_base::fmtflags ios_base::scientific = 0x1000;
const ios_base::fmtflags ios_base::fixed = 0x2000;
const ios_base::fmtflags ios_base::floatfield = 0x3000;
const ios_base::fmtflags ios_base::fmtmask = 0x3fff;
```

## 2. ios\_base::iostate

Defines the input/output state of the stream buffer.

The definition for each bit mask of **iostate** is as follows.

```
const ios_base::iostate ios_base::goodbit = 0x0;
const ios_base::iostate ios_base::eofbit = 0x1;
const ios_base::iostate ios_base::failbit = 0x2;
const ios_base::iostate ios_base::badbit = 0x4;
const ios_base::iostate ios_base::statemask = 0x7;
```

3. `ios_base::openmode`

Defines open mode of the file.

The definition for each bit mask of **openmode** is as follows.

|                                                        |                      |                                                         |
|--------------------------------------------------------|----------------------|---------------------------------------------------------|
| <code>const ios_base::openmode ios_base::in</code>     | <code>= 0x01;</code> | Opens the input file.                                   |
| <code>const ios_base::openmode ios_base::out</code>    | <code>= 0x02;</code> | Opens the output file.                                  |
| <code>const ios_base::openmode ios_base::ate</code>    | <code>= 0x04;</code> | Seeks for eof only once after the file has been opened. |
| <code>const ios_base::openmode ios_base::app</code>    | <code>= 0x08;</code> | Seeks for eof each time the file is written to.         |
| <code>const ios_base::openmode ios_base::trunc</code>  | <code>= 0x10;</code> | Opens the file in overwrite mode.                       |
| <code>const ios_base::openmode ios_base::binary</code> | <code>= 0x20;</code> | Opens the file in binary mode.                          |

4. `ios_base::seekdir`

Defines the seek state of the stream buffer.

Determines the position to continue the input/output of data in a string literal.

The definition for each bit mask of **seekdir** is as follows.

|                                                    |                     |
|----------------------------------------------------|---------------------|
| <code>const ios_base::seekdir ios_base::beg</code> | <code>= 0x0;</code> |
| <code>const ios_base::seekdir ios_base::cur</code> | <code>= 0x1;</code> |
| <code>const ios_base::seekdir ios_base::end</code> | <code>= 0x2;</code> |

5. `void ios_base::_ec2p_init_base()`

The initial settings are as follows.

```
fmtfl = skipws | dec;
wide = 0;
prec = 6;
fillch = ' ';
```

6. `void ios_base::_ec2p_copy_base(ios_base& ios_base_dt)`

Copies **ios\_base\_dt**.

7. `ios_base::ios_base ()`

Constructor of class **ios\_base**.

Calls `Init::Init()`.

8. `ios_base::~ios_base ()`

Destructor of class **ios\_base**.

9. `ios_base::fmtflags ios_base::flags() const`  
Reads format flag (**fmtfl**).  
Return value: Format flag (**fmtfl**)
10. `ios_base::fmtflags ios_base::flags (fmtflags fmtflg)`  
Sets **fmtflg**&format flag (**fmtfl**) to the format flag (**fmtfl**).  
Return value: Format flag (**fmtfl**) before setting
11. `ios_base::fmtflags ios_base::setf(fmtflags fmtflg)`  
Sets **fmtflg** to format flag (**fmtfl**).  
Return value: Format flag (**fmtfl**) before setting
12. `ios_base::fmtflags ios_base::setf( (fmtflags fmtflg, fmtflags mask)`  
Sets **~mask**&format flag (**fmtfl**) to the format flag (**fmtfl**).  
Return value: Format flag (**fmtfl**) before setting.
13. `void ios_base::unsetf(fmtflags mask)`  
Sets the result of bitwise AND of format flag (**fmtfl**) and **~mask** to the format flag (**fmtfl**).
14. `char ios_base::fill() const`  
Reads fill character (**fillch**).  
Return value: Fill character (**fillch**)
15. `char ios_base::fill (char ch)`  
Sets **ch** as fill character (**fillch**).  
Return value: Fill character (**fillch**) before setting
16. `int ios_base::precision() const`  
Reads precision (**prec**).  
Return value: Precision (**prec**)
17. `streamsize ios_base::precision (streamsize preci)`  
Sets **preci** as precision (**prec**).  
Return value: Precision (**prec**) before setting
18. `streamsize ios_base::width() const`  
References field width (**wide**).  
Return value: Field width (**wide**)

19. `streamsize ios_base::width (streamsize wd)`

Sets **wd** as field width (**wide**).

Return value: Field width (**wide**) before setting

(c) **ios Class**

| Type     | Definition Name                    | Description                                                                       |
|----------|------------------------------------|-----------------------------------------------------------------------------------|
| Variable | sb                                 | Pointer to the streambuf object                                                   |
|          | tiestr                             | Pointer to the ostream object                                                     |
|          | state                              | State flag of streambuf                                                           |
| Function | ios()                              | Constructor                                                                       |
|          | ios(streambuf* sbptr)              |                                                                                   |
|          | void init(streambuf* sbptr)        | Performs initial setting                                                          |
|          | virtual ~ios()                     | Destructor                                                                        |
|          | operator void*() const             | Tests whether an error has been generated (!state&(badbit   failbit))             |
|          | bool operator!() const             | Tests whether an error has been generated (state&(badbit   failbit))              |
|          | iosstate rdstate() const           | Reads the state flag (state)                                                      |
|          | void clear(iosstate st=goodbit)    | Clears the state flag (state) except for the specified state (st)                 |
|          | void setstate(iosstate st)         | Specifies st as the state flag (state)                                            |
|          | bool good() const                  | Tests whether an error has been generated (state==goodbit)                        |
|          | bool eof() const                   | Tests for the end of an input stream (state&eofbit)                               |
|          | bool bad() const                   | Tests whether an error has been generated (state&badbit)                          |
|          | bool fail() const                  | Tests whether input text matches the requested pattern (state&(badbit   failbit)) |
|          | ostream* tie() const               | Reads the pointer to the ostream object (tiestr)                                  |
|          | ostream* tie(ostream* tstrptr)     | Specifies tstrptr as the pointer to the ostream object (tiestr)                   |
|          | streambuf* rdbuf() const           | References the pointer to the stream buffer (sb)                                  |
|          | streambuf* rdbuf(streambuf* sbptr) | Specifies sbptr as the pointer to the stream buffer (sb)                          |
|          | ios& copyfmt(const ios& rhs)       | Copies the state flag (state) of rhs                                              |

1. `ios::ios ()`  
Constructor of class **ios**.  
Calls **init(0)** and specifies the initial value in the member object.
2. `ios::ios (streambuf* sbptr)`  
Constructor of class **ios**.  
Calls **init(sbptr)** and specifies the initial value in the member object.
3. `void ios::init (streambuf* sbptr)`  
Specifies **sbptr** to **sb**.  
Specifies state and **tiestr** to 0.
4. `virtual ios::~ios ()`  
Destructor of class **ios**.
5. `ios::operator void*() const`  
Tests whether an error has been generated (`!state&(badbit | failbit)`).  
Return value: An error has been generated: false  
No error has been generated: true
6. `bool ios::operator!() const`  
Tests whether an error has been generated (`state&(badbit | failbit)`).  
Return value: An error has been generated: true  
No error has been generated: false
7. `iosstate ios::rdstate() const`  
References the state flag (**state**).  
Return value: State flag (**state**)
8. `void ios::clear(iosstate st=goodbit)`  
Clears the state flag (**state**) except for the specified state (**st**).  
If the pointer to the streambuf object (**sb**) is 0, **badbit** is specified to the state flag (**state**).
9. `void ios::setstate(iosstate st)`  
Specifies **st** to the state flag (**state**).



10. `bool ios::good() const`  
Tests whether an error has been generated (`state==goodbit`).  
Return value: An error has been generated: `false`  
No error has been generated: `true`
11. `bool ios::eof() const`  
Tests for the end of the input stream (`state&eofbit`).  
Return value: End of the input stream has been reached: `true`  
End of the input stream has not been reached: `false`
12. `bool ios::bad() const`  
Tests whether an error has been generated (`state&badbit`).  
Return value: An error has been generated: `true`  
No error has been generated: `false`
13. `bool ios::fail() const`  
Tests whether the input text matches the requested pattern (`state&(badbit | failbit)`).  
Return value: Does not match the requested pattern: `true`  
Matches the requested pattern: `false`
14. `ostream* ios::tie() const`  
Reads the pointer (**`tiestr`**) to the **`ostream`** object.  
Return value: Pointer to the **`ostream`** object (**`tiestr`**)
15. `ostream* ios::tie (ostream* tstrptr)`  
Specifies **`tstrptr`** as the pointer (**`tiestr`**) to the **`ostream`** object.  
Return value: Pointer to the **`ostream`** object (**`tiestr`**) before setting
16. `streambuf* ios::rdbuf() const`  
Reads the pointer to the `streambuf` object (**`sb`**).  
Return value: Pointer to the `streambuf` object (**`sb`**)
17. `streambuf* ios::rdbuf ( streambuf* sbptr)`  
Specifies **`sbptr`** as the pointer to the `streambuf` object (**`sb`**).  
Return value: Pointer to the `streambuf` object (**`sb`**) before setting
18. `ios & ios::copyfmt(const ios& rhs)`  
Copies the state flag (**`state`**) of **`rhs`**.  
Return value: `*this`

**(d) ios Class Manipulators**

| Type     | Definition Name                                           | Description                                    |
|----------|-----------------------------------------------------------|------------------------------------------------|
| Function | <code>ios_base&amp; boolalpha(ios_base&amp; str)</code>   | Specifies bool type format                     |
|          | <code>ios_base&amp; noboolalpha(ios_base&amp; str)</code> | Clears bool type format                        |
|          | <code>ios_base&amp; showbase(ios_base&amp; str)</code>    | Specifies the radix display prefix mode        |
|          | <code>ios_base&amp; noshowbase(ios_base&amp; str)</code>  | Clears the radix display prefix mode           |
|          | <code>ios_base&amp; showpoint(ios_base&amp; str)</code>   | Specifies the decimal-point generation mode    |
|          | <code>ios_base&amp; noshowpoint(ios_base&amp; str)</code> | Clears the decimal-point generation mode       |
|          | <code>ios_base&amp; showpos(ios_base&amp; str)</code>     | Specifies the + sign generation mode           |
|          | <code>ios_base&amp; noshowpos(ios_base&amp; str)</code>   | Clears the + sign generation mode              |
|          | <code>ios_base&amp; skipws(ios_base&amp; str)</code>      | Specifies the space skipping mode              |
|          | <code>ios_base&amp; noskipws(ios_base&amp; str)</code>    | Clears the space skipping mode                 |
|          | <code>ios_base&amp; uppercase(ios_base&amp; str)</code>   | Specifies the uppercase letter conversion mode |
|          | <code>ios_base&amp; nouppercase(ios_base&amp; str)</code> | Clears the uppercase letter conversion mode    |
|          | <code>ios_base&amp; internal(ios_base&amp; str)</code>    | Specifies the internal fill mode               |
|          | <code>ios_base&amp; left(ios_base&amp; str)</code>        | Clears the left side fill mode                 |
|          | <code>ios_base&amp; right(ios_base&amp; str)</code>       | Clears the right side fill mode                |
|          | <code>ios_base&amp; dec(ios_base&amp; str)</code>         | Specifies the decimal mode                     |
|          | <code>ios_base&amp; hex(ios_base&amp; str)</code>         | Specifies the hexadecimal mode                 |
|          | <code>ios_base&amp; oct(ios_base&amp; str)</code>         | Specifies the octal mode                       |
|          | <code>ios_base&amp; fixed(ios_base&amp; str)</code>       | Specifies the fixed-point output mode          |
|          | <code>ios_base&amp; scientific(ios_base&amp; str)</code>  | Specifies the scientific description mode      |

1. `ios_base& boolalpha(ios_base& str)`  
Specifies bool type format.  
Return value: str
2. `ios_base& noboolalpha(ios_base& str)`  
Clears bool type format.  
Return value: str

3. `ios_base& showbase(ios_base& str)`  
Specifies an output mode of prefixing a radix at the beginning of data.  
For a hexadecimal, 0x is prefixed.  
For a decimal, nothing is prefixed. For an octal, 0 is prefixed.  
Return value: `str`
4. `ios_base& noshowbase(ios_base& str)`  
Clears the output mode of prefixing a radix at the beginning of data.  
Return value: `str`
5. `ios_base& showpoint(ios_base& str)`  
Specifies the output mode of showing decimal point.  
If no precision is specified, six decimal-point (fraction) digits are displayed.  
Return value: `str`
6. `ios_base& noshowpoint(ios_base& str)`  
Clears the output mode of showing decimal point.  
Return value: `str`
7. `ios_base& showpos(ios_base& str)`  
Specifies the output mode of generating the + sign (adds a + sign to a positive number).  
Return value: `str`
8. `ios_base& noshowpos(ios_base& str)`  
Clears the output mode of generating the + sign.  
Return value: `str`
9. `ios_base& skipws(ios_base& str)`  
Specifies the input mode of skipping spaces (skips consecutive spaces).  
Return value: `str`
10. `ios_base& noskipws (ios_base& str)`  
Clears the input mode of skipping spaces.  
Return value: `str`

11. `ios_base& uppercase(ios_base& str)`  
Specifies the output mode of converting letters to uppercases.  
In hexadecimal, the radix will be the uppercase letters 0X, and the numeric value letters will be uppercase letters. The exponential representation of a floating-point value will also use uppercase letter E.  
Return value: `str`
12. `ios_base& nouppercase(ios_base& str)`  
Clears the output mode of converting letters to uppercases.  
Return value: `str`
13. `ios_base& internal(ios_base& str)`  
When data is output in the field width (**wide**) range, it is output in the order of
  1. Sign and radix
  2. Fill character (fill)
  3. Numeric valueReturn value: `str`
14. `ios_base& left(ios_base& str)`  
When data is output in the field width (**wide**) range, it is aligned to the left.  
Return value: `str`
15. `ios_base& right(ios_base& str)`  
When data is output in the field width (**wide**) range, it is aligned to the right.  
Return value: `str`
16. `ios_base& dec(ios_base& str)`  
Specifies the conversion radix to the decimal mode.  
Return value: `str`
17. `ios_base& hex(ios_base& str)`  
Specifies the conversion radix to the hexadecimal mode.  
Return value: `str`
18. `ios_base& oct(ios_base& str)`  
Specifies the conversion radix to the octal mode.  
Return value: `str`

19. `ios_base& fixed(ios_base& str)`

Specifies the fixed-point output mode.

Return value: `str`

20. `ios_base& scientific(ios_base& str)`

Specifies the scientific description mode (exponential description).

Return value: `str`

**(e) streambuf Class**

| Type     | Definition Name                                                                                                                               | Description                                                                                                                                                                       |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Constant | eof                                                                                                                                           | Indicates the end of file.                                                                                                                                                        |
| Variable | <code>_B_cnt_ptr</code>                                                                                                                       | Pointer to the length of valid data of the buffer.                                                                                                                                |
|          | <code>B_beg_ptr</code>                                                                                                                        | Pointer to the base pointer of the buffer.                                                                                                                                        |
|          | <code>_B_len_ptr</code>                                                                                                                       | Pointer to the length of the buffer.                                                                                                                                              |
|          | <code>B_next_ptr</code>                                                                                                                       | Pointer to the next position of the buffer from which data is to be read.                                                                                                         |
|          | <code>B_end_ptr</code>                                                                                                                        | Pointer to the end position of the buffer.                                                                                                                                        |
|          | <code>B_beg_pptr</code>                                                                                                                       | Pointer to the start position of the control buffer.                                                                                                                              |
|          | <code>B_next_pptr</code>                                                                                                                      | Pointer to the next position of the buffer from which to read data.                                                                                                               |
|          | <code>C_flg_ptr</code>                                                                                                                        | Pointer to the input/output control flag of the file.                                                                                                                             |
| Function | <code>char* _ec2p_getflag() const</code>                                                                                                      | Reads the pointer for file input/output control flag.                                                                                                                             |
|          | <code>char*&amp; _ec2p_gnptr()</code>                                                                                                         | Reads the pointer to the next position of the buffer from which data is to be read.                                                                                               |
|          | <code>char*&amp; _ec2p_pnptr()</code>                                                                                                         | Reads the pointer to the next position of the buffer where data is to be written.                                                                                                 |
|          | <code>void _ec2p_bcntplus()</code>                                                                                                            | Increments the valid data length of the buffer.                                                                                                                                   |
|          | <code>void _ec2p_bcntminus()</code>                                                                                                           | Decrements the valid data length of the buffer.                                                                                                                                   |
|          | <code>void _ec2p_setbPtr(<br/>char** begptr,<br/>char** curptr,<br/>long* cntptr,<br/>long* lenptr,<br/>char* flgptr)</code>                  | Sets the pointers of streambuf.                                                                                                                                                   |
|          | <code>streambuf()</code>                                                                                                                      | Constructor.                                                                                                                                                                      |
|          | <code>virtual ~streambuf()</code>                                                                                                             | Destructor.                                                                                                                                                                       |
|          | <code>streambuf* pubsetbuf(char* s,<br/>streamsize n)</code>                                                                                  | Reserves buffer for stream input/output. This function calls <code>setbuf(s,n)</code> <sup>*1</sup> .                                                                             |
|          | <code>pos_type pubseekoff(<br/>off_type off,<br/>ios_base::seekdir way,<br/>ios_base::openmode<br/>which=ios_base::in   ios_base::out)</code> | Moves the position to read or write data in the input/output stream by using the method specified by way. This function calls <code>seekoff(off,way,which)</code> <sup>*1</sup> . |

| Type     | Definition Name                                                                                   | Description                                                                                                                 |
|----------|---------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Function | pos_type pubseekpos(<br>pos_type sp,<br>ios_base::openmode<br>which=ios_base::in   ios_base::out) | Calculates the offset from the beginning of the stream to the current position.<br>This function calls seekpos(sp,which)*1. |
|          | int pubsync()                                                                                     | Flushes the output stream.<br>This function calls sync()*1.                                                                 |
|          | streamsize in_avail()                                                                             | Calculates the offset from the end of the input stream to the current position.                                             |
|          | int_type snextc()                                                                                 | Reads the next character.                                                                                                   |
|          | int_type sbumpc()                                                                                 | Reads one character and sets the pointer to the next character.                                                             |
|          | int_type sgetc()                                                                                  | Reads one character.                                                                                                        |
|          | int sgetn(char* s, streamsize n)                                                                  | Reads n characters and sets them in the memory area specified by s.                                                         |
|          | int_type sputbackc(char c)                                                                        | Puts back the read position.                                                                                                |
|          | int sungetc()                                                                                     | Puts back the read position.                                                                                                |
|          | int sputc(char c)                                                                                 | Inserts character c.                                                                                                        |
|          | int_type sputn(const char* s,<br>streamsize n)                                                    | Inserts n characters at the position pointed to by s.                                                                       |
|          | char* eback() const                                                                               | Reads the start pointer of the input stream.                                                                                |
|          | char* gptr() const                                                                                | Reads the next pointer of the input stream.                                                                                 |
|          | char* egptr() const                                                                               | Reads the end pointer of the input stream.                                                                                  |
|          | void gbump(int n)                                                                                 | Moves the next pointer of the input stream for n.                                                                           |
|          | void setg(<br>char* gbeg,<br>char* gnext,<br>char* gend)                                          | Assigns each pointer of the input stream.                                                                                   |
|          | char* pbase() const                                                                               | Calculates the start pointer of the output stream.                                                                          |
|          | char* pptr() const                                                                                | Calculates the next pointer of the output stream.                                                                           |
|          | char* epptr() const                                                                               | Calculates the end pointer of the output stream.                                                                            |

| Type     | Definition Name                                                                                                                                       | Description                                                          |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Function | void pbump( int n)                                                                                                                                    | Moves the next pointer of the output stream by n.                    |
|          | void setp(char* pbeg, char* pend)                                                                                                                     | Assigns each pointer of the output stream.                           |
|          | virtual streambuf* setbuf(char* s, streamsize n)<br>*1                                                                                                | For each derived class, a defined operation is executed.             |
|          | virtual pos_type seekoff(<br>off_type off,<br>ios_base::seekdir way,<br>ios_base::openmode=(ios_base::openmode)<br>(ios_base::in   ios_base::out)) *1 | Changes the stream position.                                         |
|          | virtual pos_type seekpos(<br>pos_type sp,<br>ios_base::openmode=(ios_base::openmode)<br>(ios_base::in   ios_base::out)) *1                            | Changes the stream position.                                         |
|          | virtual int sync() *1                                                                                                                                 | Flushes the output stream.                                           |
|          | virtual int showmanyc() *1                                                                                                                            | Calculates the number of valid characters in the input stream.       |
|          | virtual streamsize xsgetn(char* s, streamsize n)                                                                                                      | Reads n characters and sets them in the memory area pointed to by s. |
|          | virtual int_type underflow() *1                                                                                                                       | Reads one character without moving the stream position.              |
|          | virtual int_type uflow() *1                                                                                                                           | Reads one character of the next pointer.                             |
|          | virtual int_type pbackfail(int type c = eof) *1                                                                                                       | Puts back the character specified by c.                              |
|          | virtual streamsize xsputn(const char* s,<br>streamsize n)                                                                                             | Inserts n characters in the position pointed to by s.                |
|          | virtual int_type overflow(int type c = eof) *1                                                                                                        | Inserts character c in the output stream.                            |

Note: 1. This class does not define the processing.



1. `streambuf::streambuf ()`  
 Constructor.  
 The initial settings are as follows:  
`_B_cnt_ptr = B_beg_ptr = B_next_ptr = B_end_ptr = C_flg_ptr = _B_len_ptr = 0`  
`B_beg_pptr = &B_beg_ptr`  
`B_next_pptr = &B_next_ptr`
2. `virtual streambuf::~~streambuf ()`  
 Destructor.
3. `streambuf* streambuf::pubsetbuf(char* s, streamsize n)`  
 Reserves the buffer for stream input/output.  
 This function calls **setbuf (s,n)**.  
 Return value: `setbuf(s,n)`
4. `pos_type streambuf::pubseekoff(off_type off, ios_base::seekdir way, ios_base::openmode which=(ios_base::openmode)(ios_base::in|ios_base::out))`  
 Moves the read or write position for the input/output stream by using the method specified by `way`.  
 This function calls **seekoff(off,way,which)**.  
 Return value: The stream position newly specified
5. `pos_type streambuf::pubseekpos(pos_type sp, ios_base::openmode which=(ios_base::openmode) (ios_base::in | ios_base::out))`  
 Calculates the offset from the beginning of the stream to the current position.  
 Moves the current stream pointer by the amount specified by `sp`.  
 This function calls **seekpos(sp,which)**.  
 Return value: The offset from the beginning of the stream
6. `int streambuf::pubsync()`  
 Flushes the output stream.  
 This function calls **sync()**.  
 Return value: 0
7. `streamsize streambuf::in_avail()`  
 Calculates the offset from the end of the input stream to the current position.  
 Return value: If the position where data is read is valid: The offset from the end of the stream to the current position.  
 If the position where data is read is invalid: 0 (**showmanyc()** is called)

8. `int_type streambuf::snextc()`  
Reads one character. If the character read is not **eof**, the next character is read.  
Return value: If the characters read is not **eof**: The character read  
If the characters read is **eof**: eof
9. `int_type streambuf::sbumpc()`  
Reads one character and moves forward the pointer to the next.  
Return value: If the position where data is read is valid: The character read  
If the position where data is read is invalid: eof
10. `int_type streambuf::sgetc()`  
Reads one character.  
Return value: If the position where data is read is valid: The character read  
If the position where data is read is invalid: eof
11. `int streambuf::sgetn(char* s, streamsize n)`  
Reads **n** characters and sets them in the memory area specified by **s**. If an **eof** is found in the string read, setting is terminated.  
Return value: The specified number of characters.
12. `int_type streambuf::sputback(char c) ;`  
If the data read position is correct and the put back data of the position is the same as **c**, the read position is put back.  
Return value: If the read position was put back: The value of **c**  
If the read position was not put back: eof
13. `int streambuf::sungetc()`  
If the data read position is correct, the read position is put back.  
Return value: If the read position was put back: The value that was put back  
If the read position was not put back: eof
14. `int streambuf::sputc(char c)`  
Inserts characters **c**.  
Return value: If the write position is correct: The value of **c**  
If the write position is incorrect: eof

15. `int_type streambuf::sputn(const char* s, streamsize n)`  
Inserts **n** characters at the position pointed to by **s**.  
If the buffer is smaller than **n**, the number of characters for the buffer is inserted.  
Return value: The number of characters inserted
16. `char* streambuf::eback() const`  
Calculates the start pointer of the input stream.  
Return value: Start pointer
17. `char* streambuf::gptr() const`  
Calculates the next pointer of the input stream.  
Return value: Next pointer
18. `char* streambuf::egptr() const`  
Calculates the end pointer of the input stream.  
Return value: End pointer
19. `void streambuf::gbump(int n)`  
Moves forward the next pointer of the input stream by **n**.
20. `void streambuf::setg(char* gbeg, char* gnext, char* gend)`  
Sets each pointer of the input stream as follows:  
    `*B_beg_pptr = gbeg;`  
    `*B_next_pptr = gnext;`  
    `B_end_ptr = gend;`  
    `*_B_cnt_ptr = gend-gnext;`  
    `*_B_len_ptr = gend-gbeg;`
21. `char* streambuf::pbase() const`  
Calculates the start pointer of the output stream.  
Return value: Start pointer
22. `char* streambuf::pptr () const`  
Calculates the next pointer of the output stream.  
Return value: Next pointer
23. `char* streambuf::eptr () const`  
Calculates the end pointer of the output stream.  
Return value: End pointer

24. `void streambuf::pbump (int n)`  
 Moves forward the next pointer of the output stream by **n**.
25. `void streambuf::setp(char* pbeg, char* pend)`  
 The settings for each pointer of the output stream are as follows:  
`*B_beg_pptr = pbeg;`  
`*B_next_pptr = pbeg;`  
`B_end_ptr = pend;`  
`*_B_cnt_ptr=pend-pbeg;`  
`*_B_len_ptr=pend-pbeg;`
26. `virtual streambuf* streambuf::setbuf(char* s, streamsize n)`  
 For each derived class from `streambuf`, a defined operation is executed.  
 Return value: `*this` (Process done by this member function is not defined.)
27. `virtual pos_type streambuf::seekoff(off_type off, ios_base::seekdir way ,  
ios_base::openmode=(ios_base::openmode)(ios_base::in | ios_base::out))`  
 Changes the stream position.  
 Return value: -1 (Process done by this member function is not defined.)
28. `virtual pos_type streambuf::seekpos(pos_type sp,  
ios_base::openmode=(ios_base::openmode)(ios_base::in | ios_base::out))`  
 Changes the stream position.  
 Return value: -1 (Process done by this member function is not defined.)
29. `virtual int streambuf::sync()`  
 Flushes the output stream.  
 Return value: 0 (Process done by this member function is not defined.)
30. `virtual int streambuf::showmanyc()`  
 Calculates the number of valid characters in the input stream.  
 Return value: 0 (Process done by this member function is not defined.)
31. `virtual streamsize streambuf::xsgetn(char* s, streamsize n)`  
 Reads **n** characters and sets them in the memory area specified by **s**.  
 If the buffer is smaller than **n**, the numbers of characters of the buffer is inserted.  
 Return value: The number of characters input

- 32. virtual int\_type streambuf::underflow()  
Reads one character without moving the stream position.  
Return value: eof (Process done by this member function is not defined.)
- 33. virtual int\_type streambuf::uflow()  
Reads one character of the next pointer.  
Return value: eof (Process done by this member function is not defined.)
- 34. virtual int\_type streambuf::pbackfail(int\_type c=eof)  
Puts back the character specified by **c**.  
Return value: eof (Process done by this member function is not defined.)
- 35. virtual streamsize streambuf::xsputn(const char\* s, streamsize n)  
Inserts **n** characters pointed to by **s** in to the stream position.  
If the buffer is smaller than **n**, the number of characters for the buffer is inserted.  
Return value: The number of characters inserted
- 36. virtual int\_type streambuf::overflow(int\_type c=eof)  
Inserts character **c** in the output stream.  
Return value: eof (Process done by this member function is not defined.)

**(f) istream::sentry Class**

| Type     | Definition Name                            | Description                                |
|----------|--------------------------------------------|--------------------------------------------|
| Variable | ok_                                        | Whether the current state is input-enabled |
| Function | sentry(istream& is, bool noskipws = false) | Constructor                                |
|          | ~sentry()                                  | Destructor                                 |
|          | operator bool()                            | References ok_                             |

1. istream::sentry::sentry (istream& is, bool noskipws=\_false)  
 Constructor of internal class **sentry**.  
 If **good()** is non-zero, enables input with or without a format.  
 If **tie()** is non-zero, flushes related output stream.
2. istream::sentry::~sentry ()  
 Destructor of internal class **sentry**
3. istream::sentry::operator bool()  
 Reads ok\_  
 Return value: ok\_

**(g) istream Class**

| Type     | Definition Name                                          | Description                                                             |
|----------|----------------------------------------------------------|-------------------------------------------------------------------------|
| Variable | chcount                                                  | The number of characters extracted by the input function called last.   |
| Function | int _ec2p_getistr(char* str, unsigned int dig, int mode) | Converts str with the radix specified by dig.                           |
|          | istream(streambuf* sb)                                   | Constructor.                                                            |
|          | virtual ~istream()                                       | Destructor.                                                             |
|          | istream& operator>>(bool& n)                             | Stores the extracted characters in n.                                   |
|          | istream& operator>>(short& n)                            |                                                                         |
|          | istream& operator>>(unsigned short& n)                   |                                                                         |
|          | istream& operator>>(int& n)                              |                                                                         |
|          | istream& operator>>(unsigned int& n)                     |                                                                         |
|          | istream& operator>>(long& n)                             |                                                                         |
|          | istream& operator>>(unsigned long& n)                    |                                                                         |
|          | istream& operator>>(long long& n)                        |                                                                         |
|          | istream& operator>>(unsigned long long& n)               |                                                                         |
|          | istream& operator>>(float& n)                            |                                                                         |
|          | istream& operator>>(double& n)                           |                                                                         |
|          | istream& operator>>(long double& n)                      |                                                                         |
|          | istream& operator>>(void*& p)                            |                                                                         |
|          | istream& operator >>(streambuf* sb)                      | Extracts characters and stores them in the memory area specified by sb. |
|          | streamsize gcount() const                                | Calculates chcount (number of characters extracted).                    |
|          | int_type get()                                           | Extracts a character.                                                   |

| Type     | Definition Name                                                    | Description                                                                                                                                             |
|----------|--------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| Function | istream& get(char& c)                                              | Stores the extracted characters in c.                                                                                                                   |
|          | istream& get(signed char& c)                                       |                                                                                                                                                         |
|          | istream& get(unsigned char& c)                                     |                                                                                                                                                         |
|          | istream& get(char* s, streamsize n)                                | Extracts string literals with size n-1 and stores them in the memory area specified by s.                                                               |
|          | istream& get(signed char* s, streamsize n)                         |                                                                                                                                                         |
|          | istream& get(unsigned char* s, streamsize n)                       |                                                                                                                                                         |
|          | istream& get(char* s, streamsize n, char delim)                    | Extracts string literals with size n-1 and stores them in the memory area specified by s.<br>If delim is found in the string literal, input is stopped. |
|          | istream& get(<br>signed char* s,<br>streamsize n,<br>char delim)   |                                                                                                                                                         |
|          | istream& get(<br>unsigned char* s,<br>streamsize n,<br>char delim) |                                                                                                                                                         |
|          | istream& get(streambuf& sb)                                        | Extracts string literals and stores them in the memory area specified by sb.                                                                            |
|          | istream& get(streambuf& sb, char delim)                            | Extracts string literals and stores them in the memory area specified by sb.<br>If character delim is found, input is stopped.                          |
|          | istream& getline(char* s, streamsize n)                            | Extracts string literals with size n-1 and stores them in the memory area specified by s.                                                               |
|          | istream& getline(signed char* s, streamsize n)                     |                                                                                                                                                         |
|          | istream& getline(unsigned char* s, streamsize n)                   |                                                                                                                                                         |



| Type       | Definition Name                                                             | Description                                                                                                                              |
|------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Function   | istream& getline(char* s, streamsize n, char delim)                         | Extracts string literals with size n-1 and stores them in the memory area specified by s. If character delim is found, input is stopped. |
|            | istream& getline(<br>signed char* s,<br>streamsize n,<br>char delim)        |                                                                                                                                          |
|            | istream& getline(<br>unsigned char* s,<br>streamsize n,<br>char delim)      |                                                                                                                                          |
|            | istream& ignore(<br>streamsize n=1,<br>int_type delim=streambuf::eof)       | Skips reading the number of characters specified by n. If character delim is found, skipping is stopped.                                 |
|            | int_type peek()                                                             | Seeks for input characters that can be acquired next.                                                                                    |
|            | istream& read(char* s, streamsize n)                                        | Extracts string literals with size n and stores them in the memory area specified by s.                                                  |
|            | istream& read(signed char* s, streamsize n)                                 |                                                                                                                                          |
|            | istream& read(unsigned char* s, streamsize n)                               |                                                                                                                                          |
|            | streamsize readsome(char* s, streamsize n)                                  | Extracts the number of string literals specified by n and stores them in the memory area specified by s.                                 |
|            | streamsize readsome(signed char* s, streamsize n)                           |                                                                                                                                          |
|            | streamsize readsome(<br>unsigned char* s,<br>streamsize n)                  |                                                                                                                                          |
|            | istream& putback(char c)                                                    | Puts back a character to the input stream.                                                                                               |
|            | istream& unget()                                                            | Puts back the position of the input stream.                                                                                              |
| int sync() | Checks the existence of a stream. This function calls streambuf::pubsync(). |                                                                                                                                          |

| Type     | Definition Name                                     | Description                                                                                                                                    |
|----------|-----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Function | pos_type tellg()                                    | Finds the input stream position.<br>This function calls<br>streambuf::pubseekoff(0,cur,in).                                                    |
|          | istream& seekg(pos_type pos)                        | Moves the current stream pointer<br>by the amount specified by pos.<br>This function calls<br>streambuf::pubseekpos(pos).                      |
|          | istream& seekg(off_type off, ios_base::seekdir dir) | Moves the position to read the<br>input stream by using the method<br>specified by dir.<br>This function calls<br>stream::pubseekoff(off,dir). |

1. int istream::\_ec2p\_getistr(char\* str, unsigned int dig, int mode)  
Converts **str** to the radix specified by **dig**.  
Return value: Returns the converted radix.
2. istream::istream (streambuf\* sb)  
Constructor of class **istream**.  
Calls ios::init(sb).  
Specifies chcount=0.
3. virtual istream::~istream ()  
Destructor of class **istream**.
4. istream& istream::operator>> (bool& n)  
istream& istream::operator>>(short& n)  
istream& istream::operator>>(unsigned short& n)  
istream& istream::operator>>(int& n)  
istream& istream::operator>>(unsigned int& n)  
istream& istream::operator>>(long& n)  
istream& istream::operator>>(unsigned long& n)  
istream& istream::operator>>(long long& n)  
istream& istream::operator>>(unsigned long long& n)  
istream& istream::operator>>(float& n)  
istream& istream::operator>>(double& n)  
istream& istream::operator>>(long double& n)  
Stores the extracted characters in n.  
Return value: \*this

5. `istream& istream::operator>>(void*& p)`  
Converts the extracted characters to a `void*` type and stores them in the memory specified by `p`.  
Return value: `*this`
6. `istream& istream::operator>> (streambuf* sb)`  
Extracts characters and stores them in the memory area specified by `sb`.  
If there is no extracted characters, **setstate(failbit)** is called.  
Return value: `*this`
7. `streamsize istream::gcount() const`  
References **chcount (number of extracted characters)**.  
Return value: `chcount`
8. `int_type istream::get()`  
Extracts a character.  
Return value: If characters are extracted: Extracted characters.  
If no characters are extracted: Calls **setstate(failbit)**, `streambuf::eof`.
9. `istream& istream::get (char& c)`  
`istream& istream::get(signed char& c)`  
`istream& istream::get(unsigned char& c)`  
Extracts a character and stores it in `c`. If the extracted character is `streambuf::eof`, **failbit** is set.  
Return value: `*this`
10. `istream& istream::get(char* s, streamsize n)`  
`istream& istream::get(signed char* s, streamsize n)`  
`istream& istream::get(unsigned char* s, streamsize n)`  
Extracts a string literal with size `n-1` and stores it in the memory area specified by `s`. If `ok_==false` or no character has been extracted, **failbit** is set.  
Return value: `*this`
11. `istream& istream::get (char* s, streamsize n, char delim)`  
`istream& istream::get(signed char* s, streamsize n, char delim)`  
`istream& istream::get(unsigned char* s, streamsize n, char delim)`  
Extracts a string literal with size `n-1` and stores it in the memory area specified by `s`.  
If **delim** is found in the string literal, input is stopped.  
If `ok_==false` or no character has been extracted, **failbit** is set.  
Return value: `*this`

12. `istream& istream::get (streambuf& sb)`  
 Extracts a string literal and stores it in the memory area specified by **sb**.  
 If `ok_==false` or no character has been extracted, **failbit** is set.  
 Return value: `*this`
13. `istream& istream::get (streambuf& sb, char delim)`  
 Extracts a string literal and stores it in the memory area specified by **sb**.  
 If **delim** is found in the string literal, input is stopped.  
 If `ok_==false` or no character has been extracted, **failbit** is specified.  
 Return value: `*this`
14. `istream& istream::getline(char* s, streamsize n)`  
`istream& istream::getline(signed char* s, streamsize n)`  
`istream& istream::getline(unsigned char* s, streamsize n)`  
 Extracts **s** string literal with size `n-1` and stores it in the memory area specified by **s**.  
 If `ok_==false` or no character has been extracted, **failbit** is specified.  
 Return value: `*this`
15. `istream& istream::getline (char* s, streamsize n, char delim)`  
`istream& istream::getline(signed char* s, streamsize n, char delim)`  
`istream& istream::getline(unsigned char* s, streamsize n, char delim)`  
 Extracts a string literal with size `n-1` and stores it in the memory area specified by **s**.  
 If character **delim** is found, input is stopped.  
 If `ok_==false` or no character has been extracted, **failbit** is specified.  
 Return value: `*this`
16. `istream& istream::ignore(streamsize n = 1, int_type delim = streambuf::eof)`  
 Skips reading the number of characters specified by **n**.  
 If character **delim** is found, skipping is stopped.  
 Return value: `*this`
17. `int_type istream::peek()`  
 Seeks input characters that will be acquired next.  
 Return value: If `ok_==false`: `streambuf::eof`  
 If `ok_!=false`: `rdbuf()->sgetc()`

18. `istream& istream::read(char* s, streamsize n)`  
`istream& istream::read(signed char* s, streamsize n)`  
`istream& istream::read(unsigned char* s, streamsize n)`  
If `ok_!=false`, extracts a string literal with size **n** and stores it in the memory area specified by **s**.  
If the number of extracted characters does not match with the number of **n**, **eofbit** is specified.  
Return value: `*this`
19. `streamsize istream::readsome(char* s, streamsize n)`  
`streamsize istream::readsome(signed char* s, streamsize n)`  
`streamsize istream::readsome(unsigned char* s, streamsize n)`  
Extracts a string literal with size **n** and stores it in the memory area specified by **s**.  
If the number of characters exceeds the stream size, only the number of characters equal to the stream size is stored.  
Return value: The number of extracted characters
20. `istream& istream::putback(char c)`  
Puts back character **c** to the input stream.  
If the characters put back are `streambuf::eof`, **badbit** is set.  
Return value: `*this`
21. `istream& istream::unget()`  
Puts back the pointer of the input stream by one.  
If the extracted characters are `streambuf::eof`, **badbit** is set.  
Return value: `*this`
22. `int istream::sync()`  
Checks for an input stream.  
This function calls **`streambuf::pubsync()`**.  
Return value: If there is no input stream: `streambuf::eof`  
If there is an input stream: 0
23. `pos_type istream::tellg()`  
Checks for the position of an input stream.  
This function calls **`streambuf::pubseekoff(0,cur,in)`**.  
Return value: Offset from the beginning of the stream.  
If an input processing error occurs, -1 is returned.

24. `istream& istream::seekg (pos_type pos)`

Moves the current stream pointer for **pos**.

This function calls **`streambuf::pubseekpos(pos)`**.

Return value: `*this`

25. `istream& istream::seekg(off_type off, ios_base::seekdir dir)`

Moves the position to read the input stream using the method specified by **dir**.

This function calls **`streambuf::pubseekoff(off,dir)`**. If an input processing error occurs, this processing is not performed.

Return value: `*this`

### (h) istream Class Manipulator

| Type     | Definition Name                               | Description         |
|----------|-----------------------------------------------|---------------------|
| Function | <code>istream&amp; ws(istream&amp; is)</code> | Skips reading space |

1. `istream& ws(istream& is)`  
 Skips reading white space.  
 Return value: `is`

### (i) istream Non-Member Function

| Type     | Definition Name                                                                   | Description                                                                                    |
|----------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| Function | <code>istream&amp; operator&gt;&gt;(istream&amp; in, char* s)</code>              | Extracts a string of characters and stores them in the memory area specified by <code>s</code> |
|          | <code>istream&amp; operator&gt;&gt;(istream&amp; in, signed char* s)</code>       |                                                                                                |
|          | <code>istream&amp; operator&gt;&gt;(istream&amp; in, unsigned char* s)</code>     |                                                                                                |
|          | <code>istream&amp; operator&gt;&gt;(istream&amp; in, char&amp; c)</code>          | Extracts a character and stores it in <code>c</code>                                           |
|          | <code>istream&amp; operator&gt;&gt;(istream&amp; in, signed char&amp; c)</code>   |                                                                                                |
|          | <code>istream&amp; operator&gt;&gt;(istream&amp; in, unsigned char&amp; c)</code> |                                                                                                |

1. `istream& operator>>(istream& in, char* s)`  
`istream& operator>>(istream& in, signed char* s)`  
`istream& operator>>(istream& in, unsigned char* s)`  
 Extracts characters and stores them in the memory area specified by `s`. Processing is terminated if
  - the number of characters stored is equal to field width – 1
  - `streambuf::eof` is found in the input stream
  - the next available character `c` satisfies `isspace(c) == 1`
 If no characters are stored, **failbit** is specified.  
 Return value: `in`
2. `istream& operator>>(istream& in, char& c)`  
`istream& operator>>(istream& in, signed char& c)`  
`istream& operator>>(istream& in, unsigned char& c)`  
 Extracts a character and stores it in `c`. If no character is stored, **failbit** is set.  
 Return value: `in`

**(j) ostream::sentry Class****Definition Names**

| Type     | Definition Name     | Description                                    |
|----------|---------------------|------------------------------------------------|
| Variable | ok_                 | Whether or not the current state allows output |
|          | __ec2p_os           | Pointer to the ostream object                  |
| Function | sentry(ostream& os) | Constructor                                    |
|          | ~sentry()           | Destructor                                     |
|          | operator bool()     | References ok_                                 |

1. ostream::sentry::sentry (ostream& os)  
 Constructor of the internal class **sentry**.  
 If **good()** is non-zero and **tie()** is non-zero, **flush()** is called.  
 Specifies **os** to **\_\_ec2p\_os**.
2. ostream::sentry::~sentry ()  
 Destructor of internal class **sentry**.  
 If (**\_\_ec2p\_os->flags()** & **ios\_base::unitbuf**) is true, **flush()** is called.
3. ostream::sentry::operator bool ()  
 References **ok\_**.  
 Return value: **ok\_**.



**(k) ostream Class**

| <b>Type</b> | <b>Definition Name</b>                    | <b>Description</b>                                         |
|-------------|-------------------------------------------|------------------------------------------------------------|
| Function    | ostream(streambuf* sbptr)                 | Constructor.                                               |
|             | virtual~ostream()                         | Destructor.                                                |
|             | ostream& operator<<(bool n)               | Inserts n in the output stream.                            |
|             | ostream& operator<<(short n)              |                                                            |
|             | ostream& operator<<(unsigned short n)     |                                                            |
|             | ostream& operator<<(int n)                |                                                            |
|             | ostream& operator<<(unsigned int n)       |                                                            |
|             | ostream& operator<<(long n)               |                                                            |
|             | ostream& operator<<(unsigned long n)      |                                                            |
|             | ostream& operator<<(long long n)          |                                                            |
|             | ostream& operator<<(unsigned long long n) |                                                            |
|             | ostream& operator<<(float n)              |                                                            |
|             | ostream& operator<<(double n)             |                                                            |
|             | ostream& operator<<(long double n)        |                                                            |
|             | ostream& operator<<(void* n)              |                                                            |
|             | ostream& operator<<(streambuf* sbptr)     | Inserts the output stream of sbptr into the output stream. |
|             | ostream& putc(char c)                     | Inserts a character c into the output stream.              |

| Type     | Definition Name                                                                | Description                                                                                                                                                                                                          |
|----------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Function | <code>ostream&amp; write(<br/>const char* s,<br/>streamsize n)</code>          | Inserts n characters from s into the output stream.                                                                                                                                                                  |
|          | <code>ostream&amp; write(<br/>const signed char* s,<br/>streamsize n)</code>   |                                                                                                                                                                                                                      |
|          | <code>ostream&amp; write(<br/>const unsigned char* s,<br/>streamsize n)</code> |                                                                                                                                                                                                                      |
|          | <code>ostream&amp; flush()</code>                                              | Flushes the output stream.<br>This function calls <code>streambuf::pubsync()</code> .                                                                                                                                |
|          | <code>pos_type tellp()</code>                                                  | Calculates the current write position.<br>This function calls <code>streambuf::pubseekoff(0,cur,out)</code> .                                                                                                        |
|          | <code>ostream&amp; seekp(pos_type pos)</code>                                  | Calculates the offset from the beginning of the stream to the current position.<br>Moves the current stream pointer by the amount specified by pos.<br>This function calls <code>streambuf::pubseekpos(pos)</code> . |
|          | <code>ostream&amp; seekp(off_type off, seekdir dir)</code>                     | Moves the stream write position by the amount specified by off, from dir.<br>This function calls <code>streambuf::pubseekoff(off,dir)</code> .                                                                       |

1. `ostream::ostream (streambuf* sbptr)`  
Constructor.  
Calls `ios(sbptr)`.
2. `virtual ostream::~~ostream ()`  
Destructor.

3. `ostream& ostream::operator<<(bool n)`  
`ostream& ostream::operator<<(short n)`  
`ostream& ostream::operator<<(unsigned short n)`  
`ostream& ostream::operator<<(int n)`  
`ostream& ostream::operator<<(unsigned int n)`  
`ostream& ostream::operator<<(long n)`  
`ostream& ostream::operator<<(unsigned long n)`  
`ostream& ostream::operator<<(long long n)`  
`ostream& ostream::operator<<(unsigned long long n)`  
`ostream& ostream::operator<<(float n)`  
`ostream& ostream::operator<<(double n)`  
`ostream& ostream::operator<<(long double n)`  
`ostream& ostream::operator<<(void* n)`  
If `sentry::ok_==true`, **n** is inserted into the output stream.  
If `sentry::ok_==false`, **failbit** is specified.  
Return value: `*this`
4. `ostream& ostream::operator<<(streambuf* sbptr)`  
If `sentry::ok_==true`, the output string of **sbptr** is inserted into the output stream.  
If `sentry::ok_==false`, **failbit** is specified.  
Return value: `*this`
5. `ostream& ostream::putc(char c)`  
If `(sentry::ok_==true)` and `(rddbuf()->sputc(c)!=streambuf::eof)`, **c** is inserted into the output stream.  
Otherwise **failbit** is specified.  
Return value: `*this`
6. `ostream& ostream::write(const char* s, streamsize n)`  
`ostream& ostream::write(const signed char* s, streamsize n)`  
`ostream& ostream::write(const unsigned char* s, streamsize n)`  
If `(sentry::ok_==true)` and `(rddbuf()->sputn(s, n)==n)`, **n** characters pointed to by **s** is inserted to the output stream.  
Otherwise **badbit** is specified.  
Return value: `*this`

7. `ostream& ostream::flush()`  
Flushes the output stream.  
This function calls **`streambuf::pubsync()`**.  
Return value: `*this`
  
8. `pos_type ostream::tellp()`  
Calculates the current write position.  
This function calls **`streambuf::pubseekoff(0,cur,out)`**.  
Return value: The current stream position.  
If an error occurs during processing, -1 is returned.
  
9. `ostream& ostream::seekp(pos_type pos)`  
If no error occurs, the offset from the beginning of the stream to the current position is calculated.  
Moves the current stream by the amount specified by **`pos`**.  
This function calls **`streambuf::pubseekpos(pos)`**.  
Return value: `*this`
  
10. `ostream& ostream::seekp(off_type off, seekdir dir)`  
Moves the stream write position by the amount specified by **`off`**, from **`dir`**.  
This function calls **`streambuf::pubseekoff(off,dir)`**.  
Return value: `*this`

## (l) ostream Class Manipulator

| Type     | Definition Name                                  | Description                                      |
|----------|--------------------------------------------------|--------------------------------------------------|
| Function | <code>ostream&amp; endl(ostream&amp; os)</code>  | Inserts a new line and flushes the output stream |
|          | <code>ostream&amp; ends(ostream&amp; os)</code>  | Inserts a NULL code                              |
|          | <code>ostream&amp; flush(ostream&amp; os)</code> | Flushes the output stream                        |

1. `ostream& endl(ostream& os)`  
 Inserts a new line code and flushes the output stream.  
 This function calls **flush()**.  
 Return value: `os`
2. `ostream& ends(ostream& os)`  
 Inserts a NULL code to the output line.  
 Return value: `os`
3. `ostream& flush (ostream& os)`  
 Flushes the output stream.  
 This function calls **streambuf::sync()**.  
 Return value: `os`

**(m) ostream Non-Member Function**

| Type     | Definition Name                                          | Description                      |
|----------|----------------------------------------------------------|----------------------------------|
| Function | ostream& operator<<(ostream& os, char s)                 | Inserts s into the output stream |
|          | ostream& operator<<(ostream& os, signed char s)          |                                  |
|          | ostream& operator<<(ostream& os, unsigned char s)        |                                  |
|          | ostream& operator<<(ostream& os, const char* s)          |                                  |
|          | ostream& operator<<(ostream& os, const signed char* s)   |                                  |
|          | ostream& operator<<(ostream& os, const unsigned char* s) |                                  |

1. ostream& operator<<(ostream& os, char s)  
 ostream& operator<<(ostream& os, signed char s)  
 ostream& operator<<(ostream& os, unsigned char s)  
 ostream& operator<<(ostream& os, const char\* s)  
 ostream& operator<<(ostream& os, const signed char\* s)  
 ostream& operator<<(ostream& os, const unsigned char\* s)

If (sentry::ok\_==true) and an error does not occur, **s** is inserted into the output stream. Otherwise **failbit** is specified.

Return value: os

## (n) smanip Class Manipulator

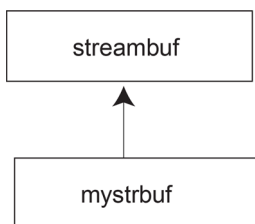
| Type     | Definition Name                               | Description                                 |
|----------|-----------------------------------------------|---------------------------------------------|
| Function | smanip resetiosflags(ios_base::fmtflags mask) | Clears the flag specified by the mask value |
|          | smanip setiosflags(ios_base::fmtflags mask)   | Specifies the format flag (fmtfl)           |
|          | smanip setbase(int base)                      | Specifies the radix used at output          |
|          | smanip setfill(char c)                        | Specifies the fill character (fillch)       |
|          | smanip setprecision(int n)                    | Specifies the precision (prec)              |
|          | smanip setw(int n)                            | Specifies the field width (wide)            |

1. smanip resetiosflags(ios\_base::fmtflags mask)  
Clears the flag specified by the **mask** value.  
Return value: Target object of input/output
2. smanip setiosflags(ios\_base::fmtflags mask)  
Specifies the format flag (**fmtfl**).  
Return value: Target object of input/output
3. smanip setbase(int base)  
Specifies the radix used by output.  
Return value: Target object of input/output
4. smanip setfill(char c);  
Specifies the fill characters (**fillch**).  
Return value: Target object of input/output
5. smanip setprecision(int n)  
Specifies the precision (**prec**).  
Return value: Target object of input/output
6. smanip setw(int n)  
Specifies the field width (**wide**).  
Return value: Target object of input/output

### (o) Example of Using EC++ Input/Output Libraries

Input/output stream can be used if a pointer to an object of the **mystrbuf** class is used instead of **streambuf** at the initialization of objects **istream** and **ostream**.

The following shows the inheritance relationship of the above classes. An arrow (->) indicates that a derived class at the start point refers to a base class at the end point.





| Type                                 | Definition Name                                                                                                                                                          | Description                                             |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| Variable                             | <code>_file_Ptr</code>                                                                                                                                                   | File pointer.                                           |
| Function                             | <code>mystdbuf()</code>                                                                                                                                                  | Constructor.                                            |
|                                      | <code>mystdbuf(void* ptr)</code>                                                                                                                                         | Initializes the streambuf buffer.                       |
|                                      | <code>virtual ~mystdbuf()</code>                                                                                                                                         | Destructor.                                             |
|                                      | <code>void* myfptr() const</code>                                                                                                                                        | Returns a pointer to the FILE type structure.           |
|                                      | <code>mystdbuf* open(<br/>const char*<br/>filename,<br/>int mode)</code>                                                                                                 | Specifies the file name and mode and opens the file.    |
|                                      | <code>mystdbuf* close()</code>                                                                                                                                           | Closes the file.                                        |
|                                      | <code>virtual streambuf* setbuf(char* s,<br/>streamsize n)</code>                                                                                                        | Reserves stream input/output buffer.                    |
|                                      | <code>virtual pos_type seekoff(<br/>off_type off,<br/>ios_base::seekdir way,<br/>ios_base::openmode=<br/>(ios_base::openmode)<br/>(ios_base::in   ios_base::out))</code> | Changes the position of the stream pointer.             |
|                                      | <code>virtual pos_type seekpos(<br/>pos_type sp,<br/>ios_base::openmode=<br/>(ios_base::openmode)<br/>(ios_base::in   ios_base::out))</code>                             | Changes the position of the stream pointer.             |
|                                      | <code>virtual int sync()</code>                                                                                                                                          | Flushes the stream.                                     |
|                                      | <code>virtual int showmanyc()</code>                                                                                                                                     | Returns the number of valid characters of input stream. |
|                                      | <code>virtual int_type underflow()</code>                                                                                                                                | Reads one character without moving the stream position. |
|                                      | <code>virtual int_type pbackfail(int type c =<br/>streambuf::eof)</code>                                                                                                 | Puts back the character specified by c.                 |
|                                      | <code>virtual int_type overflow(int type c =<br/>streambuf::eof)</code>                                                                                                  | Inserts character specified by c.                       |
| <code>void _Init(_f_type* fp)</code> | Initialization.                                                                                                                                                          |                                                         |

## &lt;Example&gt;

```
#include <istream>
#include <ostream>
#include <mystrbuf>
#include <string>
#include <new>
#include <stdio.h>

void main(void)
{
 mystrbuf myfin(stdin);
 mystrbuf myfout(stdout);
 istream mycin(&myfin);
 ostream mycout(&myfout);

 int i;
 short s;
 long l;
 char c;
 string str;

 mycin >> i >> s >> l >> c >> str;
 mycout << "This is EC++ Library." << endl
 << i << s << l << c << str << endl;

 return;
}
```

### (3) Memory Management Library

The header file for the memory management library is shown below.

<new>

Defines memory allocation/deallocation function.

By setting an exception processing function address to the **\_ec2p\_new\_handler** variable, exception processing can be executed if memory allocation fails. The **\_ec2p\_new\_handler** is a static variable and the initial value is NULL. If this handler is used, reentrance will be lost.

Operations required for the exception processing function (of the memory management library):

- Creates an allocatable area and returns the area.
- Operations are not prescribed for cases where an area cannot be created and returned.

| Type     | Definition Name                                             | Description                                                                          |
|----------|-------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Macro    | <code>new_handler</code>                                    | Pointer type to the function that returns a void type                                |
| Variable | <code>_ec2p_new_handler</code>                              | Pointer to an exception processing function                                          |
| Function | <code>void* operator new(size_t size)</code>                | Allocates memory area with a size specified by size                                  |
|          | <code>void* operator new[ ](size_t size)</code>             | Allocates array area with a size specified by size                                   |
|          | <code>void* operator new(size_t size, void* ptr)</code>     | Allocates the area specified by ptr as the memory area                               |
|          | <code>void* operator new[ ](size_t size, void* ptr)</code>  | Allocates the area specified by ptr as the array area                                |
|          | <code>void operator delete(void* ptr)</code>                | Deallocates the memory area                                                          |
|          | <code>void operator delete[ ](void* ptr)</code>             | Deallocates the array area                                                           |
|          | <code>new_handler set_new_handler(new_handler new_P)</code> | Sets exception processing function address (new_P) in <code>_ec2p_new_handler</code> |

1. `void* operator new(size_t size)`  
Allocates a memory area with the size specified by **size**.  
If allocation fails and when the **new\_handler** is set, **new\_handler** is called.  
Return value: If memory allocation succeeds: Pointer to void type  
If memory allocation fails: NULL
2. `void* operator new[ ](size_t size)`  
Allocates an array area with the size specified by **size**.  
If allocation fails and when the **new\_handler** is set, **new\_handler** is called.  
Return value: If memory allocation succeeds: Pointer to void type  
If memory allocation fails: NULL
3. `void* operator new (size_t size, void* ptr)`  
Allocates the area specified by **ptr** as the storage area.  
Return value: **ptr**
4. `void* operator new [ ](size_t size, void* ptr)`  
Allocates the area specified by **ptr** as the array area.  
Return value: **ptr**
5. `void operator delete(void* ptr)`  
Deallocates the storage area specified by **ptr**.  
If **ptr** is NULL, no operation will be performed.
6. `void operator delete [ ](void* ptr)`  
Deallocates the array area specified by **ptr**.  
If **ptr** is NULL, no operation will be performed.
7. `new_handler set_new_handler(new_handler new_P)`  
Sets **new\_P** to **\_ec2p\_new\_handler**.  
Return value: **\_ec2p\_new\_handler**

#### (4) Complex Number Calculation Class Libraries

The header file for the complex number calculation class libraries is as follows.

<complex>

Defines float\_complex class and double\_complex class.

These classes have no derivation.

**(a) float\_complex Class**

| Type                                                | Definition Name                                        | Description                                                                   |
|-----------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------------------|
| Type                                                | value_type                                             | float type.                                                                   |
| Variable                                            | _re                                                    | Defines the real part of float precision.                                     |
|                                                     | _im                                                    | Defines the imaginary part of float precision.                                |
| Function                                            | float_complex(float re = 0.0f, float im = 0.0f)        | Constructor.                                                                  |
|                                                     | float_complex(const double_complex& rhs)               |                                                                               |
|                                                     | float real() const                                     | Reads the real part (_re).                                                    |
|                                                     | float imag() const                                     | Reads the imaginary part (_im).                                               |
|                                                     | float_complex& operator=(float rhs)                    | Copies rhs to the real part.<br>0.0f is assigned to the imaginary part.       |
|                                                     | float_complex& operator+=(float rhs)                   | Adds rhs to the real part of *this and stores the sum in *this.               |
|                                                     | float_complex& operator-=(float rhs)                   | Subtracts rhs from the real part of *this and stores the difference in *this. |
|                                                     | float_complex& operator*=(float rhs)                   | Multiplies *this by rhs and stores the product in *this.                      |
|                                                     | float_complex& operator/=(float rhs)                   | Divides *this by rhs and stores the quotient in *this.                        |
|                                                     | float_complex& operator=(const float_complex& rhs)     | Copies rhs to *this.                                                          |
|                                                     | float_complex& operator+=(const float_complex& rhs)    | Adds rhs to *this and stores the sum in *this.                                |
|                                                     | float_complex& operator-=(const float_complex& rhs)    | Subtracts rhs from *this and stores the difference in *this.                  |
|                                                     | float_complex& operator*=(const float_complex& rhs)    | Multiplies *this by rhs and stores the product in *this.                      |
| float_complex& operator/=(const float_complex& rhs) | Divides *this by rhs and stores the quotient in *this. |                                                                               |

1. `float_complex::float_complex (float re=0.0f, float im=0.0f)`  
Constructor of class `float_complex`.  
The initial settings are as follows:  
`_re = re;`  
`_im = im;`
2. `float_complex::float_complex (const double_complex& rhs)`  
Constructor of class `float_complex`.  
The initial settings are as follows:  
`_re = (float)rhs.real();`  
`_im = (float)rhs.imag();`
3. `float float_complex::real() const`  
Reads the real part.  
Return value: `this->_re`
4. `float float_complex::imag() const`  
Reads the imaginary part.  
Return value: `this->_im`
5. `float_complex& float_complex::operator=(float rhs)`  
Copies **rhs** to the real part (**\_re**).  
0.0f is assigned to the imaginary part (**\_im**).  
Return value: `*this`
6. `float_complex& float_complex::operator+=(float rhs)`  
Adds **rhs** to the real part (**\_re**) and stores the sum in the real part (**\_re**).  
The value of the imaginary part (**\_im**) does not change.  
Return value: `*this`
7. `float_complex& float_complex::operator-=(float rhs)`  
Subtracts **rhs** from the real part (**\_re**) and stores the difference in the real part (**\_re**).  
The value of the imaginary part (**\_im**) does not change.  
Return value: `*this`
8. `float_complex& float_complex::operator*=(float rhs)`  
Multiplies `*this` by **rhs** and stores the product in `*this`.  
(`_re=_re*rhs, _im=_im*rhs`)  
Return value: `*this`

9. `float_complex& float_complex::operator/=(float rhs)`  
Divides `*this` by **rhs** and stores the quotient in `*this`.  
(`_re=_re/rhs, _im=_im/rhs`)  
Return value: `*this`
  
10. `float_complex& float_complex::operator=(const float_complex& rhs)`  
Copies **rhs** to `*this`.  
Return value: `*this`
  
11. `float_complex& float_complex::operator+=(const float_complex& rhs)`  
Adds **rhs** to `*this` and stores the sum in `*this`  
Return value: `*this`
  
12. `float_complex& float_complex::operator-=(const float_complex& rhs)`  
Subtracts **rhs** from `*this` and stores the difference in `*this`.  
Return value: `*this`
  
13. `float_complex& float_complex::operator*=(const float_complex& rhs)`  
Multiplies `*this` by **rhs** and stores the product in `*this`.  
Return value: `*this`
  
14. `float_complex& float_complex::operator/=(const float_complex& rhs)`  
Divides `*this` by **rhs** and stores the quotient in `*this`.  
Return value: `*this`



**(b) float\_complex Non-Member Function**

| Type     | Definition Name                                                                     | Description                                             |
|----------|-------------------------------------------------------------------------------------|---------------------------------------------------------|
| Function | float_complex operator+(<br>const float_complex& lhs)                               | Performs unary + operation of lhs                       |
|          | float_complex operator+(<br>const float_complex& lhs,<br>const float_complex& rhs)  | Adds lhs to rhs and stores the sum in lhs               |
|          | float_complex operator+(<br>const float_complex& lhs,<br>const float& rhs)          |                                                         |
|          | float_complex operator+(<br>const float& lhs,<br>const float_complex& rhs)          |                                                         |
|          | float_complex operator-(<br>const float_complex& lhs)                               | Performs unary - operation of lhs                       |
|          | float_complex operator-(<br>const float_complex& lhs,<br>const float_complex& rhs)  | Subtracts rhs from lhs and stores the difference in lhs |
|          | float_complex operator-(<br>const float_complex& lhs,<br>const float& rhs)          |                                                         |
|          | float_complex operator-(<br>const float& lhs,<br>const float_complex& rhs)          |                                                         |
|          | float_complex operator*(<br>const float_complex& lhs,<br>const float_complex& rhs)  | Multiplies lhs by rhs and stores the product in lhs     |
|          | float_complex operator*(<br>const float_complex& lhs,<br>const float& rhs)          |                                                         |
|          | float_complex operator*(<br>const float& lhs,<br>const float_complex& rhs)          |                                                         |
|          | float_complex operator/ (<br>const float_complex& lhs,<br>const float_complex& rhs) | Divides lhs by rhs and stores the quotient in lhs       |
|          | float_complex operator/ (<br>const float_complex& lhs,<br>const float& rhs)         |                                                         |

| Type     | Definition Name                                                                           | Description                                                                    |
|----------|-------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Function | <code>float_complex operator/ (const float&amp; lhs, const float_complex&amp; rhs)</code> | Divides lhs by rhs and stores the quotient in lhs                              |
|          | <code>bool operator==(const float_complex&amp; lhs, const float_complex&amp; rhs)</code>  | Compares the real parts of lhs and rhs, and the imaginary parts of lhs and rhs |
|          | <code>bool operator==(const float_complex&amp; lhs, const float&amp; rhs)</code>          |                                                                                |
|          | <code>bool operator==(const float&amp; lhs, const float_complex&amp; rhs)</code>          |                                                                                |
|          | <code>bool operator!=(const float_complex&amp; lhs, const float_complex&amp; rhs)</code>  | Compares the real parts of lhs and rhs, and the imaginary parts of lhs and rhs |
|          | <code>bool operator!=(const float_complex&amp; lhs, const float&amp; rhs)</code>          |                                                                                |
|          | <code>bool operator!=(const float&amp; lhs, const float_complex&amp; rhs)</code>          |                                                                                |
|          | <code>istream&amp; operator&gt;&gt;(istream&amp; is, float_complex&amp; x)</code>         | Inputs x in a format of u, (u), or (u,v)(u: real part, v: imaginary part)      |
|          | <code>ostream&amp; operator&lt;&lt;(ostream&amp; os, const float_complex&amp; x)</code>   | Outputs x in a format of u, (u), or (u,v)(u: real part, v: imaginary part)     |
|          | <code>float real(const float_complex&amp; x)</code>                                       | Reads the real part                                                            |
|          | <code>float imag(const float_complex&amp; x)</code>                                       | Reads the imaginary part                                                       |
|          | <code>float abs(const float_complex&amp; x)</code>                                        | Calculates the absolute value                                                  |
|          | <code>float arg(const float_complex&amp; x)</code>                                        | Calculates the phase angle                                                     |
|          | <code>float norm(const float_complex&amp; x)</code>                                       | Calculates the absolute value of the square                                    |
|          | <code>float_complex conj(const float_complex&amp; x)</code>                               | Calculates the conjugate complex number of x                                   |

| Type     | Definition Name                                                          | Description                                                                                 |
|----------|--------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Function | float_complex polar(<br>const float& rho,<br>const float& theta)         | Calculates the float_complex value for a complex number with size rho and phase angle theta |
|          | float_complex cos(const float_complex& x)                                | Calculates the complex cosine                                                               |
|          | float_complex cosh(const float_complex& x)                               | Calculates the complex hyperbolic cosine                                                    |
|          | float_complex exp(const float_complex& x)                                | Calculates the exponent function                                                            |
|          | float_complex log(const float_complex& x)                                | Calculates the natural logarithm                                                            |
|          | float_complex log10(const float_complex& x)                              | Calculates the common logarithm                                                             |
|          | float_complex pow(<br>const float_complex& x,<br>int y)                  | Calculates the x to the yth power                                                           |
|          | float_complex pow(<br>const float_complex& x,<br>const float& y)         |                                                                                             |
|          | float_complex pow(<br>const float_complex& x,<br>const float_complex& y) |                                                                                             |
|          | float_complex pow(<br>const float& x,<br>const float_complex& y)         |                                                                                             |
|          | float_complex sin(const float_complex& x)                                | Calculates the complex sine                                                                 |
|          | float_complex sinh(const float_complex& x)                               | Calculates the complex hyperbolic sine                                                      |
|          | float_complex sqrt(const float_complex& x)                               | Calculates the square root within the right half space                                      |
|          | float_complex tan(const float_complex& x)                                | Calculates the complex tangent                                                              |
|          | float_complex tanh(const float_complex& x)                               | Calculates the complex hyperbolic tangent                                                   |

1. `float_complex operator+(const float_complex& lhs)`  
Performs unary + operation of **lhs**.  
Return value: `lhs`
2. `float_complex operator+(const float_complex& lhs, const float_complex& rhs)`  
`float_complex operator+(const float_complex& lhs, const float& rhs)`  
`float_complex operator+(const float& lhs, const float_complex& rhs)`  
Adds **lhs** to **rhs** and stores the sum in **lhs**.  
Return value: `float_complex(lhs)+=rhs`
3. `float_complex operator-(const float_complex& lhs)`  
Performs unary - operation of **lhs**.  
Return value: `float_complex(-lhs.real(),-lhs.imag())`
4. `float_complex operator-(const float_complex& lhs, const float_complex& rhs)`  
`float_complex operator-(const float_complex& lhs, const float& rhs)`  
`float_complex operator-(const float& lhs, const float_complex& rhs)`  
Subtracts **rhs** from **lhs** and stores the difference in **lhs**.  
Return value: `float_complex(lhs)-=rhs`
5. `float_complex operator*(const float_complex& lhs, const float_complex& rhs)`  
`float_complex operator*(const float_complex& lhs, const float& rhs)`  
`float_complex operator*(const float& lhs, const float_complex& rhs)`  
Multiplies **lhs** by **rhs** and stores the product in **lhs**.  
Return value: `float_complex(lhs)*=rhs`
6. `float_complex operator/(const float_complex& lhs, const float_complex& rhs)`  
`float_complex operator/(const float_complex& lhs, const float& rhs)`  
`float_complex operator/(const float& lhs, const float_complex& rhs)`  
Divides **lhs** by **rhs** and stores the quotient in **lhs**.  
Return value: `float_complex(lhs)/=rhs`

7. `bool operator==(const float_complex& lhs, const float_complex& rhs)`  
`bool operator==(const float_complex& lhs, const float& rhs)`  
`bool operator==(const float& lhs, const float_complex& rhs)`  
 Compares the real parts of **lhs** and **rhs**, and the imaginary parts of **lhs** and **rhs**.  
 For a float type parameter, the imaginary part is assumed to be 0.0f.  
 Return value: `lhs.real()==rhs.real() && lhs.imag()==rhs.imag()`
8. `bool operator!=(const float_complex& lhs, const float_complex& rhs)`  
`bool operator!=(const float_complex& lhs, const float& rhs)`  
`bool operator!=(const float& lhs, const float_complex& rhs)`  
 Compares the real parts of **lhs** and **rhs**, and the imaginary parts of **lhs** and **rhs**.  
 For a float type parameter, the imaginary part is assumed to be 0.0f.  
 Return value: `lhs.real()!=rhs.real() || lhs.imag()!=rhs.imag()`
9. `istream& operator>>(istream& is, float_complex& x)`  
 Inputs **x** as a format of `u,(u)`, or `(u,v)`(`u`: real part, `v`: imaginary part).  
 The input value is converted to `float_complex`.  
 If **x** is input in a format other than the `u`, `(u)`, or `(u,v)` format, `is.setstate(ios_base::failbit)` is called.  
 Return value: `is`
10. `ostream& operator<<(ostream& os, const float_complex& x)`  
 Outputs **x** to **os**.  
 The output format is `u`, `(u)`, or `(u,v)`(`u`: real part, `v`: imaginary part).  
 Return value: `os`
11. `float real(const float_complex& x)`  
 Reads the real part.  
 Return value: `x.real()`
12. `float imag(const float_complex& x)`  
 Reads the imaginary part.  
 Return value: `x.imag()`
13. `float abs(const float_complex& x)`  
 Calculates the absolute value.  
 Return value:  $(|x.real()|^2 + |x.imag()|^2)^{1/2}$

14. `float arg (const float_complex& x)`  
 Calculates the phase angle.  
 Return value: `atan2f(x.imag(), x.real())`
  
15. `float norm(const float_complex& x)`  
 Calculates the absolute value of the square.  
 Return value: `|x.real()|^2 + |x.imag()|^2`
  
16. `float_complex conj(const float_complex& x)`  
 Calculates the conjugate complex number of **x**.  
 Return value: `float_complex(x.real(), (-1)*x.imag())`
  
17. `float_complex polar(const float& rho, const float& theta)`  
 Calculates the `float_complex` value for a complex number with size **rho** and phase angle (argument) **theta**.  
 Return value: `float_complex(rho*cosf(theta), rho*sinf(theta))`
  
18. `float_complex cos(const float_complex& x)`  
 Calculates the complex cosine.  
 Return value: `float_complex(cosf(x.real())*coshf(x.imag()), (-1)*sinf(x.real())*sinhf(x.imag()))`
  
19. `float_complex cosh(const float_complex& x)`  
 Calculates the complex hyperbolic cosine.  
 Return value: `cos(float_complex((-1)*x.imag(), x.real()))`
  
20. `float_complex exp(const float_complex& x)`  
 Calculates the exponential function.  
 Return value: `float_complex(expf(x.real())*cosf(x.imag()), expf(x.real())*sinf(x.imag()))`
  
21. `float_complex log(const float_complex& x)`  
 Calculates the natural logarithm (base e).  
 Return value: `float_complex(logf(abs(x)), arg(x))`
  
22. `float_complex log10(const float_complex& x)`  
 Calculates the common logarithm (base 10).  
 Return value: `float_complex(log10f(abs(x)), arg(x)/logf(10))`

23. `float_complex pow(const float_complex& x, int y)`  
`float_complex pow(const float_complex& x, const float& y)`  
`float_complex pow(const float_complex& x, const float_complex& y)`  
`float_complex pow(const float& x, const float_complex& y)`  
Calculates the  $x$  to the  $y$ th power.  
If `pow(0,0)`, a domain error will occur.  
Return value: If `float_complex pow (const float_complex& x, const float_complex& y)`:  
 $\exp(y \cdot \log(x))$   
Otherwise:  $\exp(y \cdot \log(x))$
24. `float_complex sin(const float_complex& x)`  
Calculates complex sine.  
Return value: `float_complex(sin(x.real())*cosh(x.imag()), cos(x.real())*sinh(x.imag()))`
25. `float_complex sinh(const float_complex& x)`  
Calculates the complex hyperbolic sine.  
Return value: `float_complex(0,-1)*sin(float_complex((-1)*x.imag(),x.real()))`
26. `float_complex sqrt(const float_complex& x)`  
Calculates the square root within the right half space.  
Return value: `float_complex(sqrtf(abs(x))*cosf(arg(x)/2), sqrtf(abs(x))*sinf(arg(x)/2))`
27. `float_complex tan(const float_complex& x)`  
Calculates the complex tangent.  
Return value:  $\sin(x) / \cos(x)$
28. `float_complex tanh(const float_complex& x)`  
Calculates the complex hyperbolic tangent.  
Return value:  $\sinh(x) / \cosh(x)$

**(c) double\_complex Class**

| Type                                                      | Definition Name                                           | Description                                                                   |
|-----------------------------------------------------------|-----------------------------------------------------------|-------------------------------------------------------------------------------|
| Type                                                      | value_type                                                | double type                                                                   |
| Variable                                                  | _re                                                       | Defines the real part of double precision                                     |
|                                                           | _im                                                       | Defines the imaginary part of double precision                                |
| Function                                                  | double_complex(<br>double re=0.0,<br>double im=0.0)       | Constructor                                                                   |
|                                                           | double_complex(const float_complex&)                      |                                                                               |
|                                                           | double real() const                                       | Reads the real part                                                           |
|                                                           | double imag() const                                       | Reads the imaginary part                                                      |
|                                                           | double_complex& operator=(double rhs)                     | Copies rhs to the real part<br>0.0 is assigned to the imaginary part          |
|                                                           | double_complex& operator+=(double rhs)                    | Adds rhs to the real part of *this and stores the sum in *this                |
|                                                           | double_complex& operator-=(double rhs)                    | Subtracts rhs from the real part of *this and stores the difference in *this. |
|                                                           | double_complex& operator*=(double rhs)                    | Multiplies *this by rhs and stores the product in *this                       |
|                                                           | double_complex& operator/=(double rhs)                    | Divides *this by rhs and stores the quotient in *this                         |
|                                                           | double_complex& operator=(<br>const double_complex& rhs)  | Copies rhs                                                                    |
|                                                           | double_complex& operator+=(<br>const double_complex& rhs) | Adds rhs to *this and stores the sum in *this                                 |
|                                                           | double_complex& operator-=(<br>const double_complex& rhs) | Subtracts rhs from *this and stores the difference in *this                   |
|                                                           | double_complex& operator*=(<br>const double_complex& rhs) | Multiplies *this by rhs and stores the product in *this                       |
| double_complex& operator/=(<br>const double_complex& rhs) | Divides *this by rhs and stores the quotient in *this     |                                                                               |



1. `double_complex::double_complex (double re=0.0, double im=0.0)`  
Constructor of class `double_complex`.  
The initial settings are as follows:  
`_re = re;`  
`_im = im;`
2. `double_complex::double_complex (const float_complex&)`  
Constructor of class `double_complex`.  
The initial settings are as follows:  
`_re = (double)rhs.real();`  
`_im = (double)rhs.imag();`
3. `double double_complex::real() const`  
Reads the real part.  
Return value: `this->_re`
4. `double double_complex::imag() const`  
Reads the imaginary part.  
Return value: `this->_im`
5. `double_complex& double_complex::operator= (double rhs)`  
Copies **rhs** to the real part (**\_re**).  
0.0 is assigned to the imaginary part (**\_im**).  
Return value: `*this`
6. `double_complex& double_complex::operator+=(double rhs)`  
Adds **rhs** to the real part (**\_re**) and stores the sum in the real part (**\_re**).  
The value of the imaginary part (**\_im**) does not change.  
Return value: `*this`
7. `double_complex& double_complex::operator-= (double rhs)`  
Subtracts **rhs** from the real part (**\_re**) and stores the difference in the real part (**\_re**).  
The value of the imaginary part (**\_im**) does not change.  
Return value: `*this`

8. `double_complex& double_complex::operator*=(double rhs)`  
Multiplies `*this` by **rhs** and stores the product in `*this`.  
(`_re=_re*rhs, _im=_im*rhs`)  
Return value: `*this`
9. `double_complex& double_complex::operator/=(double rhs)`  
Divides `*this` by **rhs** and stores the quotient in `*this`.  
(`_re=_re/rhs, _im=_im/rhs`)  
Return value: `*this`
10. `double_complex& double_complex::operator=(const double_complex& rhs)`  
Copies **rhs** to `*this`.  
Return value: `*this`
11. `double_complex& double_complex::operator+=(const double_complex& rhs)`  
Adds **rhs** to `*this` and stores the sum in `*this`.  
Return value: `*this`
12. `double_complex& double_complex::operator-=(const double_complex& rhs)`  
Subtracts **rhs** from `*this` and stores the difference in `*this`.  
Return value: `*this`
13. `double_complex& double_complex::operator*=(const double_complex& rhs)`  
Multiplies `*this` by **rhs** and stores the product in `*this`.  
Return value: `*this`
14. `double_complex& double_complex::operator/=(const double_complex& rhs)`  
Divides `*this` by **rhs** and stores the quotient in `*this`.  
Return value: `*this`

**(d) double\_complex Non-Member Function**

| Type     | Definition Name                                                                                              | Description                                             |
|----------|--------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| Function | <code>double_complex operator+(<br/>const double_complex&amp; lhs)</code>                                    | Performs unary + operation of lhs                       |
|          | <code>double_complex operator+(<br/>const double_complex&amp; lhs,<br/>const double_complex&amp; rhs)</code> | Adds rhs to lhs and stores the sum in lhs               |
|          | <code>double_complex operator+(<br/>const double_complex&amp; lhs,<br/>const double&amp; rhs)</code>         |                                                         |
|          | <code>double_complex operator+(<br/>const double&amp; lhs,<br/>const double_complex&amp; rhs)</code>         |                                                         |
|          | <code>double_complex operator-(<br/>const double_complex&amp; lhs)</code>                                    | Performs unary - operation of lhs                       |
|          | <code>double_complex operator-(<br/>const double_complex&amp; lhs,<br/>const double_complex&amp; rhs)</code> | Subtracts rhs from lhs and stores the difference in lhs |
|          | <code>double_complex operator-(<br/>const double_complex&amp; lhs,<br/>const double&amp; rhs)</code>         |                                                         |
|          | <code>double_complex operator-(<br/>const double&amp; lhs,<br/>const double_complex&amp; rhs)</code>         |                                                         |
|          | <code>double_complex operator*(<br/>const double_complex&amp; lhs,<br/>const double_complex&amp; rhs)</code> | Multiplies lhs by rhs and stores the product in lhs     |
|          | <code>double_complex operator*(<br/>const double_complex&amp; lhs,<br/>const double&amp; rhs)</code>         |                                                         |
|          | <code>double_complex operator*(<br/>const double&amp; lhs,<br/>const double_complex&amp; rhs)</code>         |                                                         |
|          | <code>double_complex operator/(<br/>const double_complex&amp; lhs,<br/>const double_complex&amp; rhs)</code> | Divides lhs by rhs and stores the quotient in lhs       |
|          | <code>double_complex operator/(<br/>const double_complex&amp; lhs,<br/>const double&amp; rhs)</code>         |                                                         |

| Type     | Definition Name                                                                              | Description                                                                    |
|----------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Function | <code>double_complex operator/ (const double&amp; lhs, const double_complex&amp; rhs)</code> | Divides lhs by rhs and stores the quotient in lhs                              |
|          | <code>bool operator==(const double_complex&amp; lhs, const double_complex&amp; rhs)</code>   | Compares the real part of lhs and rhs, and the imaginary parts of lhs and rhs  |
|          | <code>bool operator==(const double_complex&amp; lhs, const double&amp; rhs)</code>           |                                                                                |
|          | <code>bool operator==(const double&amp; lhs, const double_complex&amp; rhs)</code>           |                                                                                |
|          | <code>bool operator!=(const double_complex&amp; lhs, const double_complex&amp; rhs)</code>   | Compares the real parts of lhs and rhs, and the imaginary parts of lhs and rhs |
|          | <code>bool operator!=(const double_complex&amp; lhs, const double&amp; rhs)</code>           |                                                                                |
|          | <code>bool operator!=(const double&amp; lhs, const double_complex&amp; rhs)</code>           |                                                                                |
|          | <code>istream&amp; operator&gt;&gt;(istream&amp; is, double_complex&amp; x)</code>           | Inputs x in a format of u, (u), or (u,v) (u: real part, v: imaginary part)     |
|          | <code>ostream&amp; operator&lt;&lt;(ostream&amp; os, const double_complex&amp; x)</code>     | Outputs x in a format of u, (u), or (u,v) (u: real part, v: imaginary part)    |
|          | <code>double real(const double_complex&amp; x)</code>                                        | Reads the real part                                                            |
|          | <code>double imag(const double_complex&amp; x)</code>                                        | Reads the imaginary part                                                       |
|          | <code>double abs(const double_complex&amp; x)</code>                                         | Calculates the absolute value                                                  |
|          | <code>double arg(const double_complex&amp; x)</code>                                         | Calculates the phase angle                                                     |
|          | <code>double norm(const double_complex&amp; x)</code>                                        | Calculates the absolute value of the square                                    |
|          | <code>double_complex conj(const double_complex&amp; x)</code>                                | Calculates the conjugate complex number of x                                   |

| Type     | Definition Name                                                                            | Description                                                                                                                         |
|----------|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Function | <code>double_complex polar( const double&amp; rho, const double&amp; theta)</code>         | Calculates the <code>double_complex</code> value for a complex number with size <code>rho</code> and phase angle <code>theta</code> |
|          | <code>double_complex cos( const double_complex&amp; x)</code>                              | Calculates the complex cosine                                                                                                       |
|          | <code>double_complex cosh( const double_complex&amp; x)</code>                             | Calculates the complex hyperbolic cosine                                                                                            |
|          | <code>double_complex exp( const double_complex&amp; x)</code>                              | Calculates the exponential function                                                                                                 |
|          | <code>double_complex log( const double_complex&amp; x)</code>                              | Calculates the natural logarithm                                                                                                    |
|          | <code>double_complex log10( const double_complex&amp; x)</code>                            | Calculates the common logarithm                                                                                                     |
|          | <code>double_complex pow( const double_complex&amp; x, int y)</code>                       | Calculates the <code>x</code> to the <code>y</code> th power                                                                        |
|          | <code>double_complex pow( const double_complex&amp; x, const double&amp; y)</code>         |                                                                                                                                     |
|          | <code>double_complex pow( const double_complex&amp; x, const double_complex&amp; y)</code> |                                                                                                                                     |
|          | <code>double_complex pow( const double&amp; x, const double_complex&amp; y)</code>         |                                                                                                                                     |
|          | <code>double_complex sin( const double_complex&amp; x)</code>                              | Calculates the complex sine                                                                                                         |
|          | <code>double_complex sinh( const double_complex&amp; x)</code>                             | Calculates the complex hyperbolic sine                                                                                              |
|          | <code>double_complex sqrt( const double_complex&amp; x)</code>                             | Calculates the square root within the right half space                                                                              |
|          | <code>double_complex tan( const double_complex&amp; x)</code>                              | Calculates the complex tangent                                                                                                      |
|          | <code>double_complex tanh( const double_complex&amp; x)</code>                             | Calculates the complex hyperbolic tangent                                                                                           |

1. `double_complex operator+(const double_complex& lhs)`  
 Performs unary + operation of **lhs**.  
 Return value: **lhs**
2. `double_complex operator+(const double_complex& lhs, const double_complex& rhs)`  
`double_complex operator+(const double_complex& lhs, const double& rhs)`  
`double_complex operator+(const double& lhs, const double_complex& rhs)`  
 Adds **lhs** to **rhs** and stores the sum in **lhs**.  
 Return value: `double_complex(lhs)+=rhs`
3. `double_complex operator-(const double_complex& lhs)`  
 Performs unary - operation of **lhs**.  
 Return value: `double_complex(-lhs.real(), -lhs.imag())`
4. `double_complex operator-(const double_complex& lhs, const double_complex& rhs)`  
`double_complex operator-(const double_complex& lhs, const double& rhs)`  
`double_complex operator-(const double& lhs, const double_complex& rhs)`  
 Subtracts **rhs** from **lhs** and stores the difference in **lhs**.  
 Return value: `double_complex(lhs)-=rhs`
5. `double_complex operator*(const double_complex& lhs, const double_complex& rhs)`  
`double_complex operator*(const double_complex& lhs, const double& rhs)`  
`double_complex operator*(const double& lhs, const double_complex& rhs)`  
 Multiplies **lhs** by **rhs** and stores the product in **lhs**.  
 Return value: `double_complex(lhs)*=rhs`
6. `double_complex operator/(const double_complex& lhs, const double_complex& rhs)`  
`double_complex operator/(const double_complex& lhs, const double& rhs)`  
`double_complex operator/(const double& lhs, const double_complex& rhs)`  
 Divides **lhs** by **rhs** and stores the quotient in **lhs**.  
 Return value: `double_complex(lhs)/=rhs`
7. `bool operator==(const double_complex& lhs, const double_complex& rhs)`  
`bool operator==(const double_complex& lhs, const double& rhs)`  
`bool operator==(const double& lhs, const double_complex& rhs)`  
 Compares the real parts of **lhs** and **rhs**, and the imaginary parts of **lhs** and **rhs**.  
 For a double type parameter, the imaginary part is assumed to be 0.0.  
 Return value: `lhs.real()==rhs.real() && lhs.imag()==rhs.imag()`

8. `bool operator!=(const double_complex& lhs, const double_complex& rhs)`  
`bool operator!=(const double_complex& lhs, const double& rhs)`  
`bool operator!=(const double& lhs, const double_complex& rhs)`  
Compares the real parts of **lhs** and **rhs**, and the imaginary parts of **lhs** and **rhs**.  
For a double type parameter, the imaginary part is assumed to be 0.0.  
Return value: `lhs.real()!=rhs.real() || lhs.imag()!=rhs.imag()`
9. `istream& operator>>(istream& is, double_complex& x)`  
Inputs **x** with a format of `u,(u)`, or `(u,v)` (`u`: real part, `v`: imaginary part).  
The input value is converted to `double_complex`.  
If **x** is input in a format other than the `u`, `(u)`, or `(u,v)` format, `is.setstate(ios_base::failbit)` is called.  
Return value: `is`
10. `ostream& operator<<(ostream& os, const double_complex& x)`  
Outputs **x** to **os**.  
The output format is `u`, `(u)`, or `(u,v)` (`u`: real part, `v`: imaginary part).  
Return value: `os`
11. `double real(const double_complex& x)`  
Reads the real part.  
Return value: `x.real()`
12. `double imag(const double_complex& x)`  
Reads the imaginary part.  
Return value: `x.imag()`
13. `double abs(const double_complex& x)`  
Calculates the absolute value.  
Return value:  $(|x.real()|^2 + |x.imag()|^2)^{1/2}$
14. `double arg(const double_complex& x)`  
Calculates the phase angle.  
Return value: `atan2f(x.imag(), x.real())`
15. `double norm(const double_complex& x)`  
Calculates the absolute value of the square.  
Return value:  $|x.real()|^2 + |x.imag()|^2$

16. `double_complex conj(const double_complex& x)`  
 Calculates the conjugate complex number of **x**.  
 Return value: `double_complex(x.real(), (-1)*x.imag())`
17. `double_complex polar(const double& rho, const double& theta)`  
 Calculates the `double_complex` value for a complex number with size **rho** and phase angle (argument) **theta**.  
 Return value: `double_complex(rho*cos(theta), rho*sin(theta))`
18. `double_complex cos(const double_complex& x)`  
 Calculates the complex cosine.  
 Return value: `double_complex(cos(x.real())*cosh(x.imag()), (-1)*sin(x.real())*sinh(x.imag()))`
19. `double_complex cosh(const double_complex& x)`  
 Calculates the complex hyperbolic cosine.  
 Return value: `cos(double_complex((-1)*x.imag(), x.real()))`
20. `double_complex exp(const double_complex& x)`  
 Calculates the exponent function.  
 Return value: `exp(x.real())*cos(x.imag()),exp(x.real())*sin(x.imag())`
21. `double_complex log(const double_complex& x)`  
 Calculates the natural logarithm (base e).  
 Return value: `double_complex(log(abs(x)), arg(x))`
22. `double_complex log10(const double_complex& x)`  
 Calculates the common logarithm (base 10).  
 Return value: `double_complex(log10(abs(x)), arg(x)/log(10))`
23. `double_complex pow(const double_complex& x, int y)`  
`double_complex pow(const double_complex& x, const double& y)`  
`double_complex pow(const double_complex& x, const double_complex& y)`  
`double_complex pow(const double& x, const double_complex& y)`  
 Calculates the **x** to the **y**th power.  
 If `pow(0,0)`, a domain error will occur.  
 Return value: `exp(y*log(x))`



24. `double_complex sin(const double_complex& x)`  
Calculates the complex sine  
Return value: `double_complex(sin(x.real())*cosh(x.imag()), cos(x.real())*sinh(x.imag()))`
25. `double_complex sinh(const double_complex& x)`  
Calculates the complex hyperbolic sine  
Return value: `double_complex(0,-1)*sin(double_complex((-1)*x.imag(),x.real()))`
26. `double_complex sqrt(const double_complex& x)`  
Calculates the square root within the right half space  
Return value: `double_complex(sqrt(abs(x))*cos(arg(x)/2), sqrt(abs(x))*sin(arg(x)/2))`
27. `double_complex tan(const double_complex& x)`  
Calculates the complex tangent.  
Return value: `sin(x) / cos(x)`
28. `double_complex tanh(const double_complex& x)`  
Calculates the complex hyperbolic tangent.  
Return value: `sinh(x) / cosh(x)`

## (5) String Handling Class Library

The header files for string handling class library is as follows.

<string>

Defines the string class.

This class has no derivation.

### (a) string Class

| Type     | Definition Name                                                | Description                                                                 |
|----------|----------------------------------------------------------------|-----------------------------------------------------------------------------|
| Type     | iterator                                                       | char* type                                                                  |
|          | const_iterator                                                 | const char* type                                                            |
| Constant | npos                                                           | Maximum string literal length (UNIT_MAX characters)                         |
| Variable | s_ptr                                                          | Pointer to the memory area where the string literal is stored by the object |
|          | s_len                                                          | The length of the string literal stored by the object                       |
|          | s_res                                                          | Size of the reserved memory area to store string literal by the object      |
| Function | string(void)                                                   | Constructor                                                                 |
|          | string::string(const string& str, size_t pos=0, size_t n=npos) |                                                                             |
|          | string::string(const char* str, size_t n)                      |                                                                             |
|          | string::string(const char* str)                                |                                                                             |
|          | string::string(size_t n, char c)                               |                                                                             |
|          | ~string()                                                      | Destructor                                                                  |
|          | string& operator=(const string& str)                           | Assigns str                                                                 |
|          | string& operator=(const char* str)                             |                                                                             |
|          | string& operator=(char c)                                      | Assigns c                                                                   |
|          | iterator begin()                                               | Calculates the start pointer of the string literal                          |
|          | const_iterator begin() const                                   |                                                                             |

| Type     | Definition Name                                                   | Description                                                        |
|----------|-------------------------------------------------------------------|--------------------------------------------------------------------|
| Function | iterator end()                                                    | Calculates the end pointer of the string literal                   |
|          | const_iterator end() const                                        |                                                                    |
|          | size_t size() const                                               | Calculates the length of the stored string literal                 |
|          | size_t length() const                                             |                                                                    |
|          | size_t max_size() const                                           | Calculates the size of the reserved memory area                    |
|          | void resize(size_t n, char c)                                     | Changes the string literal length to n that can be stored          |
|          | void resize(size_t n)                                             | Changes the string literal length to n that can be stored          |
|          | size_t capacity() const                                           | Calculates the size of the reserved memory area                    |
|          | void reserve(size_t res_arg = 0)                                  | Performs re-allocation of the memory area                          |
|          | void clear()                                                      | Clears the stored string literal                                   |
|          | bool empty() const                                                | Checks whether the stored string literal length is 0               |
|          | const char& operator[](size_t pos) const                          | References s_ptr[pos]                                              |
|          | char& operator[](size_t pos)                                      |                                                                    |
|          | const char& at(size_t pos) const                                  |                                                                    |
|          | char& at(size_t pos)                                              |                                                                    |
|          | string& operator+=(const string& str)                             | Adds string literal str                                            |
|          | string& operator+=(const char* str)                               |                                                                    |
|          | string& operator+=(char c)                                        | Adds a character c                                                 |
|          | string& append(const string& str)                                 | Adds string literal str                                            |
|          | string& append(const char* str)                                   |                                                                    |
|          | string& append(<br>const string& str,<br>size_t pos,<br>size_t n) | Adds n characters of string literal str to the object position pos |

| Type     | Definition Name                                                                            | Description                                                                    |
|----------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Function | <code>string&amp; append(const char* str, size_t n)</code>                                 | Adds n characters to string literal str                                        |
|          | <code>string&amp; append(size_t n, char c)</code>                                          | Adds n characters, each of which is c                                          |
|          | <code>string&amp; assign(const string&amp; str)</code>                                     | Assigns string literal str                                                     |
|          | <code>string&amp; assign(const char* str)</code>                                           |                                                                                |
|          | <code>string&amp; assign(const string&amp; str, size_t pos, size_t n)</code>               | Add n characters to string literal str at position pos                         |
|          | <code>string&amp; assign(const char* str, size_t n)</code>                                 | Assigns n characters of string literal str                                     |
|          | <code>string&amp; assign(size_t n, char c)</code>                                          | Assigns n characters, each of which is c                                       |
|          | <code>string&amp; insert(size_t pos1, const string&amp; str)</code>                        | Inserts string literal str to position pos1                                    |
|          | <code>string&amp; insert(size_t pos1, const string&amp; str, size_t pos2, size_t n)</code> | Inserts n characters starting from pos2 of string literal str to position pos1 |
|          | <code>string&amp; insert(size_t pos, const char* s, size_t n)</code>                       | Inserts n characters of string literal str to position pos                     |
|          | <code>string&amp; insert(size_t pos, const char* str)</code>                               | Inserts string literal str to position pos                                     |
|          | <code>string&amp; insert(size_t pos, size_t n, char c)</code>                              | Inserts a string literal of n characters c to position pos                     |
|          | <code>iterator insert(iterator p, char c=char())</code>                                    | Inserts a character c before the character specified by p                      |

| Type     | Definition Name                                                                                                              | Description                                                                                                                             |
|----------|------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Function | <code>void insert(iterator p, size_t n, char c)</code>                                                                       | Inserts n characters c before the character specified by p                                                                              |
|          | <code>string&amp; erase(size_t pos=0, size_t n=npos)</code>                                                                  | Deletes n characters from position pos                                                                                                  |
|          | <code>iterator erase(iterator position)</code>                                                                               | Deletes the character specified by position                                                                                             |
|          | <code>iterator erase(iterator first, iterator last)</code>                                                                   | Deletes the characters in range [first, last]                                                                                           |
|          | <code>string&amp; replace(<br/>size_t pos1,<br/>size_t n1,<br/>const string&amp; str)</code>                                 | Replaces the string literal of n1 characters starting from position pos1 with string literal str                                        |
|          | <code>string&amp; replace(<br/>size_t pos1,<br/>size_t n1,<br/>const char* str)</code>                                       |                                                                                                                                         |
|          | <code>string&amp; replace(<br/>size_t pos1,<br/>size_t n1,<br/>const string&amp; str,<br/>size_t pos2,<br/>size_t n2)</code> | Replaces the string literal of n1 characters starting from position pos1 with string literal of n2 characters from position pos2 of str |
|          | <code>string&amp; replace(<br/>size_t pos,<br/>size_t n1,<br/>const char* str,<br/>size_t n2)</code>                         | Replaces the string literal of n1 characters starting from position pos1 with string literal str                                        |
|          | <code>string&amp; replace(<br/>size_t pos,<br/>size_t n1,<br/>size_t n2,<br/>char c)</code>                                  | Replaces the string literal of n1 characters starting from position pos1 with n2 characters, each of which is c                         |
|          | <code>string&amp; replace(<br/>iterator i1,<br/>iterator i2,<br/>const string&amp; str)</code>                               | Replaces the string literal from position i1 to i2 with string literal str                                                              |

| Type     | Definition Name                                                                   | Description                                                                                                    |
|----------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| Function | string& replace(<br>iterator i1,<br>iterator i2,<br>const char* str)              | Replaces the string literal from position i1 to i2 with string literal str                                     |
|          | string& replace(<br>iterator i1,<br>iterator i2,<br>const char* str,<br>size_t n) | Replaces string literal from position i1 to i2 with n characters of string literal str                         |
|          | string& replace(<br>iterator i1,<br>iterator i2,<br>size_t n,<br>char c)          | Replaces the string literal from position i1 to i2 with n characters, each of which is c                       |
|          | size_t copy(<br>char* str,<br>size_t n,<br>size_t pos=0) const                    | Copies the first n characters of string literal str to position pos                                            |
|          | void swap(string& str)                                                            | Swaps *this with string literal str                                                                            |
|          | const char* c_str() const                                                         | References the pointer to the memory area where the string literal is stored                                   |
|          | const char* data() const                                                          |                                                                                                                |
|          | size_t find(<br>const string& str,<br>size_t pos=0) const                         | Finds the position where the string literal same as string literal str first appears after position pos        |
|          | size_t find(<br>const char* str,<br>size_t pos=0) const                           |                                                                                                                |
|          | size_t find(<br>const char* str,<br>size_t pos,<br>size_t n) const                | Finds the position where the string literal same as the n characters of str first appears after position pos   |
|          | size_t find(char c, size_t pos=0) const                                           | Finds the position where the character c first appears after position pos                                      |
|          | size_t rfind(<br>const string& str,<br>size_t pos=npos) const                     | Finds the position where a string literal same as string literal str appears most recently before position pos |
|          | size_t rfind(<br>const char* str,<br>size_t pos=npos) const                       |                                                                                                                |

| Type     | Definition Name                                                             | Description                                                                                                                         |
|----------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Function | size_t rfind(<br>const char* str,<br>size_t pos, size_t n) const            | Finds the position where the string literal same as n characters of str appears most recently before position pos                   |
|          | size_t rfind(char c, size_t pos=npos) const                                 | Finds the position where the character c appears most recently before position pos                                                  |
|          | size_t find_first_of(<br>const string& str,<br>size_t pos=0) const          | Finds the position where any character included in string literal str first appears after position pos                              |
|          | size_t find_first_of(<br>const char* str,<br>size_t pos=0) const            |                                                                                                                                     |
|          | size_t find_first_of(<br>const char* str,<br>size_t pos,<br>size_t n) const | Finds the position where any character included in n characters of string literal str first appear after position pos               |
|          | size_t find_first_of(<br>char c,<br>size_t pos=0) const                     | Finds the position where the character c first appears after position pos                                                           |
|          | size_t find_last_of(<br>const string& str,<br>size_t pos=npos) const        | Finds the position where any character included in string literal str appears most recently before position pos                     |
|          | size_t find_last_of(<br>const char* str,<br>size_t pos=npos) const          |                                                                                                                                     |
|          | size_t find_last_of(<br>const char* str,<br>size_t pos,<br>size_t n) const  | Finds the position where any character included in the n characters of string literal str appears most recently before position pos |
|          | size_t find_last_of(<br>char c,<br>size_t pos=npos) const                   | Finds the position where the character c appears most recently before position pos                                                  |
|          | size_t find_first_not_of(<br>const string& str,<br>size_t pos=0) const      | Finds the position where a character different from any character included in string literal str first appears after position pos   |
|          | size_t find_first_not_of(<br>const char* str,<br>size_t pos=0) const        |                                                                                                                                     |

| Type     | Definition Name                                                                                       | Description                                                                                                                                                                          |
|----------|-------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Function | <code>size_t find_first_not_of(const char* str, size_t pos, size_t n) const</code>                    | Finds the position where a character different from any character in the first <i>n</i> characters of string literal <i>str</i> appears after position <i>pos</i> .                  |
|          | <code>size_t find_first_not_of(char c, size_t pos=0) const</code>                                     | Finds the position where a character different from <i>c</i> first appears after position <i>pos</i>                                                                                 |
|          | <code>size_t find_last_not_of(const string&amp; str, size_t pos=npos) const</code>                    | Finds the position where a character different from any character included in string literal <i>str</i> appears most recently before position <i>pos</i>                             |
|          | <code>size_t find_last_not_of(const char* str, size_t pos=npos) const</code>                          |                                                                                                                                                                                      |
|          | <code>size_t find_last_not_of(const char* str, size_t pos, size_t n) const</code>                     | Finds the position where a character different from any character in the first <i>n</i> characters of string literal <i>str</i> appears most recently before position <i>pos</i> .   |
|          | <code>size_t find_last_not_of(char c, size_t pos=npos) const</code>                                   | Finds the location where a character different from <i>c</i> appears most recently before position <i>pos</i>                                                                        |
|          | <code>string substr(size_t pos=0, size_t n=npos) const</code>                                         | Creates an object from a string literal in the range [ <i>pos</i> , <i>n</i> ] of the stored string literal                                                                          |
|          | <code>int compare(const string&amp; str) const</code>                                                 | Compares the string literal with string literal <i>str</i>                                                                                                                           |
|          | <code>int compare(size_t pos1, size_t n1, const string&amp; str) const</code>                         | Compares <i>n1</i> characters from position <i>pos1</i> of <i>*this</i> with <i>str</i>                                                                                              |
|          | <code>int compare(size_t pos1, size_t n1, const string&amp; str, size_t pos2, size_t n2) const</code> | Compares the string literal of <i>n1</i> characters from position <i>pos1</i> with the string literal of <i>n2</i> characters from position <i>pos2</i> of string literal <i>str</i> |
|          | <code>int compare(const char* str) const</code>                                                       | Compares <i>*this</i> with string literal <i>str</i>                                                                                                                                 |
|          | <code>int compare(size_t pos1, size_t n1, const char* str, size_t n2=npos) const</code>               | Compares the string literal of <i>n1</i> characters from position <i>pos1</i> with <i>n2</i> characters of string literal <i>str</i>                                                 |



1. `string::string (void)`

Sets as follows:

```
s_ptr = 0;
```

```
s_len = 0;
```

```
s_res = 1;
```

2. `string::string (const string& str, size_t pos=0, size_t n=npos)`

Copies **str**. Note that **s\_len** will be the smaller value of **n** and **s\_len**.

3. `string::string (const char* str, size_t n)`

Sets as follows:

```
s_ptr = str;
```

```
s_len = n;
```

```
s_res = n+1;
```

4. `string::string (const char* str)`

Sets as follows:

```
s_ptr = str;
```

```
s_len = string length of str;
```

```
s_res = string length str + 1 of;
```

5. `string::string (size_t n, char c)`

Sets as follows:

```
s_ptr=string literal of n characters, each of which is c
```

```
s_len = n;
```

```
s_res = n+1;
```

6. `string::~~string ()`

Destructor of the class `string`.

Deallocates the memory area where the string literal is stored.

7. `string& string::operator=(const string& str)`

Assigns the **str** data.

Return value: `*this`

8. `string& string::operator= (const char* str)`

Creates a string object from **str** and assigns the data of **str** to the string object.

Return value: `*this`

9. `string& string::operator= (char c)`  
Creates a string object from `c` and assigns the data of the string to the string object.  
Return value: `*this`
10. `string::iterator string::begin()`  
`string::const_iterator string::begin() const`  
Calculates the start pointer of the string literal.  
Return value: Start pointer of string literal
11. `string::iterator string::end ()`  
`string::const_iterator string::end() const`  
Calculates the end pointer of the string literal.  
Return value: End pointer of string literal
12. `size_t string::size () const`  
`size_t string::length() const`  
Calculates the length of the stored string literal.  
Return value: Length of the stored string literal
13. `size_t string::max_size() const`  
Calculates the size of the reserved memory area.  
Return value: Size of the reserved area
14. `void string::resize(size_t n, char c)`  
Changes the string literal length available to `n`.  
If `n<=size()`, replaces the string literal with the original string literal with length `n`.  
If `n>size()`, replaces the string literal with a string literal that has `c` appended to the end so that the length will be equal to `n`.  
The length must be `n<=max_size()`.  
If `n>max_size()`, the string literal length is `n=max_size()`.
15. `void string::resize (size_t n)`  
Changes the string literal length available to `n`.  
If `n<=size()`, replaces the string literal with the original string literal with length `n`.  
The length must be `n<=max_size`.
16. `size_t string::capacity() const`  
Calculates the size of the reserved memory area.  
Return value: Size of the reserved memory area

17. `void string::reserve(size_t res_arg = 0)`

Re-allocates the memory area.

After `reserve()`, `capacity()` will be equal to or larger than the `reserve()` parameter.

When memory area is re-allocated, all references, pointers, and iterator that references the elements of the numeric literal (number sequence, series) become invalid.

18. `void string::clear()`

Clears the stored string literal.

19. `bool string::empty() const`

Checks whether the stored string literal length is 0.

Return value: If the length of the stored string literal is 0: true

If the length of the stored string literal is non zero: false

20. `const char& string::operator [ ](size_t pos) const`

`char& string::operator [ ] (size_t pos)`

`const char& string::at (size_t pos) const`

`char& string::at (size_t pos)`

References `s_ptr[pos]`.

Return value: If  $n < s\_len$ : `s_ptr [pos]`

If  $n \geq s\_len$ : `'\0'`

21. `string& string::operator+= (const string& str)`

Appends the string literal stored in `str` to the left-hand-side object.

Return value: `*this`

22. `string& string::operator+=(const char* str)`

Creates a string object from `str` and adds the string literal to the left-hand-side object.

Return value: `*this`

23. `string& string::operator+= (char c)`

Creates a string object from `c` and adds the string literal.

Return value: `*this`

24. `string& string::append(const string& str)`

`string& string::append(const char* str)`

Appends string literal `str` to the object.

Return value: `*this`

25. `string& string::append (const string& str, size_t pos, size_t n);`  
Appends **n** characters of string literal **str** to the object position **pos**.  
Return value: `*this`
26. `string& string::append (const char* str, size_t n)`  
Appends **n** characters of string literal **str** to the object.  
Return value: `*this`
27. `string& string::append (size_t n, char c)`  
Appends **n** characters, each of which is **c**, to the object.  
Return value: `*this`
28. `string& string::assign(const string& str)`  
`string& string::assign(const char* str)`  
Assigns string literal **str**.  
Return value: `*this`
29. `string& string::assign (const string& str, size_t pos, size_t n)`  
Assigns **n** characters of string literal **str** to position **pos**.  
Return value: `*this`
30. `string& string::assign (const char* str, size_t n)`  
Assigns **n** characters of string literal **str**.  
Return value: `*this`
31. `string& string::assign (size_t n, char c)`  
Assigns **n** characters, each of which is **c**.  
Return value: `*this`
32. `string& string::insert(size_t pos1, const string& str)`  
Inserts string literal **str** to position **pos1**.  
Return value: `*this`
33. `string& string::insert (size_t pos1, const string& str, size_t pos2, size_t n)`  
Inserts **n** characters started from position **pos2** of string literal **str** to position **pos1**.  
Return value: `*this`
34. `string& string::insert (size_t pos, const char* str, size_t n)`  
Inserts **n** characters of string literal **str** to position **pos**.  
Return value: `*this`

35. `string& string::insert (size_t pos, const char* str)`  
Inserts string literal **str** to position **pos**.  
Return value: `*this`
36. `string& string::insert (size_t pos, size_t n, char c)`  
Inserts a string literal of **n** characters, each of which is **c**, to position **pos**.  
Return value: `*this`
37. `string::iterator string::insert (iterator p, char c=char())`  
Inserts character **c** before the character specified by **p**.  
Return value: Character inserted
38. `void string::insert (iterator p, size_t n, char c)`  
Inserts **n** characters, each of which is **c**, before the character specified by **p**.
39. `string& string::erase (size_t pos=0, size_t n=npos)`  
Deletes **n** characters starting from position **pos**.  
Return value: `*this`
40. `iterator string::erase(iterator position)`  
Deletes the character specified by position.  
Return value: If the next iterator of the element to be deleted exists:  
The next iterator of the deleted elements  
If the next iterator of the elements to be deleted do not exist: `end()`
41. `iterator string::erase (iterator first, iterator last)`  
Deletes the characters in range `[first, last]`.  
Return value: If the next iterator of last exists: The next iterator of last  
If the next iterator of last does not exists: `end()`
42. `string& string::replace(size_t pos1, size_t n1, const string& str)`  
`string& string::replace(size_t pos1, size_t n1, const char* str)`  
Replaces the string literal of **n1** characters starting from position **pos1** with string literal **str**.  
Return value: `*this`
43. `string& string::replace (size_t pos, size_t n1, const string& str, size_t pos2, size_t n2)`  
Replaces the string literal of **n1** characters starting from position **pos1** with the string literal of **n2** characters starting from position **pos2** in string literal **str**.  
Return value: `*this`

44. `string& string::replace (size_t pos, size_t n1, const char* str, size_t n2)`  
Replaces the string literal of **n1** characters starting from position **pos1** with string literal **str** of **n2** characters.  
Return value: `*this`
45. `string& string::replace (size_t pos, size_t n1, size_t n2, char c)`  
Replaces the string literal of **n1** characters starting from position **pos** with **n2** characters, each of which is **c**.  
Return value: `*this`
46. `string& string::replace (iterator i1, iterator i2, const string& str)`  
`string& string::replace(iterator i1, iterator i2, const char* str)`  
Replaces the string literal from position **i1** to **i2** with string literal **str**.  
Return value: `*this`
47. `string& string::replace (iterator i1, iterator i2, const char* str, size_t n)`  
Replaces the string literal from position **i1** to **i2** with **n** characters of string literal **str**.  
Return value: `*this`
48. `string& string::replace (iterator i1, iterator i2, size_t n, char c)`  
Replaces the characters from position **i1** to **i2** with **n** characters, each of which is **c**.  
Return value: `*this`
49. `size_t string::copy(char* str, size_t n, size_t pos=0) const`  
Copies **n** characters of string literal **str** to position **pos**.  
Return value: `rlen`
50. `void string::swap(string& str)`  
Swaps `*this` with string literal **str**.
51. `const char* string::c_str() const`  
`const char* string::data() const`  
References the pointer to the area where the string literal is stored.  
Return value: `s_ptr`

52. `size_t string::find (const string& str, size_t pos=0) const`  
`size_t string::find (const char* str, size_t pos=0) const`  
Finds the position where the string literal same as string literal **str** first appears after position **pos**.  
Return value: Offset of string literal
53. `size_t string::find (const char* str, size_t pos, size_t n) const`  
Finds the position where the string literal same as the **n** characters of **str** first appears after position **pos**.  
Return value: Offset of string literal
54. `size_t string::find (char c, size_t pos=0) const`  
Finds the position where character **c** first appears after position **pos**.  
Return value: Offset of string literal
55. `size_t string::rfind(const string& str, size_t pos=npos) const`  
`size_t string::rfind(char *str, size_t pos=npos) const`  
Finds the position where a string literal same as string literal **str** appears most recently before position **pos**.  
Return value: Offset of string literal
56. `size_t string::rfind (const char* str, size_t pos, size_t n) const`  
Finds the position where the string literal same as **n** characters of **str** appears most recently before position **pos**.  
Return value: Offset of string literal
57. `size_t string::rfind (char c, size_t pos=npos) const`  
Finds the position where character **c** appears most recently before position **pos**.  
Return value: Offset of string literal
58. `size_t string::find_first_of(const string& str, size_t pos=0) const`  
`size_t string::find_first_of(const char* str, size_t pos=0) const`  
Finds the position where any character included in string literal **str** first appears after position **pos**.  
Return value: Offset of string literal

59. `size_t string::find_first_of(const char* str, size_t pos, size_t n) const`  
Finds the position where any character included in **n** characters of string literal **str** first appear after position **pos**.  
Return value: Offset of string literal
60. `size_t string::find_first_of(char c, size_t pos=0) const`  
Finds the position where character **c** first appears after position **pos**.  
Return value: Offset of string literal
61. `size_t string::find_last_of(const string& str, size_t pos=npos) const`  
`size_t string::find_last_of(const char* str, size_t pos=npos) const`  
Finds the position where any character included in string literal **str** appears most recently before position **pos**.  
Return value: Offset of string literal
62. `size_t string::find_last_of(const char* str, size_t pos, size_t n) const`  
Finds the position where any character included in the **n** characters of string literal **str** appears most recently before position **pos**.  
Return value: Offset of string literal
63. `size_t string::find_last_of(char c, size_t pos=npos) const`  
Finds the position where character **c** appears most recently before position **pos**.  
Return value: Offset of string literal
64. `size_t string::find_first_not_of(const string& str, size_t pos=0) const`  
`size_t string::find_first_not_of(const char* str, size_t pos=0) const`  
Finds the position where a character different from any character included in string literal **str** first appears after position **pos**.  
Return value: Offset of string literal
65. `size_t string::find_first_not_of(const char* str, size_t pos, size_t n) const`  
Finds the position where a character different from any character in the first **n** characters of string literal **str** first appears after position **pos**.  
Return value: Offset of string literal
66. `size_t string::find_first_not_of(char c, size_t pos=0) const`  
Finds the position where a character different from character **c** first appears after position **pos**.  
Return value: Offset of string literal



67. `size_t string::find_last_not_of(const string& str, size_t pos=npos) const`  
`size_t string::find_last_not_of(const char* str, size_t pos=npos) const`  
 Finds the position where a character different from any character included in string literal **str** appears most recently before position **pos**.  
 Return value: Offset of string literal
68. `size_t string::find_last_not_of(const char* str, size_t pos, size_t n) const`  
 Finds the position where a character different from any character in the first **n** characters of string literal **str** appears most recently before position **pos**.  
 Return value: Offset of string literal
69. `size_t string::find_last_not_of(char c, size_t pos=npos) const`  
 Finds the position where a character different from character **c** appears most recently before position **pos**.  
 Return value: Offset of string literal
70. `string string::substr(size_t pos=0, size_t n=npos) const`  
 Creates an object from a string literal in the range [pos,n] of the stored string literal.  
 Return value: Object address with string literal range [pos,n]
71. `int string::compare(const string& str) const`  
 Compares the string literal with string literal **str**.  
 Return value: If the string literals are the same: 0  
                   If the string literals are different: 1 when `this->s_len > str.s_len`,  
                   -1 when `this->s_len < str.s_len`
72. `int string::compare(size_t pos1, size_t n1, const string& str) const`  
 Compares **n1** characters from position **pos1** of `*this` with string literal **str**.  
 Return value: If the string literals are the same: 0  
                   If the string literals are different: 1 when `this->s_len > str.s_len`,  
                   -1 when `this->s_len < str.s_len`
73. `int string::compare(size_t pos1, size_t n1, const string& str, size_t pos2, size_t n2) const`  
 Compares a string literal of **n1** characters from position **pos1** with the string literal of **n2** characters from position **pos2** of string literal **str**.  
 Return value: If the string literals are the same: 0  
                   If the string literals are different: 1 when `this->s_len > str.s_len`,  
                   -1 when `this->s_len < str.s_len`

74. `int string::compare (const char* str) const`

Compares `*this` with string literal `str`.

Return value: If the string literals are the same: 0

If the string literals are different: 1 when `this->s_len > str.s_len`,

-1 when `this->s_len < str.s_len`

75. `int string::compare (size_t pos1, size_t n1, const char* str, size_t n2=npos) const`

Compares the string literal of `n1` characters from position `pos1` with `n2` characters of string literal `str`.

Return value: If the string literals are the same: 0

If the string literals are different: 1 when `this->s_len > str.s_len`,

-1 when `this->s_len < str.s_len`

**(b) string Class Manipulators**

| Type     | Definition Name                                                | Description                                                                                                                                                  |
|----------|----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Function | string operator +(<br>const string& lhs,<br>const string& rhs) | Appends the string literal (or characters) of rhs to the string literal (or character) of lhs, creates an object and stores the string literal in the object |
|          | string operator+(const char* lhs, const string& rhs)           |                                                                                                                                                              |
|          | string operator+(char lhs, const string& rhs)                  |                                                                                                                                                              |
|          | string operator+(const string& lhs, const char* rhs)           |                                                                                                                                                              |
|          | string operator+(const string& lhs, char rhs)                  |                                                                                                                                                              |
|          | bool operator==(const string& lhs,<br>const string& rhs)       | Compares the string literal of lhs with the string literal of rhs                                                                                            |
|          | bool operator==(const char* lhs, const string& rhs)            |                                                                                                                                                              |
|          | bool operator==(const string& lhs, const char* rhs)            |                                                                                                                                                              |
|          | bool operator!=(const string& lhs, const string& rhs)          | Compares the string literal of lhs with the string literal of rhs                                                                                            |
|          | bool operator!=(const char* lhs, const string& rhs)            |                                                                                                                                                              |
|          | bool operator!=(const string& lhs, const char* rhs)            |                                                                                                                                                              |
|          | bool operator<(const string& lhs, const string& rhs)           | Compares the string literal length of lhs with the string literal length of rhs                                                                              |

| Type                                                                | Definition Name                                                                                                 | Description                                                                                        |
|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Function                                                            | <code>bool operator&lt;(const char* lhs, const string&amp; rhs)</code>                                          | Compares the string literal length of lhs with the string literal length of rhs                    |
|                                                                     | <code>bool operator&lt;(const string&amp; lhs, const char* rhs)</code>                                          |                                                                                                    |
|                                                                     | <code>bool operator&gt;(const string&amp; lhs, const string&amp; rhs)</code>                                    | Compares the string literal length of lhs with the string literal length of rhs                    |
|                                                                     | <code>bool operator&gt;(const char* lhs, const string&amp; rhs)</code>                                          |                                                                                                    |
|                                                                     | <code>bool operator&gt;(const string&amp; lhs, const char* rhs)</code>                                          |                                                                                                    |
|                                                                     | <code>bool operator&lt;=(const string&amp; lhs, const string&amp; rhs)</code>                                   | Compares the string literal length of lhs with the string literal length of rhs                    |
|                                                                     | <code>bool operator&lt;=(const char* lhs, const string&amp; rhs)</code>                                         |                                                                                                    |
|                                                                     | <code>bool operator&lt;=(const string&amp; lhs, const char* rhs)</code>                                         | Compares the string literal length of lhs with the string literal length of rhs                    |
|                                                                     | <code>bool operator&gt;=(const string&amp; lhs, const string&amp; rhs)</code>                                   |                                                                                                    |
|                                                                     | <code>bool operator&gt;=(const char* lhs, const string&amp; rhs)</code>                                         |                                                                                                    |
|                                                                     | <code>bool operator&gt;=(const string&amp; lhs, const char* rhs)</code>                                         |                                                                                                    |
|                                                                     | <code>void swap(string&amp; lhs, string&amp; rhs)</code>                                                        | Swaps the string literal of lhs with the string literal of rhs                                     |
|                                                                     | <code>istream&amp; operator&gt;&gt;(istream&amp; is, string&amp; str)</code>                                    | Extracts the string literal to str                                                                 |
|                                                                     | <code>ostream&amp; operator&lt;&lt;(ostream&amp; os, const string&amp; str)</code>                              | Inserts string literal str                                                                         |
|                                                                     | <code>istream&amp; getline(istream&amp; is, string&amp; str, char delim)</code>                                 | Extracts a string literal from is and appends it to str. If 'delim' is detected, terminates input. |
| <code>istream&amp; getline(istream&amp; is, string&amp; str)</code> | Extracts a string literal from is and appends it to str. If a new-line character is detected, terminates input. |                                                                                                    |

1. string operator+(const string& lhs, const string& rhs)  
string operator+(const char\* lhs, const string& rhs)  
string operator+(char lhs, const string& rhs)  
string operator+(const string& lhs, const char\* rhs)  
string operator+(const string& lhs, char rhs)  
Appends the string literal (characters) of **lhs** with the strings literal (characters) of **rhs**, creates an object and stores the string literal in the object.  
Return value: Object where the linked string literals are stored
2. bool operator==(const string& lhs, const string& rhs)  
bool operator==(const char\* lhs, const string& rhs)  
bool operator==(const string& lhs, const char\* rhs)  
Compares the string literal of **lhs** with the string literal of **rhs**.  
Return value: If the string literals are the same: true  
If the string literals are different: false
3. bool operator!=(const string& lhs, const string& rhs)  
bool operator!=(const char\* lhs, const string& rhs)  
bool operator!=(const string& lhs, const char\* rhs)  
Compares the string literal of **lhs** with the string literal of **rhs**.  
Return value: If the string literals are the same: false  
If the string literals are different: true
4. bool operator<(const string& lhs, const string& rhs)  
bool operator<(const char\* lhs, const string& rhs)  
bool operator<(const string& lhs, const char\* rhs)  
Compares the string literal length of **lhs** with the string literal length of **rhs**.  
Return value: If lhs.s\_len < rhs.s\_len: true  
If lhs.s\_len >= rhs.s\_len: false
5. bool operator>(const string& lhs, const string& rhs)  
bool operator>(const char\* lhs, const string& rhs)  
bool operator>(const string& lhs, const char\* rhs)  
Compares the string literal length of **lhs** with the string literal length of **rhs**.  
Return value: If lhs.s\_len > rhs.s\_len: true  
If lhs.s\_len <= rhs.s\_len: false

6. `bool operator<=(const string& lhs, const string& rhs)`  
`bool operator<=(const char* lhs, const string& rhs)`  
`bool operator<=(const string& lhs, const char* rhs)`  
Compares the string literal length of **lhs** with the string literal length of **rhs**.  
Return value: If `lhs.s_len <= rhs.s_len`: true  
                  If `lhs.s_len > rhs.s_len`: false
7. `bool operator>=(const string& lhs, const string& rhs)`  
`bool operator>=(const char* lhs, const string& rhs)`  
`bool operator>=(const string& lhs, const char* rhs)`  
Compares the string literal length of **lhs** with the string literal length of **rhs**.  
Return value: If `lhs.s_len >= rhs.s_len`: true  
                  If `lhs.s_len < rhs.s_len`: false
8. `void swap (string& lhs,string& rhs)`  
Swaps the string literal of **lhs** with the string literal of **rhs**.
9. `istream& operator>>(istream& is,string& str)`  
Extracts a string literal to **str**.  
Return value: `is`
10. `ostream& operator<<(ostream& os, const string& str)`  
Inserts string literal **str**.  
Return value: `os`
11. `istream& getline (istream& is, string& str, char delim)`  
Extracts a string literal from `is` and appends it to **str**.  
If the character **delim** is found, the input is terminated.  
Return value: `is`
12. `istream& getline (istream& is, string& str)`  
Extracts a string literal from `is` and appends it to **str**.  
If a new-line character is found, the input is terminated.  
Return value: `is`

### 10.4.3 Reentrant Library

A library created by using the **reent** option of the standard library generator is able to execute all reentrants except for the **rand** and **srand** functions.

Table 10.50 lists libraries that are reentrant when the **reent** option is not specified. A function that is marked with  $\Delta$  in the table sets the **errno** variable. Such a function can be assumed to be reentrant unless the program refers to **errno**.

**Table 10.50 Reentrant Library List**

| No.   | Standard Include File | Function Name | Reentrant |
|-------|-----------------------|---------------|-----------|
| 1     | stddef.h              | offsetof      | O         |
| 2     | assert.h              | assert        | X         |
| 3     | ctype.h               | isalnum       | O         |
|       |                       | isalpha       | O         |
|       |                       | iscntrl       | O         |
|       |                       | isdigit       | O         |
|       |                       | isgraph       | O         |
|       |                       | islower       | O         |
|       |                       | isprint       | O         |
|       |                       | ispunct       | O         |
|       |                       | isspace       | O         |
|       |                       | isupper       | O         |
|       |                       | isxdigit      | O         |
|       |                       | tolower       | O         |
|       |                       | toupper       | O         |
|       |                       | 4             | math.h    |
| asin  | $\Delta$              |               |           |
| atan  | $\Delta$              |               |           |
| atan2 | $\Delta$              |               |           |
| cos   | $\Delta$              |               |           |
| sin   | $\Delta$              |               |           |
| tan   | $\Delta$              |               |           |

**Table 10.50 Reentrant Library List (cont)**

| No. | Standard Include File | Function Name | Reentrant |
|-----|-----------------------|---------------|-----------|
| 4   | math.h(cont)          | cosh          | △         |
|     |                       | sinh          | △         |
|     |                       | tanh          | △         |
|     |                       | exp           | △         |
|     |                       | frexp         | △         |
|     |                       | ldexp         | △         |
|     |                       | log           | △         |
|     |                       | log10         | △         |
|     |                       | modf          | △         |
|     |                       | pow           | △         |
|     |                       | sqrt          | △         |
|     |                       | ceil          | △         |
|     |                       | fabs          | △         |
|     |                       | floor         | △         |
|     |                       | fmod          | △         |
| 5   | mathf.h               | acosf         | △         |
|     |                       | asinf         | △         |
|     |                       | atanf         | △         |
|     |                       | atan2f        | △         |
|     |                       | cosf          | △         |
|     |                       | sinf          | △         |
|     |                       | tanf          | △         |
|     |                       | coshf         | △         |
|     |                       | sinhf         | △         |
|     |                       | tanhf         | △         |
|     |                       | expf          | △         |
|     |                       | frexpf        | △         |
|     |                       | ldexpf        | △         |
|     |                       | logf          | △         |
|     |                       | log10f        | △         |



**Table 10.50 Reentrant Library List (cont)**

| No.   | Standard Include File | Function Name | Reentrant |
|-------|-----------------------|---------------|-----------|
| 5     | mathf.h (cont)        | modff         | Δ         |
|       |                       | powf          | Δ         |
|       |                       | sqrtrf        | Δ         |
|       |                       | ceil          | Δ         |
|       |                       | fabsf         | Δ         |
|       |                       | floorf        | Δ         |
|       |                       | fmodf         | Δ         |
| 6     | setjmp.h              | setjmp        | O         |
|       |                       | longjmp       | O         |
| 7     | stdarg.h              | va_start      | O         |
|       |                       | va_arg        | O         |
|       |                       | va_end        | O         |
| 8     | stdio.h               | fclose        | X         |
|       |                       | fflush        | X         |
|       |                       | fopen         | X         |
|       |                       | freopen       | X         |
|       |                       | setbuf        | X         |
|       |                       | setvbuf       | X         |
|       |                       | fprintf       | X         |
|       |                       | fscanf        | X         |
|       |                       | printf        | X         |
|       |                       | scanf         | X         |
|       |                       | sprintf       | Δ         |
|       |                       | sscanf        | Δ         |
|       |                       | vfprintf      | X         |
|       |                       | vprintf       | X         |
|       |                       | vsprintf      | Δ         |
|       |                       | fgetc         | X         |
|       |                       | fgets         | X         |
| fputc | X                     |               |           |

**Table 10.50 Reentrant Library List (cont)**

| No. | Standard Include File | Function Name | Reentrant |
|-----|-----------------------|---------------|-----------|
| 8   | stdio.h (cont)        | fputs         | X         |
|     |                       | getc          | X         |
|     |                       | getchar       | X         |
|     |                       | gets          | X         |
|     |                       | putc          | X         |
|     |                       | putchar       | X         |
|     |                       | puts          | X         |
|     |                       | ungetc        | X         |
|     |                       | fread         | X         |
|     |                       | fwrite        | X         |
|     |                       | fseek         | X         |
|     |                       | ftell         | X         |
|     |                       | rewind        | X         |
|     |                       | clearerr      | X         |
|     |                       | feof          | X         |
|     |                       | ferror        | X         |
|     |                       | perror        | X         |
| 9   | stdlib.h              | atof          | Δ         |
|     |                       | atoi          | Δ         |
|     |                       | atol          | Δ         |
|     |                       | atoll         | Δ         |
|     |                       | atofixed      | Δ         |
|     |                       | atolaccum     | Δ         |
|     |                       | strtod        | Δ         |
|     |                       | strtol        | Δ         |
|     |                       | strtoul       | Δ         |
|     |                       | strtoll       | Δ         |
|     |                       | strtoull      | Δ         |
|     |                       | strtolfixed   | Δ         |
|     |                       | strtolaccum   | Δ         |

**Table 10.50 Reentrant Library List (cont)**

| No.   | Standard Include File | Function Name | Reentrant |
|-------|-----------------------|---------------|-----------|
| 9     | stdlib.h (cont)       | rand          | X         |
|       |                       | srand         | X         |
|       |                       | calloc        | X         |
|       |                       | free          | X         |
|       |                       | malloc        | X         |
|       |                       | realloc       | X         |
|       |                       | free__X       | X         |
|       |                       | malloc__X     | X         |
|       |                       | realloc__X    | X         |
|       |                       | calloc__X     | X         |
|       |                       | free__Y       | X         |
|       |                       | malloc__Y     | X         |
|       |                       | realloc__Y    | X         |
|       |                       | calloc__Y     | X         |
|       |                       | bsearch       | O         |
|       |                       | qsort         | O         |
|       |                       | abs           | O         |
|       |                       | div           | Δ         |
|       |                       | labs          | O         |
|       |                       | llabs         | O         |
| ldiv  | Δ                     |               |           |
| lldiv | Δ                     |               |           |

| No. | Standard Include File | Function Name | Reentrant |
|-----|-----------------------|---------------|-----------|
| 10  | string.h              | memcpy        | O         |
|     |                       | memcpy__X__X  | O         |
|     |                       | memcpy__X__Y  | O         |
|     |                       | memcpy__Y__X  | O         |
|     |                       | memcpy__Y__Y  | O         |
|     |                       | strcpy        | O         |
|     |                       | strncpy       | O         |
|     |                       | strcat        | O         |
|     |                       | strncat       | O         |
|     |                       | memcmp        | O         |
|     |                       | strcmp        | O         |
|     |                       | strncmp       | O         |
|     |                       | memchr        | O         |
|     |                       | strchr        | O         |
|     |                       | strcspn       | O         |
|     |                       | strpbrk       | O         |
|     |                       | strrchr       | O         |
|     |                       | strspn        | O         |
|     |                       | strstr        | O         |
|     |                       | strtok        | X         |
|     |                       | memset        | O         |
|     |                       | strerror      | O         |
|     |                       | strlen        | O         |
|     |                       | memmove       | O         |

Reentrant column:  
 O: Reentrant  
 X: Non-reentrant  
 Δ: errno is set.

## 10.4.4 Unsupported Libraries

Table 10.51 lists the libraries not supported by this compiler.

**Table 10.51 Unsupported Libraries**

| No. | Standard Include File | Reentrant                                                                      |
|-----|-----------------------|--------------------------------------------------------------------------------|
| 1   | locale.h*             | setlocale, localeconv                                                          |
| 2   | signal.h*             | signal, raise                                                                  |
| 3   | stdio.h               | remove, rename, tmpfile, tmpnam, fgetpos, fsetpos                              |
| 4   | stdlib.h              | abort, atexit, exit, getenv, system, mblen, mbtowc, wctomb, mbstowcs, wcstombs |
| 5   | string.h              | strcoll, strxfrm                                                               |
| 6   | time.h*               | clock, difftime, mktime, time, asctime, ctime, gmtime, localtime, strftime     |

Note: The header file is not supported.

## 10.4.5 DSP Library

### (1) Overview

This section describes a digital signal processing (DSP) library for use with the SH2-DSP, the SH3-DSP, and the SH4AL-DSP (called SH-DSP hereafter). This library includes standard DSP functions, so various DSP operations can be performed by using a single function or using several functions in sequence.

This library includes the following functions.

- Fast Fourier Transforms
- Window Functions
- Filters
- Convolution and Correlation
- Miscellaneous

These are reentrant library functions except for the fast Fourier transforms and filters.

When using this library, include files shown in table 10.52, and link the library suitable for the target CPU and compiler options as shown in table 10.53.

After calling the library, a return value, **EDSP\_OK**, is returned if a function is correctly terminated, and a return value, **EDSP\_BAD\_ARG** or **EDSP\_NO\_HEAP**, is returned if a function is not correctly terminated. For details on the return values, refer to the description of each function.

**Table 10.52 Include Files for DSP Library**

| Library Type | Contents                   | Include File                 |
|--------------|----------------------------|------------------------------|
| DSP library  | Library for DSP operations | <ensigdsp.h><br><filt_ws.h>* |

Note: When the filter functions are used in a program, **filt\_ws.h** must be included once.

**Table 10.53 DSP Libraries**

| CPU       | Option | Library                          |
|-----------|--------|----------------------------------|
| SH2-DSP   | -pic=0 | shdsplib.lib                     |
|           | -pic=1 | shdsppl.lib                      |
| SH3-DSP   | -pic=0 | -endian=big<br>sh3dspnb.lib      |
|           | -pic=1 | -endian=big<br>sh3dspnb.lib      |
|           | -pic=0 | -endian=little<br>sh3dspnl.lib   |
|           | -pic=1 | -endian=little<br>sh3dsppl.lib   |
| SH4AL-DSP | -pic=0 | -endian=big<br>sh4aldspnb.lib    |
|           | -pic=1 | -endian=big<br>sh4aldspnb.lib    |
|           | -pic=0 | -endian=little<br>sh4aldspnl.lib |
|           | -pic=1 | -endian=little<br>sh4aldsppl.lib |

## (2) Data Formats

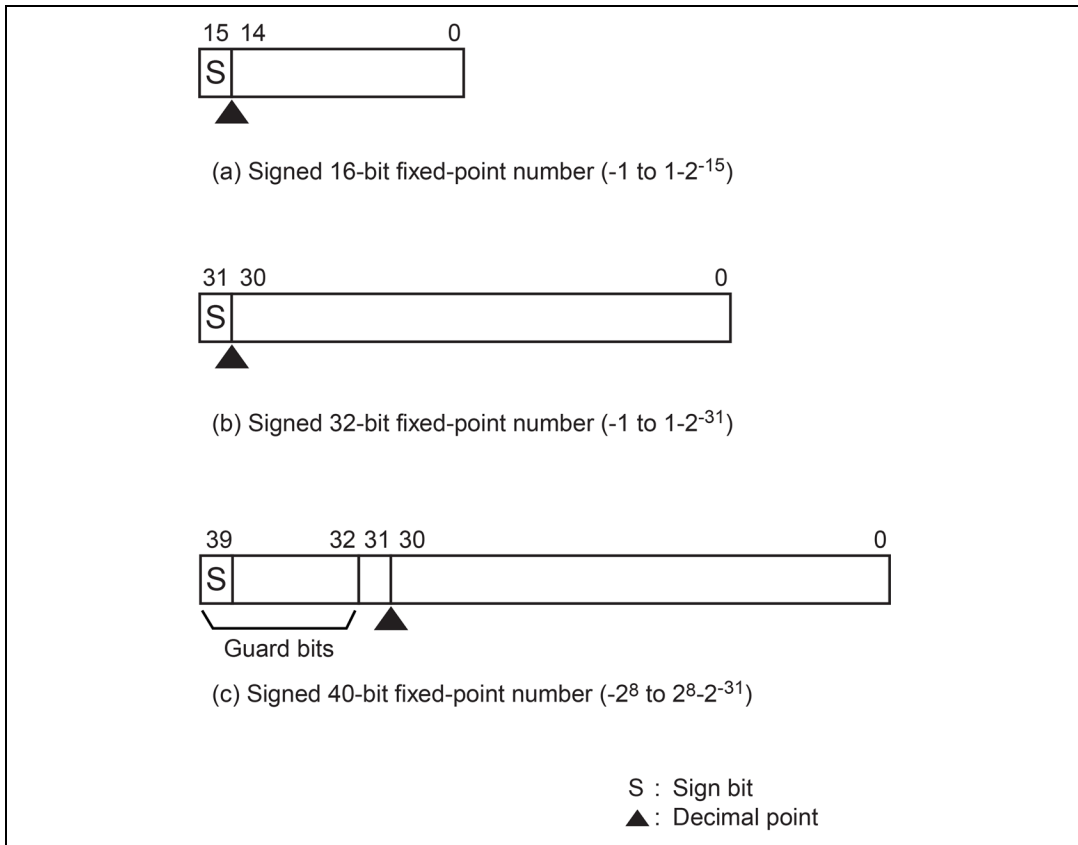
This library regards data as a signed 16-bit fixed-point number. The signed 16-bit fixed-point number has a data format where the decimal point is fixed at the right of the most significant bit (MSB) as shown in figure 10.8 (a). The signed 16-bit fixed-point number can represent values in the range from -1 to  $1-2^{-15}$ . The library accepts data with a short-type data format. Therefore, it is necessary to represent data as signed 16-bit fixed-point number when this library is used in a C/C++ program.

For example, +0.5 is H'4000 when represented with signed 16-bit fixed-point number. Therefore, the short-type real argument sent to the library function is H'4000.

For the operation within the library, signed 32-bit fixed-point numbers and signed 40-bit fixed-point numbers are also used. The data format of the signed 32-bit fixed-point number is shown in figure 10.8 (b). Values in the range from -1 to  $1-2^{-31}$  can be represented. As shown in figure 10.8 (c), the signed 40-bit fixed-point number has a data format with eight guard bits. Values in the range from  $-2^8$  to  $2^8-2^{-31}$  can be represented.

The product of signed 16-bit fixed-point numbers is stored as a signed 32-bit fixed-point number. An overflow will occur only if H'8000 is multiplied by H'8000 for fixed-point multiplication by using a DSP instruction. The least significant bit (LSB) of a product is always 0. To use the product for the next operation, the upper 16 bits are converted to a signed 16-bit fixed-point number. At that time, an underflow can occur, and accuracy can be lost.

For multiply-and-accumulate operation, the sum is stored in a signed 40-bit fixed-point number. Be careful to prevent an overflow from occurring during addition. If an overflow occurs during the operation, the result will be incorrect. To avoid an overflow, a scaling of the coefficient and input data must be performed. This library incorporates a scaling function. For details on scaling, refer to the description of each function.



**Figure 10.8 Data Format**



### (3) Efficiency

This library function is optimized for fast execution on the SH-DSP. To use the library efficiently, the following two recommendations should be observed whenever possible in defining the memory map of a target system.

- The program code segment should be located in the memory that supports single cycle 32-bit reads.
- The data segment should be located in the memory that supports single cycle 16 (or 32) bit reads and writes.

If there is sufficient internal 32-bit memory, this would be a suitable location for the library code and data. If other memory is used, the recommendations above should be followed whenever possible.

### (4) Use with DSP-C

The DSP library can be used with the DSP-C language in a program. When a library function has two types in the description of each function, the type listed above is used when the **dspe** option is not specified, and the type listed below is used when the **dspe** option is specified.

When a library function has only one type, the type can be used in both cases when the **dspe** option is specified and not specified.

## (5) Fast Fourier Transforms

### (a) Overview

| Function      | Description                                    |
|---------------|------------------------------------------------|
| FftComplex    | Executes not-in-place, complex FFT.            |
| FftReal       | Executes not-in-place, real FFT.               |
| IfftComplex   | Executes not-in-place, complex inverse FFT.    |
| IfftReal      | Executes not-in-place, real inverse FFT.       |
| FftInComplex  | Executes in-place, complex FFT.                |
| FftInReal     | Executes in-place, real FFT.                   |
| IfftInComplex | Executes in-place, complex inverse FFT.        |
| IfftInReal    | Executes in-place, real inverse FFT.           |
| LogMagnitude  | Converts complex data to log magnitude format. |
| InitFft       | Generates FFT lookup tables.                   |
| FreeFft       | Releases FFT lookup table memory.              |

Note: For details on not-in-place and in-place, refer to section 10.4.5 (5) (e), FFT Structure.

These functions calculate the forward and inverse fast Fourier transforms with a user-defined scaling. The forward Fourier transform is defined by:

$$y_n = 2^{-s} \sum_{n=0}^N e^{-2j\pi n/N} \cdot x_n$$

where  $s$  is the number of stages in which scaling is performed and  $N$  is the number of data.

The inverse Fourier transform is defined by:

$$y_n = 2^{-s} \sum_{n=0}^N e^{2j\pi n/N} \cdot x_n$$

For details on scaling, refer to (d) Scaling below.

(b) Complex Data Array Format

In **FFT** and **IFFT** routines, complex data are stored using two arrays: the real part of data in *X* memory and the imaginary part of data in *Y* memory. However, the locations of real **FFT** output data and real **IFFT** input data differ. Assuming the arrays *x* and *y* could have real and imaginary parts respectively, element *x*[0] contains the real part of the DC component of the signal, and *y*[0] contains the real part of the  $F_s/2$  frequency (both DC and  $F_s/2$  components are real, and their imaginary parts are zero).

(c) Real Data Array Format

Real data can be specified in three possible formats:

- The data is represented in a single array, located in any memory block.
- The data is represented in a single array, located in *X* memory.
- The data is split into two arrays, each of which has size  $N/2$ . The first half of the data is stored in the *X* memory; the second half is stored in the *Y* memory.

**FftReal** uses only the first representation for the real data. **IfftReal**, **FftInReal** and **IfftInReal** allow the user to select either the second or third representation.

(d) Scaling

In an **FFT**, the signal power doubles at each natural radix-2 stage; the peak signal amplitude can also double. This doubling can cause overflow when transforming a high power signal, but can be prevented by a division by two at each radix-2 stage (this is called scaling). However, excessive scaling will generate an unnecessary quantization error.

The optimum balance among overflow, quantization error, and scaling depends highly on the characteristics of the input signal. When a peak of a signal spectrum is very large, for example, the maximum scaling will be required to avoid overflow, whereas an impulse signal will require very little scaling.

The safest approach is to perform scaling at every radix-2 stage. As long as each complex input data is scaled to have power less than  $2^{30}$ , this approach guarantees that overflow will not occur. This library allows finer control of scaling, with scaling selectable individually for each radix-2 stage. Careful selection of this scaling allows the combined effects of overflow and quantization to be minimized.

To allow specification of the required approach each **FFT** function has a scale parameter. The scale is interpreted starting with the least significant bit, with each bit corresponding to each radix-2 stage. A division by two is performed at each radix-2 stage only if its corresponding scale bit has been set to 1.

The **FFT** implementation used in this library takes advantage of the radix-4 stages to improve execution speed. The scale is interpreted starting with the least significant bit, with each pair of bits corresponding to each radix-4 stage. If either in the pair is set to 1, a division by two is performed; if both in the pair are set to 1, a division by four is performed. This gives the same overall scaling between two radix-2 stages and a radix-4 stage, with minor differences in the quantization error.

For example:

- **scale = H'FFFFFFFF** (or size-1) specifies to perform scaling on every radix-2 stage, with a guarantee that no overflow will occur if the input data all have signal power less than  $2^{30}$ .
- **scale = H'55555555** specifies to perform scaling on alternate radix-2 FFT stages.
- **scale = 0** specifies no scaling.

**EFFTALLSCALE (H'FFFFFFFF)**, **EFFTMIDSCALE (H'55555555)** and **EFFTNOSCALE (0)**, defined in **ensigdsp.h**, can be used to provide these values.

#### (e) **FFT** Structure

This library has two types of **FFT** structures: **not-in-place FFT** and **in-place FFT**. When a not-in-place **FFT** structure is used, input data is fetched from the RAM, **FFT** is executed, and output data is stored in another area of the RAM specified by the user. When an in-place **FFT** structure is used, input data is fetched from the RAM, **FFT** is executed, and output data is stored in the same area of the RAM. When an in-place **FFT** structure is used, the used memory space can be reduced but the **FFT** execution time increases. Use not-in-place **FFT** to use the same input data in other functions. Use **in-place FFT** to reduce the memory space required.

```
int FftComplex (short op_x[], short op_y[], const short ip_x[],
 const short ip_y[], long size, long scale)
int FftComplex (__X__fixed op_x[], __Y__fixed op_y[],
 const __X__fixed ip_x[], const __Y__fixed ip_y[], long size, long scale)
```

Description: Executes a complex Fast Fourier Transform.

Header: <ensigdsp.h>

Return value: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            size < 4  
                                          size not a power of 2  
                                          size > max\_fft\_size

Parameters: op\_x[ ]            real part of output data  
 op\_y[ ]            imaginary part of output data  
 ip\_x[ ]            real part of input data  
 ip\_y[ ]            imaginary part of input data  
 size                size of FFT  
 scale                scaling specification

- Remarks:
1. This routine calculates a complex Fast Fourier Transform. The calculation is **not-in-place**, so the input and output arrays must not overlap.
  2. The storage of complex data arrays is described in section 10.4.5 (5) (b), Complex Data Array Format.
  3. Before calling this routine the lookup table and **max\_fft\_size** should be initialized by calling **InitFft**.
  4. Scaling specification is described in section 10.4.5 (5) (d), Scaling.
  5. Only the lower **log<sub>2</sub> (size)** bits of **scale** are used.
  6. This routine is not reentrant.

```
int FftReal (short op_x[], short op_y[], const short ip[], long size, long scale)
int FftReal (__X__fixed op_x[], __Y__fixed op_y[], const __fixed ip[],
 long size, long scale)
```

Description: Executes a real Fast Fourier Transform.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            size < 8  
                                          size not a power of 2  
                                          size > max\_fft\_size

Parameters: op\_x[ ]            real part of positive output data  
 op\_y[ ]            imaginary part of positive output data  
 ip[ ]              real input data  
 size              size of FFT  
 scale             scaling specification

Remarks:

1. On returning, **op\_x** and **op\_y** contain (**size/2**) positive output data only. The negative data are simply the conjugate complex number of the positive data. Since the output data values at both 0 and  $F_s/2$  are real, the  $F_s/2$  value is placed in **op\_y[0]**.
2. The calculation is **not-in-place**, so the input and output arrays must not overlap.
3. The storage of complex and real data arrays is described in section 10.4.5 (5) (b), Complex Data Array Format, and section 10.4.5 (5) (c), Real Data Array Format.
4. Before calling this routine the lookup table and **max\_fft\_size** should be initialized by calling **InitFft**.
5. Scaling specification is described in section 10.4.5 (5)(d), Scaling.
6. Only the lower **log<sub>2</sub> (size)** bits of **scale** are used.
7. This routine is not reentrant.

```
int IfftComplex (short op_x[], short op_y[], const short ip_x[], const short ip_y[], long size,
 long scale)
int IfftComplex (__X__fixed op_x[], __Y__fixed op_y[],
 const __X__fixed ip_x[], const __Y__fixed ip_y[], long size, long scale)
```

Description: Executes a complex inverse Fast Fourier Transform.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            size < 4  
                                          size not a power of 2  
                                          size > max\_fft\_size

Parameters: op\_x[ ]            real part of output data  
 op\_y[ ]            imaginary part of output data  
 ip\_x[ ]            real part of input data  
 ip\_y[ ]            imaginary part of input data  
 size                size of inverse FFT  
 scale                scaling specification

Remarks:

1. The calculation is **not-in-place**, so the input and output arrays must not overlap.
2. The storage of complex data arrays is described in section 10.4.5 (5) (b), Complex Data Array Format.
3. Before calling this routine the lookup table and **max\_fft\_size** should be initialized by calling **InitFft**.
4. Scaling specification is described in section 10.4.5 (5) (d), Scaling.
5. Only the lower **log<sub>2</sub> (size)** bits of **scale** are used.
6. This routine is not reentrant.

```
int IfftReal (short op_x[], short scratch_y[], const short ip_x[],
 const short ip_y[], long size, long scale, int op_all_x)
int IfftReal (_X__fixed op_x[], _Y__fixed scratch_y [], const _X__fixed ip_x[],
 const _Y__fixed ip_y[], long size, long scale, int op_all_x)
```

Description: Executes a real inverse Fast Fourier Transform.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG       size < 8  
                                  size not a power of 2  
                                  size > max\_fft\_size  
                                  op\_all\_x ≠ 0 or 1

Parameters: op\_x[ ]            real output data  
 scratch\_y[ ]    scratch memory or real output data  
 ip\_x[ ]            real part of positive input data  
 ip\_y[ ]            imaginary part of positive input data  
 size                size of inverse FFT  
 scale                scaling specification  
 op\_all\_x            format specification of output data

Remarks:

1. **ip\_x** and **ip\_y** should contain the positive input data only. The negative data are simply the conjugate complex number of the positive data. Since the input data values at both 0 and  $F_s/2$  can only be real, the input value at  $F_s/2$  should be placed in **ip\_y[0]**.
2. **op\_all\_x** specifies the output data format.  
 If **op\_all\_x** is 1, all output is stored in **op\_x**. If **op\_all\_x** is 0, the first **size/2** output data are stored in **op\_x**; the remaining **size/2** output data are stored in **scratch\_y**.
3. The calculation is **not-in-place**, so the input and output arrays must not overlap.
4. Storage of complex and real data arrays is described in section 10.4.5 (5) (b), Complex Data Array Format, and section 10.4.5 (5) (c), Real Data Array Format.
5. **ip\_x** and **ip\_y** should have **size/2** elements. **op\_x** should have **size** or **size/2** elements as required by the value of **op\_all\_x**.
6. Before calling this routine the lookup table and **max\_fft\_size** should be initialized by calling **InitFft**.
7. Scaling specification is described in section 10.4.5 (5) (d), Scaling.



8. Only the lower **log<sub>2</sub> (size)** bits of **scale** are used.
9. This routine is not reentrant.

```
int FftInComplex (short data_x[], short data_y[], long size, long scale)
int FftInComplex (__X__fixed data_x[], __Y__fixed data_y[], long size,
 long scale)
```

Description: Executes an in-place complex Fast Fourier Transform.

Header: <ensigdsp.h>

Return values: EDSP\_OK            successfully completed  
EDSP\_BAD\_ARG    size < 4  
                 size not a power of 2  
                 size > max\_fft\_size

Parameters: data\_x[ ]    real part of data  
             data\_y[ ]    imaginary part of data  
             size        size of FFT  
             scale       scaling specification

Remarks:

1. The storage of complex data arrays is described in section 10.4.5 (5) (b), Complex Data Array Format.
2. Before calling this routine the lookup table and **max\_fft\_size** should be initialized by calling **InitFft**.
3. Scaling specification is described in section 10.4.5 (5) (d), Scaling.
4. Only the lower **log<sub>2</sub> (size)** bits of **scale** are used.
5. This routine is not reentrant.

```
int FftInReal (short data_x[], short data_y[], long size, long scale, int ip_all_x)
int FftInReal (__X__fixed data_x[], __Y__fixed data_y[], long size,
 long scale, int ip_all_x)
```

Description: Executes an in-place real Fast Fourier Transform.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            size < 8  
                                          size not a power of 2  
                                          size > max\_fft\_size  
                                          ip\_all\_x ≠ 0 or 1

Parameters: data\_x[ ]            real data on input, real part of positive data on output  
 data\_y[ ]            real data or unused on input, imaginary part of  
                                          positive data on output  
 size                    size of FFT  
 scale                   scaling specification  
 ip\_all\_x               format specification of input data

Remarks:

1. The format of the input data is specified by **ip\_all\_x**. If **ip\_all\_x** is 1, the input data are taken from the **data\_x**. If **ip\_all\_x** is 0, the first **size/2** data are taken from **data\_x**, and the remaining **size/2** data are taken from **data\_y**.
2. On returning, **data\_x** and **data\_y** contain **size/2** positive data only. The negative output data are simply the conjugate complex number of the positive data. Since the output data at both 0 and  $F_s/2$  are real, the output value at  $F_s/2$  is placed in **data\_y[0]**.
3. The storage of complex and real data arrays is described in section 10.4.5 (4) (b), Complex Data Array Format, and section 10.4.5 (5) (c), Real Data Array Format.
4. **data\_y** should have **size/2** elements. **data\_x** should have **size** or **size/2** elements as required by the value of **ip\_all\_x**.
5. Before calling this routine the lookup table and **max\_fft\_size** should be initialized by calling **InitFft**.
6. Scaling specification is described in section 10.4.5 (5) (d), Scaling.
7. Only the lower **log<sub>2</sub>(size)** bits of **scale** are used.
8. This routine is not reentrant.

**int IfftInComplex (short data\_x[ ], short data\_y[ ], long size, long scale)**  
**int IfftInComplex ( \_\_X\_\_fixed data\_x[ ], \_\_Y\_\_fixed data\_y[ ], long size,  
long scale)**

Description: Executes an in-place complex inverse Fast Fourier Transform.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG       size < 4  
                                         size not a power of 2  
                                         size > max\_fft\_size

Parameters: data\_x[ ]       real part of data  
              data\_y[ ]       imaginary part of data  
              size            size of inverse FFT  
              scale            scaling specification

Remarks:

1. The storage of complex data arrays is described in section 10.4.5 (5) (b), Complex Data Array Format.
2. Before calling this routine the lookup table and **max\_fft\_size** should be initialized by calling **InitFft**.
3. Scaling specification is described in section 10.4.5 (5) (d), Scaling.
4. Only the lower **log<sub>2</sub> (size)** bits of **scale** are used.
5. This routine is not reentrant.

**int IfftInReal (short data\_x[ ], short data\_y[ ], long size, long scale, int op\_all\_x)**  
**int IfftInReal ( \_\_X \_\_fixed data\_x[ ], \_\_Y \_\_fixed data\_y[ ], long size,**  
**long scale, int op\_all\_x)**

Description: Executes an in-place real inverse Fast Fourier Transform.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            size < 8  
                                          size not a power of 2  
                                          size > max\_fft\_size  
                                          op\_all\_x ≠ 0 or 1

Parameters: data\_x[ ]            real part of positive data on input, real data on output  
 data\_y[ ]            imaginary part of positive data on input, real data or unused on  
                                          output  
 size                    size of inverse FFT  
 scale                   scaling specification  
 op\_all\_x              format specification of output data

Remarks:

1. **data\_x** and **data\_y** should contain **size/2** positive input data only. The negative data are simply the conjugate complex number of the positive data. Since the input data values at both 0 and  $F_s/2$  can only be real, the input value at  $F_s/2$  should be placed in **data\_y[0]**.
2. **op\_all\_x** specifies the output data format. If **op\_all\_x** is 1, all output is stored in **data\_x**. If **op\_all\_x** is 0, the first **size/2** output data are stored in **data\_x**; the remaining **size/2** output data are stored in **data\_y**.
3. The storage of complex and real data arrays is described in section 10.4.5 (5) (b), Complex Data Array Format, and section 10.4.5 (5) (c), Real Data Array Format.
4. **data\_y** should have **size/2** elements. **data\_x** should have **size** or **size/2** elements as required by the value of **op\_all\_x**.
5. Before calling this routine the lookup table and **max\_fft\_size** should be initialized by calling **InitFft**.
6. Scaling specification is described in section 10.4.5 (5) (d), Scaling.
7. Only the lower **log<sub>2</sub>(size)** bits of **scale** are used.
8. This routine is not reentrant.

```
int LogMagnitude (short output[], const short ip_x[], const short ip_y[],
 long no_elements, float fscale)
int LogMagnitude (__fixed output[], const __X__fixed ip_x[],
 const __Y__fixed ip_y[], long no_elements, float fscale)
```

Description: Executes the log magnitude of the complex input data in decibels, and writes the scaled result into the output array

Header: <ensigdsp.h>

Return values: EDSP\_OK            successfully completed  
EDSP\_BAD\_ARG    no\_elements < 1  
                 no\_elements > 32767  
                 |fscale| ≥ 2<sup>15</sup>/(10log<sub>10</sub>2<sup>31</sup>)

Parameters:    output[ ]      real output data z  
                 ip\_x[ ]        real part of input data x  
                 ip\_y[ ]        imaginary part of input data y  
                 no\_elements    number of output data N  
                 fscale         output scaling factor

Remarks:       $z(n)=10fscale \cdot \log_{10}(x(n)^2+y(n)^2)$        $0 \leq n < N$

The storage of complex data arrays is described in section 10.4.5 (5) (b),  
Complex Data Array Format.

**int InitFft (long max\_size)**

Description: Generates the (quarter size) lookup tables used by the FFT functions.

Header: <ensigdsp.h>

|                |              |                                          |
|----------------|--------------|------------------------------------------|
| Return values: | EDSP_OK      | successfully completed                   |
|                | EDSP_NO_HEAP | insufficient space available from malloc |
|                | EDSP_BAD_ARG | max_size < 2                             |
|                |              | max_size not a power of 2                |
|                |              | max_size > 32768                         |

Parameters: max\_size Maximum size of FFT that will be required.

Remarks:

1. The lookup tables are stored in memory allocated by **malloc**.
2. Once the lookup tables have been generated the global variable **max\_fft\_size** is updated to indicate the maximum permitted **FFT** size.
3. This routine must be called once before calling the first **FFT** function.
4. **max\_size** must be 8 or larger.
5. The lookup tables are generated for the transform size specified by **max\_size**. Smaller transforms will be performed using the same lookup tables.
6. The addresses of the lookup tables are stored in internal variables; they should not be accessed by user programs.
7. This routine is not reentrant.

**void FreeFft (void)**

Description: Release the memory used for storing FFT lookup tables.

Header: <ensigdsp.h>

Remarks:

1. Set the **max\_fft\_size** global variable as 0. To use a **FFT** function again after executing **FreeFft**, **InitFft** must be executed.
2. This function is not reentrant.

## (6) Window Function

### (a) Overview

| <b>Function</b> | <b>Description</b>           |
|-----------------|------------------------------|
| GenBlackman     | Generates a Blackman window. |
| GenHamming      | Generates a Hamming window.  |
| GenHanning      | Generates a Hanning window.  |
| GenTriangle     | Generates a Triangle window. |

**int GenBlackman (short output[ ], long win\_size)****int GenBlackman ( \_\_fixed output[ ], long win\_size)**Description: Generates a Blackman window in **output**.

Header: &lt;ensigdsp.h&gt;

Return values: EDSP\_OK                      successfully completed  
EDSP\_BAD\_ARG                      win\_size ≤ 1Parameters: output[ ]                      output data W(n)  
win\_size                      window size NRemarks: **VectorMult** can be used to apply the window to a data array.  
The function used is:

$$W(n) = (2^{15} - 1) \left[ 0.42 - 0.5 \cos\left(\frac{2\pi n}{N}\right) + 0.08 \cos\left(\frac{4\pi n}{N}\right) \right] \quad 0 \leq n < N$$

**int GenHamming (short output[ ], long win\_size)****int GenHamming ( \_\_fixed output[ ], long win\_size)**Description: Generates a Hamming window in **output**.

Header: &lt;ensigdsp.h&gt;

Return values: EDSP\_OK                      successfully completed  
EDSD\_BAD\_ARG                      win\_size ≤ 1Parameters: output[ ]                      output data W(n)  
win\_size                      window size NRemarks: **VectorMult** can be used to apply the window to a data array.  
The function used is:

$$W(n) = (2^{15} - 1) \left[ 0.54 - 0.46 \cos\left(\frac{2\pi n}{N}\right) \right] \quad 0 \leq n < N$$



**int GenHanning (short output[ ], long win\_size)**  
**int GenHanning ( \_\_fixed output[ ], long win\_size)**

Description: Generates a Hanning window in **output**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG       win\_size ≤ 1

Parameters: output[ ]        output data W(n)  
win\_size        window size N

Remarks: **VectorMult** can be used to apply the window to a data array.  
The function used is:

$$W(n) = \left(\frac{2^{15} - 1}{2}\right) \left[1 - \cos\left(\frac{2\pi n}{N}\right)\right] \quad 0 \leq n < N$$

**int GenTriangle (short output[ ], long win\_size)**  
**int GenTriangle ( \_\_fixed output[ ], long win\_size)**

Description: Generates a Triangle window in **output**

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG       win\_size ≤ 1

Parameters: output[ ]        output data W(n)  
win\_size        window size N

Remarks: **VectorMult** can be used to apply the window to a data array.  
The function used is:

$$W(n) = (2^{15} - 1) \left[1 - \left| \frac{2n - N + 1}{N + 1} \right| \right] \quad 0 \leq n < N$$

## (7) Filters

### (a) Overview

| Function | Description                                                                           |
|----------|---------------------------------------------------------------------------------------|
| Fir      | Executes a finite impulse response filter.                                            |
| Fir1     | Executes a finite impulse response filter for a single input data.                    |
| lir      | Executes an infinite impulse response filter.                                         |
| lir1     | Executes an infinite impulse response filter for a single input data.                 |
| Dlir     | Executes a double precision infinite impulse response filter.                         |
| Dlir1    | Executes a double precision infinite impulse response filter for a single input data. |
| Lms      | Executes a real adaptive FIR filter.                                                  |
| Lms1     | Executes a real adaptive FIR filter for a single input data.                          |
| InitFir  | Allocates a workspace for FIR filter.                                                 |
| Initlir  | Allocates a workspace for IIR filter.                                                 |
| InitDlir | Allocates a workspace for double precision DIIR filter.                               |
| InitLms  | Allocates a workspace for LMS filter.                                                 |
| FreeFir  | Releases a workspace allocated by InitFir.                                            |
| Freelir  | Releases a workspace allocated by Initlir.                                            |
| FreeDlir | Releases a workspace allocated by InitDlir.                                           |
| FreeLms  | Releases a workspace allocated by InitLms.                                            |

Note: When the filter functions are used in a program, **filt\_ws.h** must be included once.

### (b) Coefficient Scaling

Filtering is likely to introduce saturation or quantization error. It can be minimized by scaling the filter coefficients. However, the scaling of coefficients must be performed carefully to balance the effects of saturation and quantization. If the coefficients are too large, saturation may occur; if they are too small, excessive quantization error may be introduced.

For **FIR** (finite impulse response) filters, no saturation will occur if

$\text{coeff}[i] \neq H'8000$  for all  $i$ ,

$\sum|\text{coeff}| < 2^{24}$ , and

$\text{res\_shift} = 24$ .

Here, **coeff** is a filter coefficient, and **res\_shift** is the number of bits shifted to the right at output.

For many input signals, smaller **res\_shift** values (or larger **coeff** values) can be used with a low likelihood of saturation, and with significantly reduced quantization error. If H'8000 may be among the inputs, all **coeff** values should be limited to the range from H'8001 to H'7FFF.

**IIR** (infinite impulse response) filters have a recursive structure, which means that the scaling approach described above is inappropriate.

**LMS** (least mean squared) adaptive filters obey the same conventions as **FIR** filters.

However, the coefficients may be pushed into saturation as the coefficients are adapted. In that case, the coefficients should not include H'8000.

### (c) Workspace

Digital filters have state that must be preserved from the processing of one data to the next. This filter state must be stored in memory that can be accessed with minimum overhead - on this library, the Y-RAM area is used. The workspace must be initialized by the **Init** function before calling a filter function.

The structure of the workspace memory is liable to change in the future, so user programs should not attempt to read or modify this memory, it should only be accessed by the library functions.

### (d) Memory Usage

To allow efficient use of the SH-DSP for all filters, the coefficients must be located in X memory. The input and output data may be located in any memory segment.

The filter coefficients must be located in X memory using the **#pragma section** directive. When the **dspc** option is specified, **\_\_X** memory qualifier should be used. In this case the **#pragma** specification is not required.

Each individual filter is allocated to workspace from a global buffer using the **Init** routines. The global buffer must be located in Y memory.

```
int Fir (short output[], const short input[], long no_samples, const short coeff[],
 long no_coefs, int res_shift, short *workspace)
int Fir (__fixed output[], const __fixed input[], long no_samples,
 const __X__fixed coeff[], long no_coefs, int res_shift, __Y__fixed *workspace)
```

Description: Executes a finite impulse response (**FIR**) filter.

Header: <ensigdsp.h>

Return values:

|              |                        |
|--------------|------------------------|
| EDSP_OK      | successfully completed |
| EDSP_BAD_ARG | no_samples < 1         |
|              | no_coefs ≤ 6           |
|              | res_shift < 0          |
|              | res_shift > 25         |

Parameters:

|            |                                             |
|------------|---------------------------------------------|
| output[ ]  | output data y                               |
| input[ ]   | input data x                                |
| no_samples | number of data N                            |
| coeff[ ]   | filter coefficients h                       |
| no_coefs   | number of coefficients K (length of filter) |
| res_shift  | right shift applied to each output          |
| workspace  | pointer to workspace                        |

Remarks:

1. It uses workspace to record the most recent input data. The result of filtering the data in **input** is written to **output**:

$$y(n) = \left[ \sum_{k=0}^{K-1} h(k) x(n-k) \right] \cdot 2^{-\text{res\_shift}}$$

2. For multiply-accumulate operation, the sum is accumulated in 39 bits. Each 16-bit output y(n) is extracted from the lower 16 bits of **res\_shift** bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
3. Coefficient scaling is described in section 10.4.5 (7) (b), Coefficient Scaling.
4. Before calling this routine for a new filter, initialize the filter workspace by calling **InitFir**.
5. When **output** is specified the same as **input**, **input** is overwritten.
6. This routine is not reentrant.

**int Fir1 (short \*output, short input, const short coeff[ ],  
 long no\_coefs, int res\_shift, short \*workspace)**

Description: Executes a finite impulse response (**FIR**) filter for a single input data only.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG      no\_coefs ≤ 6  
                                               res\_shift < 0  
                                               res\_shift > 25

Parameters:      output            pointer to output data y(n)  
                   input             input data x(n)  
                   coeff[ ]        filter coefficients h  
                   no\_coefs      number of coefficients K (length of filter)  
                   res\_shift     right shift applied to each output  
                   workspace     pointer to workspace

Remarks:      1. It uses workspace to record the most recent input data. The result of filtering the data in **input** is written to **output**:

$$y(n) = \left[ \sum_{k=0}^{K-1} h(k) x(n-k) \right] \cdot 2^{-\text{res\_shift}}$$

2. For multiply-accumulate operation, the sum is accumulated in 39 bits. Each 16 bit output is extracted from the lower 16 bits of **res\_shift** bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
3. Coefficient scaling is described in section 10.4.5 (7) (b), Coefficient Scaling.
4. Before calling this routine for a new filter, initialize the filter workspace by calling **InitFir**.
5. This routine is not reentrant.

```
int Iir (short output[], const short input[], long no_samples, const short coeff[],
 long no_sections, short *workspace)
int Iir (__fixed output[], const __fixed input[], long no_samples,
 const __X __fixed coeff[], long no_sections, __Y __fixed *workspace)
```

Description: Executes an infinite impulse response (IIR) filter.

Header: <ensigdsp.h>

Return values:

|              |                        |
|--------------|------------------------|
| EDSP_OK      | successfully completed |
| EDSP_BAD_ARG | no_samples < 1         |
|              | no_sections < 1        |
|              | a <sub>0k</sub> < 0    |
|              | a <sub>0k</sub> > 16   |

Parameters:

|             |                                          |
|-------------|------------------------------------------|
| output[ ]   | output data y <sub>K-1</sub>             |
| input[ ]    | input data x <sub>0</sub>                |
| no_samples  | number of data N                         |
| coeff[ ]    | filter coefficients                      |
| no_sections | number of second order filter sections K |
| workspace   | pointer to workspace                     |

Remarks:

- The filter is implemented as a cascade of K second order filters called biquads, with an additional scaling performed on the biquad output. The coefficients are specified in signed 16-bit fixed-point numbers and the output of each biquad is given by:
 
$$D_k(n)=[a_{1k}d_k(n-1)+a_{2k}d_k(n-2)+2^{15}x(n)]\cdot 2^{-15}$$

$$y_k(n)=[b_{0k}d_k(n)+b_{1k}d_k(n-1)+b_{2k}d_k(n-2)]\cdot 2^{-a_{0k}}$$
- The input x<sub>k</sub>(n) to the kth section is the output y<sub>k-1</sub>(n) of the previous section. The input to the first (k=0) section is taken from **input**. The output from the last (k = K-1) section is written to **output**.
- The filter coefficients should be specified in **coeff** in the order: a<sub>00</sub>, a<sub>10</sub>, a<sub>20</sub>, b<sub>00</sub>, b<sub>10</sub>, b<sub>20</sub>, a<sub>01</sub>, a<sub>11</sub>, a<sub>21</sub>, b<sub>01</sub>... b<sub>2K-1</sub>. Here, a<sub>0k</sub> is the number of bits shifted to the right at kth biquad output.
- Each biquad is calculated in 32 bits using saturating arithmetic. Each biquad output is extracted from the lower 16 bits of accumulator after 15 or a<sub>0k</sub> bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
- Before calling this routine for a new filter, initialize the filter workspace by calling **InitIir**.

6. When **output** is specified the same as **input**, **input** is overwritten.
7. This routine is not reentrant.

**int lir1 (short \*output, short input, const short coeff[ ], long no\_sections,  
short \*workspace)**

Description: Executes an infinite impulse response (**IIR**) filter for a single input data only.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            no\_sections < 1  
                                          a<sub>0k</sub> < 0  
                                          a<sub>0k</sub> > 16

Parameters:     output            pointer to output data y<sub>k-1</sub> (n)  
                   input            input data x<sub>0</sub> (n)  
                   coeff[ ]        filter coefficients  
                   no\_sections    number of second order filter sections K  
                   workspace     pointer to workspace

- Remarks:
1. The filter is implemented as a cascade of K second order filters called biquads, with an additional scaling performed on the biquad output. The coefficients are specified in signed 16-bit fixed-point numbers and the output of each biquad is given by:  

$$D_k(n)=[a_{1k}d_k(n-1)+a_{2k}d_k(n-2)+2^{15}x(n)]\cdot 2^{-15}$$

$$y_k(n)=[b_{0k}d_k(n)+b_{1k}d_k(n-1)+b_{2k}d_k(n-2)]\cdot 2^{-a_{0k}}$$
  2. The input x<sub>k</sub>(n) to the kth section is the output y<sub>k-1</sub>(n) of the previous section. The input to the first (k=0) section is taken from **input**. The output from the last (k = K-1) section is written to **output**.
  3. The filter coefficients should be specified in **coeff** in the order:  
 a<sub>00</sub>, a<sub>10</sub>, a<sub>20</sub>, b<sub>00</sub>, b<sub>10</sub>, b<sub>20</sub>, a<sub>01</sub>, a<sub>11</sub>, a<sub>21</sub>, b<sub>01</sub>... b<sub>2K-1</sub>  
 Here, a<sub>0k</sub> is the number of bits shifted to the right at kth biquad output.
  4. Each biquad is calculated in 32 bits using saturating arithmetic. Each biquad output is extracted from the lower 16 bits of accumulator after 15 or a<sub>0k</sub> bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
  5. Before calling this routine for a new filter, initialize the filter workspace by calling **Initlir**.
  6. This routine is not reentrant.

```
int DIir (short output[], const short input[], long no_samples,
 const long coeff[], long no_sections, long *workspace)
int DIir (__fixed output[], const __fixed input[], long no_samples,
 const __X long __fixed coeff[], long no_sections, __Y long __fixed *workspace)
```

Description: Executes an infinite impulse response (**IIR**) filter with double precision coefficients.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            no\_samples < 1  
                                          no\_sections < 1  
                                          a<sub>0k</sub> < 3  
                                          a<sub>0k</sub> > 32 for k < K-1  
                                          a<sub>0k</sub> > 48 for k = K-1

Parameters: output[ ]            pointer to output data y<sub>k-1</sub>  
 input[ ]                    input data x  
 no\_samples                number of data N  
 coeff[ ]                    filter coefficients  
 no\_sections                number of second order filter sections K  
 workspace                  pointer to workspace

- Remarks:
- The filter is implemented as a cascade of K second order filters called biquads, with an additional scaling performed on the biquad output. The coefficients are specified in signed 32-bit fixed-point numbers and the output of each biquad is given by:  

$$D_k(n)=[a_{1k}d_k(n-1)+a_{2k}d_k(n-2)+2^{29}x(n)]\cdot 2^{-31}$$

$$y_k(n)=[b_{0k}d_k(n)+b_{1k}d_k(n-1)+b_{2k}d_k(n-2)](2^{-(a_{0k})})^2$$
  - The input x<sub>k</sub>(n) to the kth section is the output y<sub>k-1</sub>(n) of the previous section. The input to the first (k=0) section is taken from **input** after 16 bits shifted to the left. The output from the last (k = K-1) section is written to **output**.
  - The filter coefficients should be specified in **coeff** in the order:  
 a<sub>00</sub>, a<sub>10</sub>, a<sub>20</sub>, b<sub>00</sub>, b<sub>10</sub>, b<sub>20</sub>, a<sub>01</sub>, a<sub>11</sub>, a<sub>21</sub>, b<sub>01</sub>... b<sub>2K-1</sub>  
 Here, a<sub>0k</sub> is the number of bits shifted to the right at kth biquad output.
  - DIir** differs from **Iir** in that the filter coefficients are specified as 32 rather than 16 bit values. For multiply-accumulate operation, the sum is accumulated in 64 bits. Intermediate biquad outputs are extracted from the lower 32 bits of accumulator after a<sub>0k</sub> bits shifted to the right. If an



- overflow occurs, output is saturated to positive or negative maximum value.
5. In the final stage, output is extracted from the lower 16 bits of accumulator after  $a_{0K-1}$  bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
  6. Before calling this routine for a new filter, initialize the filter workspace by calling **InitDfir**.
  7. Delay nodes  $d_k(n)$  are rounded to 30-bit quantities. If an overflow occurs, they are saturated to positive or negative maximum value.
  8. The most common use of **Dfir** specifies the coefficients in signed 32-bit fixed-point numbers. In this case,  $a_{0k}$  should be set to 31 for  $k < K-1$  and to 47 for  $k = K-1$ .
  9. When double-precision calculation is not required, **ifir** should be used in preference to **Dfir** as it runs faster on the SH-DSP.
  10. When **output** is specified the same as **input**, **input** is overwritten.
  11. This routine is not reentrant.

**int Dllr1 (short \*output, const short input, const long coeff[ ],  
long no\_sections, long \*workspace)**

**Description:** Executes a double precision infinite impulse response (**IIR**) filter for a single input data only.

**Header:** <ensigdsp.h>

**Return values:**

|              |                                  |
|--------------|----------------------------------|
| EDSP_OK      | successfully completed           |
| EDSP_BAD_ARG | no_sections < 1                  |
|              | a <sub>0k</sub> < 3              |
|              | a <sub>0k</sub> > 32 for k < K-1 |
|              | a <sub>0k</sub> > 48 for k = K-1 |

**Parameters:**

|             |                                             |
|-------------|---------------------------------------------|
| output      | pointer to output data y <sub>k-1</sub> (n) |
| input       | input data x <sub>0</sub> (n)               |
| coeff[ ]    | filter coefficients                         |
| no_sections | number of second order filter sections K    |
| workspace   | pointer to workspace                        |

- Remarks:**
- The filter is implemented as a cascade of K second order filters called biquads, with an additional scaling performed on the biquad output. The coefficients are specified in signed 32-bit fixed-point numbers and the output of each biquad is given by:  

$$D_k(n)=[a_{1k}d_k(n-1)+a_{2k}d_k(n-2)+2^{29}x(n)]\cdot 2^{-31}$$

$$y_k(n)=[b_{0k}d_k(n)+b_{1k}d_k(n-1)+b_{2k}d_k(n-2)](2^{-(a_{0k})})^2$$
  - The input x<sub>k</sub>(n) to the kth section is the output y<sub>k-1</sub>(n) of the previous section. The input to the first (k=0) section is taken from **input** after 16 bits shifted to the left. The output from the last (k = K-1) section is written to **output**.
  - The filter coefficients should be specified in **coeff** in the order:  
a<sub>00</sub>, a<sub>10</sub>, a<sub>20</sub>, b<sub>00</sub>, b<sub>10</sub>, b<sub>20</sub>, a<sub>01</sub>, a<sub>11</sub>, a<sub>21</sub>, b<sub>01</sub>... b<sub>2K-1</sub>  
Here, a<sub>0k</sub> is the number of bits shifted to the right at kth biquad output.
  - Dllr1** differs from **Ilr1** in that the filter coefficients are specified as 32 rather than 16-bit values. For multiply-accumulate operation, the sum is accumulated in 64 bits. Intermediate biquad outputs are extracted from the lower 32 bits of accumulator after a<sub>0k</sub> bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
  - In the final stage, output is extracted from the lower 16 bits of accumulator after a<sub>0K-1</sub> bits shifted to the right. If an overflow occurs,

output is saturated to positive or negative maximum value.

6. Before calling this routine for a new filter, initialize the filter workspace by calling **InitDfir**.
7. Delay nodes  $d_k(n)$  are rounded to 30-bit quantities. If an overflow occurs, they are saturated to positive or negative maximum value.
8. The most common use of **Dfir** specifies the coefficients in signed 32-bit fixed-point numbers. In this case,  $a_{0k}$  should be set to 31 for  $k < K-1$  and to 47 for  $k = K-1$ .
9. When double-precision calculation is not required, **Iir1** should be used in preference to **Dfir1** as it runs faster on the SH-DSP.
10. This routine is not reentrant.

```
int Lms (short output[], const short input[], const short ref_output[],
 long no_samples, short coeff[], long no_coefs, int res_shift,
 short conv_fact, short *workspace)
int Lms (__fixed output[], const __fixed input[], const __fixed ref_output[],
 long no_samples, __X __fixed coeff[], long no_coefs, int res_shift,
 short conv_fact, __Y __fixed *workspace)
```

Description: Executes a real adaptive **FIR** filter using the least mean square algorithm (LMS).

Header: <ensigdsp.h>

Return values:

|              |                        |
|--------------|------------------------|
| EDSP_OK      | successfully completed |
| EDSP_BAD_ARG | no_samples < 1         |
|              | no_coefs ≤ 6           |
|              | res_shift < 0          |
|              | res_shift > 25         |

Parameters:

|               |                                    |
|---------------|------------------------------------|
| output[ ]     | output data y                      |
| input[ ]      | input data x                       |
| ref_output[ ] | desired output value d             |
| no_samples    | number of data N                   |
| coeff[ ]      | adaptive filter coefficients h     |
| no_coefs      | number of coefficients K           |
| res_shift     | right shift applied to each output |
| conv_fact     | convergence factor 2 $\mu$         |
| workspace     | pointer to workspace               |

Remarks: 1. The **FIR** filter is defined as:

$$y(n) = \left[ \sum_{k=0}^{K-1} h_n(k) x(n-k) \right] \cdot 2^{-\text{res\_shift}}$$

- For multiply-accumulate operation, the sum is accumulated in 39 bits. Each 16-bit output is extracted from the lower 16 bits of **res\_shift** bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
- The **Widrow-Hoff** algorithm is used to update the filter coefficients:  
 $h_{n+1}(k) = h_n(k) + 2\mu e(n)x(n-k)$   
 where  $e(n)$  is the error between the desired signal and the actual filter output:  
 $e(n) = d(n) - y(n)$

4. The calculation of  $2\mu e(n)x(n-k)$  requires two (16 bits)  $\times$  (16 bits) multiplies. In both multiplies, upper 16 bits are stored and if an overflow occurs, data are saturated to positive or negative maximum value. If updated coefficients include H'8000, an overflow may occur for multiply-accumulate operation. In this case, the coefficients must set in the range from H'8001 to H'7FFF.
5. Coefficient specification is described in section 10.4.5 (7) (b), Coefficient Scaling. As the coefficients are adapted by LMS filters, the safest scaling scheme is to use fewer than 256 coefficients and set **res\_shift** to 24.
6. **conv\_fact** should normally be positive; it should never be H'8000.
7. Before calling this routine for a new filter, initialize the filter workspace by calling **InitLms**.
8. When the **output** array is specified the same as the **input** or **ref\_output** array, **input** or **ref\_output** is overwritten.
9. This routine is not reentrant.

**int Lms1 (short \*output, short input, short ref\_output, short coeff[ ],  
long no\_coefs, int res\_shift, short conv\_fact, short \*workspace)**

Description: Executes a real adaptive **FIR** filter using the least mean square algorithm (LMS), for a single input data.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            no\_coefs  $\leq$  6  
                                                                                  res\_shift < 0  
                                                                                  res\_shift > 25

Parameters:     output            pointer to output data y(n)  
                   input            input data x(n)  
                   ref\_output        desired output value d(n)  
                   coeff[ ]        adaptive filter coefficients h  
                   no\_coefs        number of coefficients K  
                   res\_shift        right shift applied to each output  
                   conv\_fact        convergence factor  $2\mu$   
                   workspace        pointer to workspace

Remarks:

1. The **FIR** filter is defined as:

$$y(n) = \left[ \sum_{k=0}^{K-1} h_n(k) \times (n - k) \right] \cdot 2^{-\text{res\_shift}}$$

2. For multiply-accumulate operation, the sum is accumulated in 39 bits. Each 16-bit output  $y(n)$  is extracted from the lower 16 bits of **res\_shift** bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
3. The **Widrow-Hoff** algorithm is used to update the filter coefficients:  
 $h_{n+1}(k) = h_n(k) + 2\mu e(n)x(n-k)$   
 where  $e(n)$  is the (saturated) error between the desired signal and the actual filter output:  
 $e(n) = d(n) - y(n)$
4. The calculation of  $2\mu e(n)x(n-k)$  requires two (16 bits)  $\times$  (16 bits) multiplies. In both multiplies, upper 16 bits are stored and if an overflow occurs, data are saturated to positive or negative maximum value. If updated coefficients include H'8000, an overflow may occur for multiply-accumulate operation. In this case, the coefficients must be set in the range from H'8001 to H'7FFF.
5. Coefficient specification is described in section 10.4.5 (7) (b), Coefficient Scaling. As the coefficients are adapted by LMS filters, the safest scaling scheme is to use fewer than 256 coefficients and set **res\_shift** to 24.
6. **conv\_fact** should normally be positive; it should never be H'8000.
7. Before calling this routine for a new filter, initialize the filter workspace by calling **InitLms**.
8. This routine is not reentrant.

**int InitFir (short \*\*workspace, long no\_coefs)**  
**int InitFir (\_ \_Y \_ \_fixed \*\*workspace, long no\_coefs)**

Description: Allocates the memory required for subsequent calls to **Fir** and **Fir1**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_NO\_HEAP        insufficient space available for workspace buffer  
EDSP\_BAD\_ARG        no\_coefs ≤ 2

Parameters: workspace    pointer to pointer to workspace  
no\_coefs        number of coefficients K

Remarks: 1. Previous input data are initialized to zero.  
2. The workspace buffer allocated by **InitFir** should only be manipulated by **Fir**, **Fir1**, **Lms** and **Lms1**. It should not be accessed by user programs.  
3. This routine is not reentrant.

**int InitIir (short \*\*workspace, long no\_sections)**  
**int InitIir (\_ \_Y \_ \_fixed \*\*workspace, long no\_sections)**

Description: Allocates the memory required for subsequent calls to **Iir** and **Iir1**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_NO\_HEAP        insufficient space available for workspace buffer  
EDSP\_BAD\_ARG        no\_sections < 1

Parameters: workspace    pointer to pointer to workspace  
no\_sections    number of second order filter sections K

Remarks: 1. Previous input data are initialized to zero.  
2. The workspace buffer allocated by **InitIir** should only be manipulated by **Iir** and **Iir1**. It should not be accessed by user programs.  
3. This routine is not reentrant.

**int InitDlir (long \*\*workspace, long no\_sections)**

**int InitDlir ( \_\_Y \_\_fixed \*\*workspace, long no\_sections)**

Description: Allocates the memory required for subsequent calls to **Dlir** and **Dlir1**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_NO\_HEAP            insufficient space available for workspace buffer  
 EDSP\_BAD\_ARG            no\_sections < 1

Parameters: workspace    pointer to pointer to workspace  
 no\_sections    number of second order filter sections K

Remarks

1. Previous input data are initialized to zero.
2. The workspace buffer allocated by **InitDlir** should only be manipulated by **Dlir** and **Dlir1**. It should not be accessed by user programs.
3. This routine is not reentrant.

**int InitLms (short \*\*workspace, long no\_coeffs)**

**int InitLms ( \_\_Y \_\_fixed \*\*workspace, long no\_coeffs)**

Description: Allocates the memory required for subsequent calls to **Lms** and **Lms1**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_NO\_HEAP            insufficient space available for workspace buffer  
 EDSP\_BAD\_ARG            no\_coeffs ≤ 2

Parameters: workspace    pointer to pointer to workspace  
 no\_coeffs    number of coefficients K

Remarks:

1. Previous input data are initialized to zero.
2. The workspace buffer allocated by **InitLms** should only be manipulated by **Fir**, **Fir1**, **Lms** and **Lms1**. It should not be accessed by user programs.
3. This routine is not reentrant.



**int FreeFir (short \*\*workspace, long no\_coefs)**

**int FreeFir (\_Y\_\_fixed \*\*workspace, long no\_coefs)**

Description: Frees workspace memory previously allocated by **InitFir**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG      no\_coefs ≤ 2

Parameters: workspace    pointer to pointer to workspace  
no\_coefs      number of coefficients K

Remarks: This routine is not reentrant.

**int FreeIir (short \*\*workspace, long no\_sections)**

**int FreeIir (\_Y\_\_fixed \*\*workspace, long no\_sections)**

Description: Frees workspace memory previously allocated by **InitIir**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG      no\_sections < 1

Parameters: workspace    pointer to pointer to workspace  
no\_sections    number of second order filter sections K

Remarks: This routine is not reentrant.

**int FreeDlir (long \*\*workspace, long no\_sections)**

**int FreeDlir (\_Y long \_\_fixed \*\*workspace, long no\_sections)**

Description: Frees workspace memory previously allocated by **InitDlir**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG        no\_sections ≤ 2

Parameters: workspace    pointer to pointer to workspace  
no\_sections    number of second order filter sections K

Remarks: This routine is not reentrant.

**int FreeLms (short \*\*workspace, long no\_coefs)**

**int FreeLms (\_Y \_\_fixed \*\*workspace, long no\_coefs)**

Description: Frees workspace memory previously allocated by **InitLms**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG        no\_coefs < 1

Parameters: workspace    pointer to pointer to workspace  
no\_coefs        number of coefficients K

Remarks: This routine is not reentrant.

## (8) Convolution and Correlation

### (a) Overview

| Function     | Description                       |
|--------------|-----------------------------------|
| ConvComplete | Completely convolves two arrays.  |
| ConvCyclic   | Cyclically convolves two arrays.  |
| ConvPartial  | Partially convolves two arrays.   |
| Correlate    | Correlates two arrays.            |
| CorrCyclic   | Cyclically correlates two arrays. |

In each case, one of two input arrays must be located in X memory and the other in Y memory. The output array may be located in any memory area.

```
int ConvComplete (short output[], const short ip_x[], const short ip_y[],
 long x_size, long y_size, int res_shift)
int ConvComplete (__fixed output[], const __X __fixed ip_x[], const __Y __fixed ip_y[],
 long x_size, long y_size, int res_shift)
```

Description: Completely convolves the two input arrays x and y, and puts the result in the output array z.

Header: <ensigdsp.h>

Return values: EDSP\_OK            successfully completed  
 EDSP\_BAD\_ARG    x\_size < 1  
                   y\_size < 1  
                   res\_shift < 0  
                   res\_shift > 25

Parameters: output[ ]        output z  
 ip\_x[ ]            input x  
 ip\_y[ ]            input y  
 x\_size            size of ip\_x X  
 y\_size            size of ip\_y Y  
 res\_shift        right shift applied to each output

Remarks: 1.  $z(m) = \left[ \sum_{i=0}^{X-1} x(i) y(m-i) \right] \cdot 2^{-\text{res\_shift}}$          $0 \leq m < X + Y - 1$   
 2. Elements outside the input array are read as zero.  
 3. The output array size must be set more than **X + Y - 1**.

```
int ConvCyclic (short output[], const short ip_x[], const short ip_y[],
 long size, int res_shift)
int ConvCyclic (__fixed output[], const __X__fixed ip_x[], const __Y__fixed ip_y[],
 long size, int res_shift)
```

Description:           Cyclically convolves the two input arrays and puts the result in the output array.

Header:                <ensigdsp.h>

Return values:        EDSP\_OK                successfully completed  
                       EDSP\_BAD\_ARG        size < 6  
                                               res\_shift < 0  
                                               res\_shift > 25

Parameters:           output[ ]        output z  
                       ip\_x[ ]         input x  
                       ip\_y[ ]         input y  
                       size            size of arrays N  
                       res\_shift       right shift applied to each output

Remarks:             
$$z(m) = \left[ \sum_{i=0}^{N-1} x(i) y(|m - i + N|_N) \right] \cdot 2^{-res\_shift} \quad 0 \leq m < N$$
  
                       where  $|i|_N$  is residue of i modulo N.

```

int ConvPartial (short output[], const short ip_x[], const short ip_y[],
 long x_size, long y_size, int res_shift)
int ConvPartial (_fixed output[], const __X__fixed ip_x[], const __Y__fixed ip_y[],
 long x_size, long y_size, int res_shift)

```

Description: Partially convolves the two input arrays x and y, and puts the result to output array z.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG        x\_size < 5  
                                           y\_size < 1  
                                           res\_shift < 0  
                                           res\_shift > 25

Parameters: output[ ]        output z  
 ip\_x[ ]            input x  
 ip\_y[ ]            input y  
 x\_size            size of ip\_x, X  
 y\_size            size of ip\_y, Y  
 res\_shift        right shift applied to each output

Remarks: 1. This routine does not include outputs derived from elements outside the input array.

$$z(m) = \left[ \sum_{i=0}^{A-1} a(i) b(m + A - 1 - i) \right] \cdot 2^{-\text{res\_shift}} \quad 0 \leq m \leq |A - B|$$

where a is the smaller input array, A is its size, b is the other array and B is its size.

2. The output array size must be set more than  $|X-Y|+1$ .
3. Elements outside the input arrays are read as zero.

```
int Correlate (short output[], const short ip_x[], const short ip_y[], long x_size,
 long y_size, long no_corr, int x_is_larger, int res_shift)
int Correlate (_fixed output[], const __X__fixed ip_x[], const __Y__fixed ip_y[],
 long x_size, long y_size, long no_corr, int x_is_larger, int res_shift)
```

Description: Correlates the two input arrays x and y, and puts the result in the output array z.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            x\_size < 1  
                                           y\_size < 1  
                                           no\_corr < 1  
                                           res\_shift < 0  
                                           res\_shift > 25  
                                           x\_is\_larger ≠ 0 or 1

Parameters:            output[ ]            output z  
                          ip\_x[ ]                input x  
                          ip\_y[ ]                input y  
                          x\_size                size of ip\_x X  
                          y\_size                size of ip\_y Y  
                          no\_corr                number of correlations M  
                          x\_is\_larger        array specification, if X=Y  
                          res\_shift            right shift applied to each output

Remarks: 1. In this calculation a is the larger input array, A is its size, b is the other input (if X and Y are equal, **x\_is\_larger = 1** defines a to be x and **x\_is\_larger = 0** defines b to be x). Then:

$$z(m) = \left[ \sum_{i=0}^{A-1} a(i) b(i+m) \right] \cdot 2^{-\text{res\_shift}} \quad 0 \leq m < M$$

2. **A < X+M** is permissible. In this case, elements outside the input arrays are read as zero.
3. **res\_shift = 0** corresponds to an integer calculation.  
**res\_shift = 15** corresponds to a fractional calculation.

```
int CorrCyclic (short output[], const short ip_x[], const short ip_y[], long size,
 int reverse, int res_shift)
int CorrCyclic (__fixed output[], const __X__fixed ip_x[], const __Y__fixed ip_y[],
 long size, int reverse, int res_shift)
```

Description: Cyclically correlates array x with array y and puts the result in the output array z.

Header: <ensigdsp.h>

Return values: EDSP\_OK            successfully completed  
 EDSP\_BAD\_ARG    size < 5  
                   res\_shift < 0  
                   res\_shift > 25  
                   reverse ≠ 0 or 1

Parameters: output[ ]        output z  
 ip\_x[ ]            input x  
 ip\_y[ ]            input y  
 size                size of arrays N  
 reverse            reverse flag  
 res\_shift         right shift applied to each output

Remarks: 
$$z(m) = \left[ \sum_{i=0}^{N-1} x(i) y(|i+m|_N) \right] \cdot 2^{-\text{res\_shift}} \quad 0 \leq m < N$$

where  $|i|_N$  is residue of  $i$  modulo  $N$ . If reverse is 1 the elements in output are reversed, to give the effective calculation:

$$z(m) = \left[ \sum_{i=0}^{N-1} y(i) x(|i+m|_N) \right] \cdot 2^{-\text{res\_shift}} \quad 0 \leq m < N$$



## (9) Miscellaneous

### (a) Overview

| Function   | Description                                           |
|------------|-------------------------------------------------------|
| Limit      | Exchanges data from H'8000 to H'8001.                 |
| CopyXtoY   | Copies array from X memory to Y memory.               |
| CopyYtoX   | Copies array from Y memory to X memory.               |
| CopyToX    | Copies array from a specified location to X memory.   |
| CopyToY    | Copies array from a specified location to Y memory.   |
| CopyFromX  | Copies array from X memory to a specified location.   |
| CopyFromY  | Copies array from Y memory to a specified location.   |
| GenGWhite  | Generates Gaussian white noise.                       |
| MatrixMult | Multiplies two matrices.                              |
| VectorMult | Multiplies two data.                                  |
| MsPower    | Calculates mean square power.                         |
| Mean       | Calculates mean.                                      |
| Variance   | Calculates mean and variance.                         |
| MaxI       | Searches for maximum in integer array.                |
| MinI       | Searches for minimum in integer array.                |
| PeakI      | Searches for maximum absolute value in integer array. |

**int Limit (short data\_xy[ ], long no\_elements, int data\_is\_x)**  
**int Limit ( \_\_fixed data\_xy[ ], long no\_elements, int data\_is\_x)**

Description: Exchanges data from H'8000 to H'8001. Therefore an overflow does not occur for fixed-point multiply operation.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            no\_elements < 1  
                                          data\_is\_x ≠ 0 or 1

Parameters: data\_xy            data array  
 no\_elements    number of elements  
 data\_is\_x       location specification of data

Remarks: 1. Even if this routine is performed, an overflow may occur for accumulate operation.  
 2. If **data\_is\_x** is 1, **data\_xy** should be located in X memory.  
 If **data\_is\_x** is 0, **data\_xy** should be located in Y memory.

**int CopyXtoY (short op\_y[ ], const short ip\_x[ ], long n)**  
**int CopyXtoY ( \_\_Y \_\_fixed op\_y[ ], const \_\_X \_\_fixed ip\_x[ ], long n)**

Description: Copies the array **ip\_x** to **op\_y**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            n < 6

Parameters: op\_y[ ]            output data  
 ip\_x[ ]            input data  
 n                    number of elements

Remarks: **ip\_x** is located in X memory and **op\_y** is located in Y memory.

**int CopyYtoX (short op\_x[ ], const short ip\_y[ ], long n)**  
**int CopyYtoX ( \_\_X \_\_fixed op\_x[ ], const \_\_Y \_\_fixed ip\_y[ ], long n)**

Description: Copies the array **ip\_y** to **op\_x**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG        n < 1

Parameters: op\_x[ ]            output data  
ip\_y[ ]            input data  
n                    number of elements

Remarks: **op\_x** is located in X memory and **ip\_y** is located in Y memory.

**int CopyToX (short op\_x[ ], const short input[ ], long n)**  
**int CopyToX ( \_\_X \_\_fixed op\_x[ ], const \_\_fixed input[ ], long n)**

Description: Copies the array **input** to **op\_x**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG        n < 1

Parameters: op\_x[ ]            output data  
input[ ]            input data  
n                    number of elements

Remarks: **op\_x** is located in X memory and **input** is located in any memory area.

**int CopyToY (short op\_y[ ], const short input[ ], long n)**

**int CopyToY ( \_\_Y \_\_fixed op\_y[ ], const \_\_fixed input[ ], long n)**

Description: Copies the array **input** to **op\_y**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG        n < 1

Parameters: op\_y[ ]            output data  
input[ ]            input data  
n                    number of elements

Remarks: **op\_y** is located in Y memory and **input** is located in any memory area.

**int CopyFromX (short output[ ], const short ip\_x[ ], long n)**

**int CopyFromX ( \_\_X \_\_fixed output[ ], const \_\_X \_\_fixed ip\_x[ ], long n)**

Description: Copies the array **ip\_x** to **output**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG        n < 1

Parameters: output[ ]            output data  
ip\_x[ ]            input data  
n                    number of elements

Remarks: **ip\_x** is located in X memory and **output** is located in any memory area.

**int CopyFromY (short output[ ], const short ip\_y[ ], long n)**  
**int CopyFromY ( \_\_fixed output[ ], const \_\_Y \_\_fixed ip\_y[ ], long n)**

Description: Copies the array **ip\_y** to **output**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
EDSP\_BAD\_ARG        n < 1

Parameters: output[ ]        output data  
ip\_y[ ]            input data  
n                    number of elements

Remarks: **ip\_y** is located in Y memory and **output** is located in any memory area.

**int GenGWnoise (short output[ ], long no\_samples, float variance)**

**int GenGWnoise ( \_\_fixed output[ ], long no\_samples, float variance)**

Description: Generates Gaussian white noise with zero mean and user-specified variance.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG            no\_samples < 1  
                                                                          variance ≤ 0.0

Parameters: output[ ]            output white noise data  
 no\_samples    number of output data  
 variance        variance of noise distribution  $\sigma^2$

Remarks: 1. Output data are produced in pairs. To produce a pair of output data, the standard random number generator provided by **rand** is used to generate pairs of random numbers  $\gamma_1$  and  $\gamma_2$  between -1 and 1, until a pair is found whose sum of squares  $x$  is less than 1. The pair of output data  $o_1$  and  $o_2$  are then calculated:

$$o_1 = \sigma\gamma_1\sqrt{-2\ln(x)/x}$$

$$o_2 = \sigma\gamma_2\sqrt{-2\ln(x)/x}$$

2. If an odd number of samples are requested, the second data of the last pair is discarded.
3. This routine is not strictly reentrant since any calls to **rand** will affect the sequence of random numbers used. However, such calls will not affect the random properties of the white noise generated.
4. Floating-point arithmetic is used in this function and this degrades the processing speed, so its use should be restricted to test programs rather than application programs whenever possible.

```
int MatrixMult (void *op_matrix, const void *ip_x, const void *ip_y, long m,
 long n, long p, int x_first, int res_shift)
int MatrixMult (void *op_matrix, const __X void *ip_x, const __Y void *ip_y,
 long m, long n, long p, int x_first, int res_shift)
```

Description: Multiplies the two matrices x and y and stores the result in **op\_matrix**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                    successfully completed  
 EDSP\_BAD\_ARG                    m, n or p < 5  
                                           res\_shift < 0  
                                           res\_shift > 25  
                                           x\_first ≠ 0 or 1

Parameters: op\_matrix    pointer to the first element of output  
 ip\_x                    pointer to the first element of input x  
 ip\_y                    pointer to the first element of input y  
 m                        row dimension of matrix1  
 n                        column dimension of matrix1, row dimension of matrix2  
 p                        column dimension of matrix2  
 x\_first                order specification of matrix multiply  
 res\_shift              right shift applied to each output

- Remarks:
1. If **x\_first** is 1 the product **x × y** is calculated. In this case **ip\_x** is **m × n**, **ip\_y** is **n × p** and **op\_matrix** is **m × p**.
  2. If **x\_first** is 0 the product **y × x** is calculated. In this case **ip\_y** is **m × n**, **ip\_x** is **n × p** and **op\_matrix** is **m × p**.
  3. For multiply-accumulate operation, the sum is accumulated in 39 bits. Each 16-bit output is extracted from the lower 16 bits of **res\_shift** bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
  4. Each matrix is stored in the normal 'C' manner (row major order):

$$\begin{pmatrix} a_0 & a_1 & a_2 & a_3 \\ a_4 & a_5 & a_6 & a_7 \\ a_8 & a_9 & a_{10} & a_{11} \end{pmatrix}$$

5. The function prototype specifies the array parameters as void \* to allow arbitrary array sizes to be specified. These parameters should point to

short-type data.

6. **ip\_x**, **ip\_y** and **op\_matrix** must not overlap.

```
int VectorMult (short output[], const short ip_x[], const short ip_y[],
 long no_elements, int res_shift)
```

```
int VectorMult (__fixed output[], const __X__fixed ip_x[], const __Y__fixed ip_y[],
 long no_elements, int res_shift)
```

Description: Multiplies pairs of elements from **ip\_x** and **ip\_y** and stores the results in **output**.

Header: <ensigdsp.h>

Return values:

|              |                                                    |
|--------------|----------------------------------------------------|
| EDSP_OK      | successfully completed                             |
| EDSP_BAD_ARG | no_elements < 4<br>res_shift < 0<br>res_shift > 16 |

Parameters:

|             |                                    |
|-------------|------------------------------------|
| output[ ]   | output                             |
| ip_x[ ]     | input1                             |
| ip_y[ ]     | input2                             |
| no_elements | number of elements                 |
| res_shift   | right shift applied to each output |

Remarks:

1. Output is extracted from the lower 16 bits of **res\_shift** bits shifted to the right. If an overflow occurs, output is saturated to positive or negative maximum value.
2. This routine performs element-wise multiplication. To calculate a dot product use **MatrixMult** with **m** and **p** set to 1.



```
int MsPower (long *output, const short input[], long no_elements, int src_is_x)
int MsPower (long __fixed * output, const __fixed input[], long no_elements,
 int src_is_x)
```

Description:           Calculates the mean square power of the input data

Header:                <ensigdsp.h>

Return values:        EDSP\_OK                successfully completed  
                      EDSP\_BAD\_ARG       no\_elements < 6  
                                              src\_is\_x ≠ 0 or 1

Parameters:           output            pointer to output  
                      input[ ]        input x  
                      no\_elements    number of elements N  
                      src\_is\_x        location specification of data

Remarks:            1. Mean square power =  $\frac{1}{N} \sum_{i=0}^{N-1} x(i)^2$   
                      2. The division result is rounded to the nearest integral value.  
                      3. The sum is accumulated in 63 bits. If **no\_elements** is more than  $2^{32}$ ,  
                          an overflow may occur.  
                      4. If **src\_is\_x** is 1, data is located in X memory.  
                          If **src\_is\_x** is 0, data is located in Y memory.

**int Mean (short \*mean, const short input[ ], long no\_elements, int src\_is\_x)**

**int Mean ( \_\_fixed \*mean, const \_\_fixed input[ ], long no\_elements, int src\_is\_x)**

Description: Calculates the mean of input

Header: <ensigdsp.h>

Return values: EDSP\_OK successfully completed  
 EDSP\_BAD\_ARG no\_elements < 6  
 src\_is\_x ≠ 0 or 1

Parameters: mean pointer to mean x of input  
 input[ ] input x  
 no\_elements number of elements N  
 src\_is\_x location specification of data

Remarks:

1.  $\bar{x} = \frac{1}{N} \sum_{i=0}^{N-1} x(i)$
2. The division result is rounded to the nearest integral value.
3. The sum is accumulated in 32 bits. If **no\_elements** is more than  $2^{16}-1$ , an overflow may occur.
4. If **src\_is\_x** is 1, data is located in X memory.  
 If **src\_is\_x** is 0, data is located in Y memory.

```
int Variance (long *variance, short *mean, const short input[],
 long no_elements, int src_is_x)
int Variance (long __fixed *variance_ptr, __fixed *mean_ptr,
 const __fixed input[], long no_elements, int src_is_x)
```

Description:           Calculates the mean and variance of input

Header:                 <ensigdsp.h>

Return values:         EDSP\_OK                 successfully completed  
                        EDSP\_BAD\_ARG         no\_elements < 4  
                                                  src\_is\_x ≠ 0 or 1

Parameters:           variance             pointer to the variance  $\sigma^2$  of input  
                        mean                 pointer to mean x of data  
                        input[ ]            input x  
                        no\_elements        number of elements N  
                        src\_is\_x           location specification of data

Remarks:             1.  $\bar{x} = \frac{1}{N} \sum_{i=0}^{N-1} x(i)$   
                                                 $\sigma^2 = \frac{1}{N} \sum_{i=0}^{N-1} x(i)^2 - \bar{x}^2$

2. The division results are rounded to the nearest integral values.
3. x is accumulated in 32 bits and is not checked for overflow. If **no\_elements** is more than  $2^{16}-1$ , an overflow may occur.
4.  $\sigma^2$  is accumulated in 63 bits and is not checked for overflow.
5. If **src\_is\_x** is 1, data is located in X memory.  
       If **src\_is\_x** is 0, data is located in Y memory.

**int MaxI (short \*\*max\_ptr, short input[ ], long no\_elements, int src\_is\_x)****int MaxI ( \_\_fixed \*\*max\_ptr, \_\_fixed input[ ], long no\_elements, int src\_is\_x)**

Description: Searches for maximum value of array **input**, and returns its address in **max\_ptr**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                  successfully completed  
EDSP\_BAD\_ARG              no\_elements < 1  
                                        src\_is\_x ≠ 0 or 1

Parameters: max\_ptr            pointer to pointer to the maximum element  
input[ ]            input  
no\_elements        number of elements  
src\_is\_x            location specification of data

Remarks: 1. If several elements have the same maximum value the one nearest the  
start of input is returned.  
2. If **src\_is\_x** is 1, data is located in X memory.  
If **src\_is\_x** is 0, data is located in Y memory.

**int MinI (short \*\*min\_ptr, short input[ ], long no\_elements, int src\_is\_x)****int MinI ( \_\_fixed \*\*min\_ptr, \_\_fixed input[ ], long no\_elements, int src\_is\_x)**

Description: Searches for minimum value of array input, and returns its address in **min\_ptr**.

Header: <ensigdsp.h>

Return values: EDSP\_OK                  successfully completed  
EDSP\_BAD\_ARG              no\_elements < 1  
                                        src\_is\_x ≠ 0 or 1

Parameters: min\_ptr            pointer to pointer to the minimum element  
input[ ]            input  
no\_elements        number of elements  
src\_is\_x            location specification of data

Remarks: 1. If several elements have the same minimum value the one nearest the  
start of input is returned.

2. If **src\_is\_x** is 1, data is located in X memory.  
If **src\_is\_x** is 0, data is located in Y memory.

**int PeakI (short \*\*peak\_ptr, short input[ ], long no\_elements, int src\_is\_x)**  
**int PeakI ( \_\_fixed \*\*peak\_ptr, \_\_fixed input[ ], long no\_elements, int src\_is\_x)**

Description: Searches for maximum absolute value of array **input**, and returns its address in **peak\_ptr**

Header: <ensigdsp.h>

Return values: EDSP\_OK                      successfully completed  
EDSP\_BAD\_ARG       no\_elements < 1  
                                          src\_is\_x ≠ 0 or 1

Parameters: peak\_ptr       pointer to pointer to the peak element  
              input[ ]       input  
              no\_elements   number of elements  
              src\_is\_x       location specification of data

Remarks

1. If several elements have the same peak value the one nearest the start of **input** is returned.
2. If **src\_is\_x** is 1, data is located in X memory.  
If **src\_is\_x** is 0, data is located in Y memory.



## Section 11 Assembly Specifications

### 11.1 Program Elements

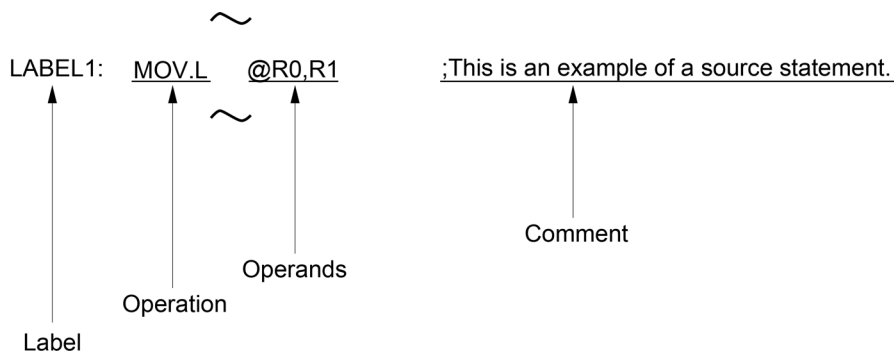
#### 11.1.1 Source Statements

##### (1) Source Statement Structure

The following shows the structure of a source statement.

```
[<label>] [Δ <operation>[Δ <operand(s)>]] [<comment>]
```

Example:



##### (a) Label

A symbol or a local symbol is written as a tag attached to a source statement.

A symbol is a name defined by the programmer.

##### (b) Operation

The mnemonic of an executable instruction, a DSP instruction, an extended instruction, an assembler directive, or a directive statement is written as the operation.

Executable instructions and DSP instructions are microprocessor instructions.

Extended instructions are instructions that are expanded into executable instructions and constant data (literals) or several executable instructions.

Assembler directives are instructions that give directions to the assembler.

Directive statements are used for file inclusion, conditional assembly, and macro functions.

## (c) Operand

The object(s) of the operation's execution are written as the operand.

The number of operands and their types are determined by the operation. There are also operations which do not require any operands.

## (d) Comment

Notes or explanations that make the program easier to understand are written as the comment.

## (2) Coding of Source Statements

Source statements are written using ASCII characters. String literals and comments can include Japanese characters (shift JIS code or EUC code) or LATIN1 code character.

In principle, a single statement must be written on a single line. The maximum length of a line is 8192 bytes.

## (a) Coding of Label

The label is written as follows:

- Written starting in the first column,

Or:

- Written with a colon (:) appended to the end of the label.

Examples:

**LABEL1** ; This label is written starting in the first column.

**LABEL2:** ; This label is terminated with a colon.

---

**LABEL3** ; This label is regarded as an error by the assembler,  
; since it is neither written starting in the first column  
; nor terminated with a colon.



(b) Coding of Operation

The operation is written as follows:

— When there is no label:

Written starting in the second or later column.

— When there is a label:

Written after the label, separated by one or more spaces or tabs.

Example:

**ADD** R0,R1 ; An example with no label.

**LABEL1: ADD** R1,R2 ; An example with a label.

(c) Coding of Operand

The operand is written following the operation field, separated by one or more spaces or tabs.

Example:

**ADD R0,R1** ; The ADD instruction takes two operands.

**SHAL R1** ; The SHAL instruction takes one operand.

(d) Coding of Comment

The comment is written following a semicolon (;).

The assembler regards all characters from the semicolon to the end of the line as the comment.

Example:

**ADD R0,R1 ; Adds R0 to R1.**

### (3) Coding of Source Statements across Multiple Lines

A single source statement can be written across several lines in the following situations:

- When the source statement is too long as a single statement.
- When it is desirable to attach a comment to each operand.

Write source statements across multiple lines using the following procedure.

- (a) Insert a new line after a comma that separates operands.
- (b) Insert a plus sign (+) in the first column of the new line.
- (c) Continue writing the source statement following the plus sign.

Spaces and tabs can be inserted following the plus sign. A comment can be written at the end of each line.

Example:

```
.DATA.L H'FFFF0000,
+ H'FF00FF00,
+ H'FFFFFFFF
```

; In this example, a single source statement is written across three lines.

A comment can be attached at the end of each line.

Example:

```
.DATA.L H'FFFF0000, ; Initial value 1.
+ H'FF00FF00, ; Initial value 2.
+ H'FFFFFFFF ; Initial value 3.
```

; In this example, a comment is attached to each operand.

### 11.1.2 Reserved Words

Reserved words are names that the assembler reserves as symbols with special meanings.

Register names, operators, and the location counter are used as reserved words. Register names are different depending on the target CPU. Refer to the programming manual of the target CPU, for details.

Reserved words must not be used as symbols.

- Register names  
R0 to R15, FR0 to FR15, DR0 to DR14 (only even values), XD0 to XD14 (only even values), FV0 to FV12 (only multiples of four), R0\_BANK to R7\_BANK, SP\*, SR, GBR, VBR, MACH, MACL, PR, PC, SSR, SPC, FPUL, FPSCR, MOD, RE, RS, DSR, A0, A0G, A1, A1G, M0, M1, X0, X1, Y0, Y1, XMTRX, DBR, SGR, TBR
- Operators  
STARTOF, SIZEOF, HIGH, LOW, HWORD, LWORD, \$EVEN, \$ODD, \$EVEN2, \$ODD2
- Location counter  
\$

Note: R15 and SP indicate the same register.

### 11.1.3 Symbols

#### (1) Functions of Symbols

Symbols are names defined by the programmer, and perform the following functions.

- Address symbols: Express data storage or branch destination addresses.
- Constant symbols: Express constants.
- Aliases of register names: Express general registers and floating-point registers.
- Section names: Express section names.

The following shows examples of symbol usage.

Examples:

~

```
BRA SUB1 ;BRA is a branch instruction.
 ;SUB1 is the address symbol of the destination.
```

~

**SUB1:**

-----

~

```
MAX: .EQU 100 ;EQU is an assembler directive that sets a value to a
 ;symbol.
```

```
MOV.B #MAX,R0 ;MAX expresses the constant value 100.
```

~

-----

~

```
MIN: .REG R0 ;.REG is an assembler directive that defines a register
 ;alias.
```

```
MOV.B #100,MIN ;MIN is an alias for R0.
```

~

-----

~

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

```
 ;.SECTION is an assembler directive that declares a section.
```

```
 ;CD is the name of the current section.
```

~

## (2) Naming Symbols

### (a) Available Characters

The following ASCII characters can be used.

- Alphabetical uppercase and lowercase letters (A to Z, a to z)
- Numbers (0 to 9)
- Underscore (\_)
- Dollar sign (\$)

The assembler distinguishes uppercase letters from lowercase letters in symbols.

### (b) First Character in a Symbol

The first character in a symbol must be one of the following.

- Alphabetical uppercase and lowercase letters (A to Z, a to z)
- Underscore (\_)
- Dollar sign (\$)

Note: The dollar sign character used alone is a reserved word that expresses the location counter.

### (c) Maximum Length of a Symbol

Not limited.

### (d) Names that Cannot Be Used as Symbols

Reserved words cannot be used as symbols. Names of the following type must not be used because such names are used as internal symbols by the assembler.

\_ $\$$ Ommmmm (m is a number from 0 to F.)

\_ $\$$ nnnnn (n is a number from 0 to 9.)

Note: Internal symbols are necessary for assembler internal processing. Internal symbols are not output to assemble listings or object modules.

### (e) Defining and Referencing Symbols

To define a symbol, it must be entered as a label. To reference a symbol, it must be entered as an operand. Symbols that are entered as operands for .SECTION or .MACRO, however, constitute an exception. To reference a symbol (macro name) that has been defined by .MACRO, the symbol must be entered as an operation (macro call).

A symbol may be referenced before it has been defined. We reference to such as reference as a forward reference. Such references can usually be used, but in some cases they are prohibited.

When a program consists of multiple source files, symbols may be referenced from more than one file. The way a symbol defined in one file is referenced to from another file is called external definition. To reference a symbol that is defined in another file is called external reference. External definitions can be declared by `.EXPORT` and `.GLOBAL`. External references can be defined by `.IMPORT` and `.GLOBAL`. Be careful with the use of forward and external references, because in some cases, external references such as forward references are prohibited.

#### 11.1.4 Constants

##### (1) Integer Constants

Integer constants are expressed with a prefix that indicates the radix.

The radix indicator prefix is a notation that indicates the radix of the constant.

- Binary numbers            The radix indicator "B" plus a binary constant.
- Octal numbers            The radix indicator "Q" plus an octal constant.
- Decimal numbers        The radix indicator "D" plus a decimal constant.
- Hexadecimal numbers    The radix indicator "H" plus a hexadecimal constant.

The assembler does not distinguish uppercase letters from lowercase letters in the radix indicator.

The radix indicator and the constant value must be written with no intervening space.

The radix indicator can be omitted. Integer constants with no radix indicator are normally decimal constants, although the radix for such constants can be changed with `.RADIX`.

Example:

```
.DATA.B B'10001000 ;
.DATA.B Q'210 ;These source statements express the same
.DATA.B D'136 ;numerical value.
.DATA.B H'88 ;
```

Note: "Q" is used instead of "O" to avoid confusion with the digit 0.

## (2) Character Constants

Character constants are considered to be constants that represent character codes.

Character constants are written by enclosing up to four-byte characters in double quotation marks.

The following ASCII characters can be used in character constants.

ASCII code    { H'09 (tab)  
                  { H'20 (space) to H'7E (tilde)

In addition, Japanese characters (shift JIS code or EUC code) and LATIN1 code character can be used. Use two double quotation marks in succession to indicate a single double quotation mark in a character constant. When using Japanese characters in shift JIS code or EUC code, be sure to specify the **sjis** or **euc** command line option, respectively. When using LATIN1 code character, be sure to specify the **latin1** command line option. Note that the shift JIS code, EUC code, and LATIN1 code character cannot be used together in one source program.

### Example 1:

```
.DATA.L "ABC" ;This is the same as .DATA.L H'00414243.
.DATA.W "AB" ;This is the same as .DATA.W H'4142.
.DATA.B "A" ;This is the same as .DATA.B H'41.
 ;The ASCII code for A is: H'41
 ;The ASCII code for B is: H'42
 ;The ASCII code for C is: H'43
```

### Example 2:

```
.DATA.B "''''''''" ;This is a character constant consisting of a single
 ;double quotation mark.
```

## (3) Floating-Point Constants

Floating-point constants can be specified as operands in assembler directives for reserving floating-point constants.

## (a) Floating-Point Constant Representation:

Floating-point constants can be represented in decimal and hexadecimal.

- Decimal representation

$$F'[\{\pm\}] \left\{ \begin{array}{l} n[. [m]] \\ . m \end{array} \right\} [t[\{\pm\}]xx]$$

F'

Indicates that the number is decimal. It cannot be omitted.

$$[\{\pm\}] \left\{ \begin{array}{l} n[. [m]] \\ . m \end{array} \right\}$$

"n" indicates the integer part in decimal. "m" indicates the fraction part in decimal. Either the integer part or the fraction part can be omitted. If the sign ( $\pm$ ) is omitted, the assembler assumes it is positive.

t

Indicates that the number is in either of the following precisions

S: Single precision

D: Double precision

If omitted, the assembler assumes the operation size of the assembler directive.

[\{\pm\}]xx

Indicates the exponent part in decimal. If omitted, the assembler assumes 0. If the sign ( $\pm$ ) is omitted, the assembler assumes it is positive.

Example:

$$F'0.5S-2 = 0.5 \times 10^{-2} = 0.005 = H'3BA3D70A$$

$$F'.123D3 = 0.123 \times 10^3 = 123 = H'405EC000000000$$



- Hexadecimal representation

H'xxxx[.t]

H' Indicates that the number is hexadecimal. It cannot be omitted.

xxxx Indicates the bit pattern of the floating-point constant in hexadecimal. If the bit pattern is shorter than the specified data length, it is aligned to the right end of the reserved area and 0s are added to the remaining bits in the reserved area. If the bit pattern is longer than the specified data length, the right-side bits of the bit pattern are allocated for the specified data length and the remaining bits of the bit pattern are ignored.

t Indicates that the number is in either of the following precisions  
 S: Single precision  
 D: Double precision  
 If omitted, the assembler assumes the operation size of the assembler directive.

This format directly specifies the bit pattern of the floating-point constant to represent data that is difficult to represent in decimal format, such as 0s or infinity for the specified precision.

Example:

H'0123456789ABCDEF.S = H'89ABCDEF  
 H'FFFF.D = H'000000000000FFFF

(b) Floating-Point Data Range:

Table 11.1 lists the floating-point data types.

**Table 11.1 Floating-Point Data Types**

| <b>Data Type</b>    | <b>Description</b>                                                                                 |
|---------------------|----------------------------------------------------------------------------------------------------|
| Normalized number   | The absolute value is between the underflow and overflow boundaries including the boundary values. |
| Denormalized number | The absolute value is between 0 and the underflow boundary.                                        |
| Zero                | The absolute value is 0.                                                                           |
| Infinity            | The absolute value is larger than the overflow boundary.                                           |
| Not-a-Number (NaN)  | A value that is not a numerical value. Includes sNaN (signaling NaN) and qNaN (quiet NaN).         |

These data types are shown on the following number line. NAN cannot be shown on the number line because it is not handled as a numerical value.

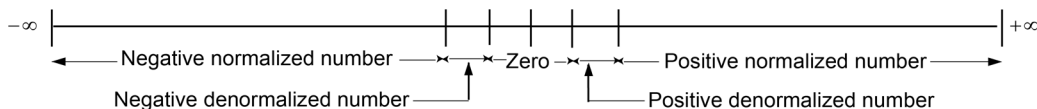


Table 11.2 lists the numerical value ranges the assembler can use.

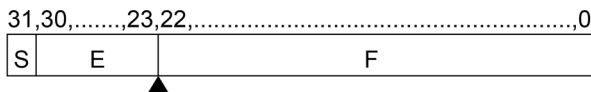
**Table 11.2 Data Types and Numerical Value Ranges (Absolute Value)**

| Data Type           |               | Single Precision       | Double Precision        |
|---------------------|---------------|------------------------|-------------------------|
| Normalized number   | Maximum value | $3.40 \times 10^{38}$  | $1.79 \times 10^{308}$  |
|                     | Minimum value | $1.18 \times 10^{-38}$ | $2.23 \times 10^{-308}$ |
| Denormalized number | Maximum value | $1.17 \times 10^{-38}$ | $2.22 \times 10^{-308}$ |
|                     | Minimum value | $1.40 \times 10^{-45}$ | $4.94 \times 10^{-324}$ |

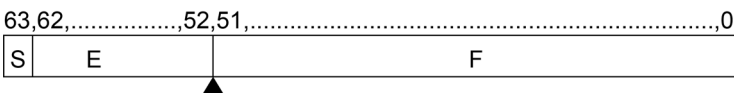
(c) Floating-Point Data Format:

The floating-point data format is shown below:

Single Precision:



Double Precision:



- ▲ : Decimal point
- S : Sign bit
- E : Exponent part
- F : Fraction part

- Sign bit (S)  
Indicates the sign of a value. Positive and negative are represented by 0 and 1, respectively.
- Exponent part (E)  
Indicates the exponent of a value. The actual exponent value is obtained by subtracting the bias value from the value specified in this exponent part.
- Fraction part (F)  
Each bit has its own significance and corresponds to  $2^{-1}$ ,  $2^{-2}$ , ...,  $2^{-n}$  from the start bit, respectively ("n" is the bit length of the fraction part).

Table 11.3 shows the size of each parameter in data format.

**Table 11.3 Data Format Size**

| Parameter              | Single Precision | Double Precision |
|------------------------|------------------|------------------|
| Bit length             | 32 bits          | 64 bits          |
| Sign bit (S)           | 1 bit            | 1 bit            |
| Exponent part (E)      | 8 bits           | 11 bits          |
| Fraction part (F)      | 23 bits          | 52 bits          |
| Bias of exponent value | 127              | 1023             |

A floating-point number is represented using the symbols in table 11.3 as follows:

$$2^{E-\text{bias}} \cdot (-1)^S \cdot \begin{cases} (1. F) & : \text{Normalized number} \\ (0. F) & : \text{Denormalized number} \end{cases}$$

$$(1. F) = 1 + b_0 \times 2^{-1} + b_1 \times 2^{-2} + \dots + b_{n-1} \times 2^{-n}$$

$$(0. F) = b_0 \times 2^{-1} + b_1 \times 2^{-2} + \dots + b_{n-1} \times 2^{-n}$$

b: Bit location in the fraction part

n: Bit length of the fraction part

Table 11.4 shows the floating-point representation for each data type. NAN cannot be represented because it is not handled as a numerical value.

**Table 11.4 Floating-Point Representation for Each Data Type**

| <b>Data Type</b>    | <b>Single Precision</b>               | <b>Double Precision</b>                |
|---------------------|---------------------------------------|----------------------------------------|
| Normalized number   | $(-1)^s \cdot 2^{E-127} \cdot (1. F)$ | $(-1)^s \cdot 2^{E-1023} \cdot (1. F)$ |
| Denormalized number | $(-1)^s \cdot 2^{-126} \cdot (0. F)$  | $(-1)^s \cdot 2^{-1022} \cdot (0. F)$  |
| Zero                | $(-1)^s \cdot 0$                      | $(-1)^s \cdot 0$                       |
| Infinity            | $(-1)^s \cdot \infty$                 | $(-1)^s \cdot \infty$                  |
| Not-a-Number (NaN)  | quiet NaN, signaling NaN              | quiet NaN, signaling NaN               |

**(d) Rounding of Floating-Point Constants:**

When converting floating-point constants used in assembler directives for reserving floating-point numbers into object codes, the assembler rounds them in the following two modes to set the valid range.

- Round to Nearest even (RN)  
Rounds the least significant bit in the object code to its nearest absolute value. When two absolute values are at the same distance, rounds the least significant bit to become zero.
- Round to Zero (RZ)  
Rounds the least significant bit toward zero.

Example:

Object code of .FDATA.S F' 1S-1

RN: H'3DCCCCCD

RZ: H'3DCCCCC

**(e) Handling Denormalized Numbers:**

The assembler handles denormalized numbers differently depending on the target CPU. In a CPU that does not handle denormalized numbers, if a value in the denormalized number range is used, warning 841 occurs and the object code is output as zero.

In a CPU that handles denormalized numbers, if a value in the denormalized number range is used, warning 842 occurs and the object code is output in denormalized numbers.

How to handle denormalized numbers can be switched with the **denormalize** option.

Example:

CPU not handling denormalized numbers:

```
.FDATA.S F' 1S-40 Warning 841, Object code H'00000000
```

CPU handling denormalized numbers:

```
.FDATA.S F' 1S-40 Warning 842, Object code H'000116C2
```

#### (4) Floating-Point Arithmetic Operations

Floating-point arithmetic operations can be specified in the assembler directive for reserving floating-point data.

##### (a) Rounding of Results:

When the result of floating-point arithmetic operations exceeds the valid fraction digits in internal representation, the assembler rounds it as follows:

- Rounds the result to the nearest of two internal representations of floating-point constants.
- Rounds the result so that the least significant digit of the fraction part becomes zero when two internal representations are at the same distance from the result.
- For the SH-2E CPU, truncates the section that exceeds the valid digits.
- For the SH-4, SH-4A, or SH2A-FPU CPU, rounds the section that exceeds the valid digits to the nearest value when **round=nearest** is specified, and truncates the section that exceeds the valid digits when **round=zero** is specified.

##### (b) Handling of Overflows, Underflows, and Invalid Operations:

The assembler handles overflows, underflows, and invalid operations as follows:

- For an overflow, handles the result as a positive or negative infinity depending on the sign of the result.
- For an underflow, handles the result as a positive or negative zero depending on the sign of the result.
- For an invalid operation, which occurs when infinity values of the opposite sign are added or when an infinity value is subtracted from another infinity value of the same sign, handles the result as a not-a-number.

Note: Arithmetic operations on constant expressions are performed during assembly. If an overflow, underflow, or invalid operation occurs during assembly, a warning level error message is output.

## (5) Fixed-Point Constants

Fixed-point constants can be specified as operands in the assembler directive for reserving fixed-point data.

## (a) Fixed-Point Number Representation:

Fixed-point numbers express real numbers ranging from  $-1.0$  to  $1.0$  in decimal. Word size and longword size are available for fixed-point numbers.

- Word-size fixed-point numbers

Two-byte signed integers expressing real numbers ranging from  $-1.0$  to  $1.0$ .

The real number expressed by 2-byte signed integer  $x$  ( $-32,768 < x < 32,767$ ) is  $x/32768$ .

Example:

| Fixed-point number | Word-size representation |
|--------------------|--------------------------|
| -1.0               | H'8000                   |
| -0.5               | H'C000                   |
| 0.0                | H'0000                   |
| 0.5                | H'4000                   |
| 1.0                | H'7FFF                   |

- Longword-size fixed-point numbers

Four-byte signed integers expressing real numbers ranging from  $-1.0$  to  $1.0$ . The real number expressed by 4-byte signed integer  $x$  ( $-2,147,483,648 < x < 2,147,483,647$ ) is  $x/2147483648$ .

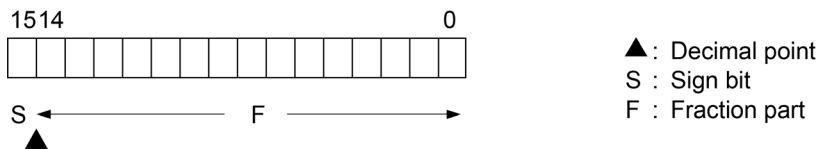
Example:

| Fixed-point number | Longword-size representation |
|--------------------|------------------------------|
| -1.0               | H'80000000                   |
| -0.5               | H'C0000000                   |
| 0.0                | H'00000000                   |
| 0.5                | H'40000000                   |
| 1.0                | H'7FFFFFFF                   |

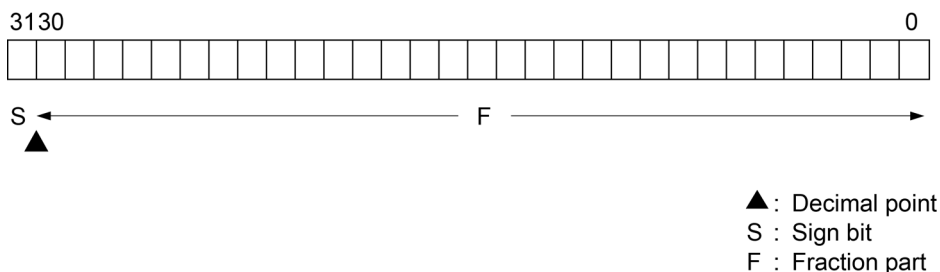
(b) Fixed-Point Data Format:

The fixed-point data format consists of a sign bit and a 15-bit fraction part in word size, and a sign bit and a 31-bit fraction part in longword size. The decimal point is assumed to be fixed on the right of the sign bit.

- Word size



- Longword size



— Sign bit (S)

Indicates the sign of a value. Positive and negative are represented by 0 and 1, respectively.

— Fraction part (F)

Each bit has its own significance and corresponds to  $2^{-1}$ ,  $2^{-2}$ , ...,  $2^{-31}$  from the start bit, respectively.

(c) Valid Range for Fixed-Point Numbers:

In longword size, 31 bits can represent nine digits of data in decimal, but the assembler handles ten digits in decimal as a valid number, rounds the 32nd bit in RN (round to the nearest absolute value) mode, and uses the high-order 31 bits of the result as fixed-point data.

Note: The actual fixed-point data range is  $-1.0$  to  $0.9999999999$ , but the assembler assumes  $1.0$  as  $0.9999999999$  and represents it as H'7FFFFFFF.

### 11.1.5 Location Counter

The location counter expresses the address (location) in memory where the corresponding object code (the result of converting executable instructions and data into code the microprocessor can understand) is stored.

The value of the location counter is automatically adjusted according to the object code output. The value of the location counter can be changed intentionally using assembler directives.

Examples:

```

~
.ORG H'00001000 ;This assembler directive sets the location counter to H'00001000

.DATA.W H'FF ;The object code generated by this assembler directive has
 ;a length of 2 bytes.
 ;The location counter changes to H'00001002.
.DATA.W H'F0 ;The object code generated by this assembler directive has
 ;a length of 2 bytes.
 ;The location counter changes to H'00001004.
.DATA.W H'10 ;The object code generated by this assembler directive has
 ;a length of 2 bytes.
 ;The location counter changes to H'00001006.
.ALIGN 4 ;The value of the location counter is corrected to be a
 ;multiple of 4.
 ;The location counter changes to H'00001008.

```



```
.DATA.L H'FFFFFFF ;The object code generated by this assembler directive has
 ;a length of 4 bytes.
 ;The location counter changes to H'0000100C.
 ;.ORG is an assembler directive that sets the value of the
 ;location ;counter.
 ;.ALIGN is an assembler directive that adjusts the value of
 ;the ;location
 ;.DATA is an assembler directive that reserves data in memory.
 ;.W is a specifier that indicates that data is handled in word
 ;(2 ;bytes) size.
 ;.L is a specifier that indicates that data is handled in longword
 ;(4 ;bytes) size.
 ~
```

The location counter is referenced using the dollar sign symbol.

Examples:

```
LABEL1: .EQU $;This assembler directive sets the value of the
 ;location counter to the symbol LABEL1.
 ;.EQU is an assembler directive that sets the value to a symbol.
```

### 11.1.6 Expressions

Expressions are combinations of constants, symbols, and operators that derive a value, and are used as the operands of executable instructions and assembler directives.

#### (1) Elements of Expression

An expression consists of terms, operators, and parentheses.

##### (a) Terms

The terms are the followings:

- A constant
- The location counter reference (\$)
- A symbol (excluding aliases of the register name)
- The result of a calculation specified by a combination of the above terms and an operator.

An individual term is also a kind of expression.

## (b) Operators

Table 11.5 shows the operators supported by the assembler.

**Table 11.5 Operators**

| Operator Type           | Operator | Operation                                            | Coding                 |
|-------------------------|----------|------------------------------------------------------|------------------------|
| Arithmetic operations   | +        | Unary plus                                           | + <term>               |
|                         | –        | Unary minus                                          | – <term>               |
|                         | +        | Addition                                             | <term1> + <term2>      |
|                         | –        | Subtraction                                          | <term1> – <term2>      |
|                         | *        | Multiplication                                       | <term1> * <term2>      |
|                         | /        | Division                                             | <term1> / <term2>      |
| Logic operations        | ~        | Unary negation                                       | ~ <term>               |
|                         | &        | Logical AND                                          | <term1> & <term2>      |
|                         |          | Logical OR                                           | <term1>   <term2>      |
|                         | ~        | Exclusive OR                                         | <term1> ~ <term2>      |
| Shift operations        | <<       | Arithmetic left shift                                | <term 1> << <term 2>   |
|                         | >>       | Arithmetic right shift                               | <term 1> >> <term 2>   |
| Section set operations* | STARTOF  | Determines the starting address of a section set.    | STARTOF <section name> |
|                         | SIZEOF   | Determines the size of a section set in bytes.       | SIZEOF <section name>  |
| Even/odd operations     | \$EVEN   | 1 when the value is a multiple of 2, and 0 otherwise | \$EVEN <symbol>        |
|                         | \$ODD    | 0 when the value is a multiple of 2, and 1 otherwise | \$ODD <symbol>         |
|                         | \$EVEN2  | 1 when the value is a multiple of 4, and 0 otherwise | \$EVEN2 <symbol>       |
|                         | \$ODD2   | 0 when the value is a multiple of 4, and 1 otherwise | \$ODD2 <symbol>        |
| Extraction operations   | HIGH     | Extracts the high-order byte                         | HIGH <term>            |
|                         | LOW      | Extracts the low-order byte                          | LOW <term>             |
|                         | HWORD    | Extracts the high-order word                         | HWORD <term>           |
|                         | LWORD    | Extracts the low-order word                          | LWORD <term>           |

(c) Parentheses

Parentheses modify the operation precedence.

(2) Operation Precedence

When multiple operations appear in a single expression, the order in which the processing is performed is determined by the operator precedence and by the use of parentheses. The assembler processes operations according to the following rules.

— Rule 1

Processing starts from operations enclosed in parentheses.

When there are multiple parentheses, processing starts with the operations surrounded by the innermost parentheses.

— Rule 2

Processing starts with the operator with the highest precedence.

— Rule 3

Processing proceeds in the direction of the operator association rule when operators have the same precedence.

Table 11.6 shows the operator precedence and the association rule.

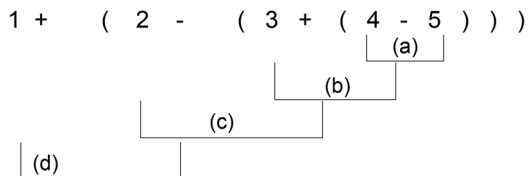
**Table 11.6 Operator Precedence and Association Rules**

| Precedence | Operator                                                                     | Association Rule                            |
|------------|------------------------------------------------------------------------------|---------------------------------------------|
| 1 (high)   | + - ~ STARTOF SIZEOF<br>\$EVEN \$ODD \$EVEN2 \$ODD2<br>HIGH LOW HWORD LWORD* | Operators are processed from right to left. |
| 2          | * /                                                                          | Operators are processed from left to right. |
| 3          | + -                                                                          | Operators are processed from left to right. |
| 4          | << >>                                                                        | Operators are processed from left to right. |
| 5          | &                                                                            | Operators are processed from left to right. |
| 6 (low)    | ~                                                                            | Operators are processed from left to right. |

Note: The operators of precedence 1 (highest precedence) are for unary operation.

The figures below show examples of expressions.

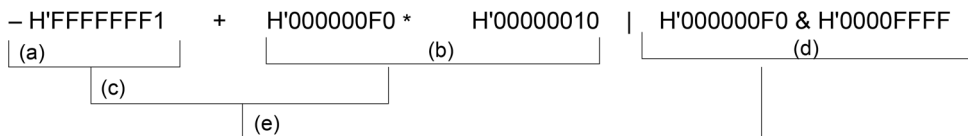
Example 1:

$$1 + ( 2 - ( 3 + ( 4 - 5 ) ) )$$


The assembler calculates this expression in the order (a) to (d).

|                         |                                              |
|-------------------------|----------------------------------------------|
| The result of (a) is -1 | } The final result of this calculation is 1. |
| The result of (b) is 2  |                                              |
| The result of (c) is 0  |                                              |
| The result of (d) is 1  |                                              |

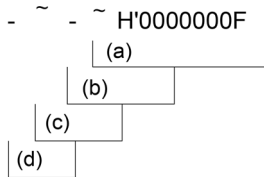
Example 2:

$$- \text{H'FFFFFFF1} + \text{H'000000F0} * \text{H'00000010} | \text{H'000000F0} \& \text{H'0000FFFF}$$


The assembler calculates this expression in the order (a) to (e).

|                                 |                                                       |
|---------------------------------|-------------------------------------------------------|
| The result of (a) is H'0000000F | } The final result of this calculation is H'00000FFF. |
| The result of (b) is H'00000F00 |                                                       |
| The result of (c) is H'00000F0F |                                                       |
| The result of (d) is H'000000F0 |                                                       |
| The result of (e) is H'00000FFF |                                                       |

Example 3:



The assembler calculates this expression in the order (a) to (d).

The result of (a) is H'FFFFFFF0  
The result of (b) is H'00000010  
The result of (c) is H'FFFFFFEF  
The result of (d) is H'00000011

} The final result of this calculation is H'00000011.

### (3) Detailed Description on Operation

#### (a) STARTOF Operation

Determines the start address of a section set after the specified sections are linked by the optimizing linkage editor.

#### (b) SIZEOF Operation

Determines the size of a section set after the specified sections are linked by the optimizing linkage editor.

## Example:

```

 .CPU SH1
 .SECTION INIT_RAM, DATA, ALIGN=4
 .RES.B H'100
 .SECTION INIT_DATA, DATA, ALIGN=4
INIT_BGN .DATA.L (STARTOF INIT_RAM); (1)
INIT_END .DATA.L (STARTOF INIT_RAM) + (SIZEOF INIT_RAM) ...; (2)
;
;
 .SECTION MAIN, CODE, ALIGN=4
INITIAL:
 MOV.L DATA1, R6
 MOV #0, R5
 MOV.L DATA1+4, R3
 BRA LOOP2
 MOV.L @R3, R4
LOOP1:
 MOV.L R5, @R4
 ADD #4, R4
LOOP2:
 MOV.L @R6, R3
 CMP/HI R3, R4
 BF LOOP1
 RTS
 NOP
DATA1:
 .DATA.L INIT_END
 .DATA.L INIT_BGN
 .END

```

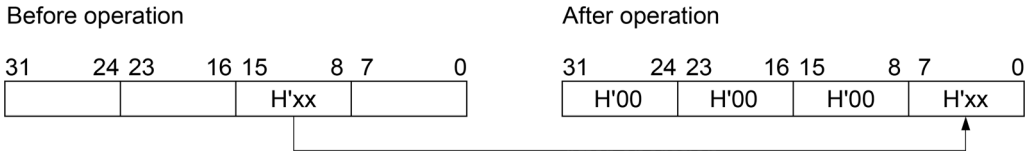
} Initializes the data area in section  
INIT\_RAM to 0.

(1) Determines the start address of section INIT\_RAM.

(2) Determines the end address of section INIT\_RAM.

(c) HIGH Operation

Extracts the high-order byte from the low-order two bytes of a 4-byte value.



Example:

```
LABEL .EQU H'00007FFF
```

```
 .DATA HIGH LABEL ; Reserves integer data H'0000007F on memory.
```

(d) LOW Operation

Extracts the lowest-order one byte from a 4-byte value.



(e) HWORD Operation

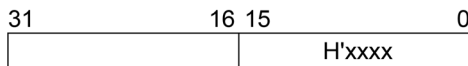
Extracts the high-order two bytes from a 4-byte value.



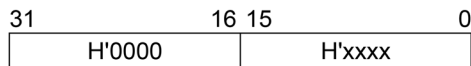
## (f) LWORD Operation

Extracts the low-order two bytes from a 4-byte value.

Before operation



After operation



## (g) EVEN/ODD Operation

Determines if the value of the address symbol is a multiple of 2 or 4.

Table 11.7 shows the even/odd operations.

**Table 11.7 Even/Odd Operations**

| Operator | Operation                                            |
|----------|------------------------------------------------------|
| \$EVEN   | 1 when the value is a multiple of 2, and 0 otherwise |
| \$ODD    | 0 when the value is a multiple of 2, and 1 otherwise |
| \$EVEN2  | 1 when the value is a multiple of 4, and 0 otherwise |
| \$ODD2   | 0 when the value is a multiple of 4, and 1 otherwise |

Example:

To obtain the current program counter value using an \$ODD2 operator.

LAB:

```

MOVA @(0,PC),R0
ADD #4+2*$ODD2 LAB,R0 ;$ODD2 gives 0 when LAB is
 ;a multiple of 4, and gives 1 when
 ;LAB is not a multiple of 4.

```



#### (4) Notes on Expressions

##### (a) Internal Processing

The assembler regards expression values as 32-bit signed values.

Example:

`~H'F0`

The assembler regards `H'F0` as `H'000000F0`.

Therefore, the value of `~H'F0` is `H'FFFFFF0F`. (Note that this is not `H'0000000F`.)

##### (b) Arithmetic Operators

Where values must be determined at assembly, the multiplication and division operators cannot take terms that contain relative values as their operands.

Also, a divisor of 0 cannot be used with the division operator.

Example:

`.IMPORT SYM`

`.DATA SYM/10 ;Correctly assembled.`

`.ORG SYM/10 ;An error will occur.`

##### (c) Logic Operators

The logic operators cannot take terms that contain relative values as their operands.

### 11.1.7 String Literals

String literals are sequences of character data.

The following ASCII characters can be used in string literals.

ASCII code { H'09 (tab)  
H'20 (space) to H'7E (tilde)

A single character in a string literal has as its value the ASCII code for that character and is represented as a byte sized data object. In addition, Japanese characters in shift JIS code or EUC code, and LATIN1 code character can be used. When using Japanese characters in shift JIS code or EUC code, be sure to specify the **sjis** or **euc** option, respectively. If not specified, Japanese characters are handled as the Japanese code specified by the host computer. When using LATIN1 code character, be sure to specify the **latin1** option.

String literals must be written enclosed in double quotation marks.

Use two double quotation marks in succession to indicate a single double quotation mark in a string literal.

Examples:

```
.SDATA "Hello" ; This statement reserves the string literal data
 ; Hello!
```

```
.SDATA " " "Hello!" " " ; This statement reserves the string literal data
 ; " Hello! "
```

; .SDATA is an assembler directive that reserves string literal data in memory.

Note: The difference between character constants and string literals is as follows.

Character constants are numeric values. They have a data size of either 1 byte, 2 bytes, or 4 bytes.

String literals cannot be handled as numeric values. A string literal has a data size between 1 byte and 255 bytes.

### 11.1.8 Local Label

#### (1) Local Label Functions

A local label is valid locally between address symbols. Since a local label does not conflict with the other labels outside its scope, the user does not have to consider other label names. A local label can be defined by writing in the label field in the same way as a normal address symbol, and can be referenced by an operand.

An example of local label descriptions is shown below.

Note: A local label cannot be referenced during debugging.  
 A local label cannot be specified as any of the following items:

- Macro name
- Section name
- Object module name
- Label in .ASSIGNA, .ASSIGNC, .EQU, .ASSIGN, .REG, or .FREG
- Operand in .EXPORT, .IMPORT, or .GLOBAL

Example:

```

LABEL1: ;Local block 1 start
?0001:
 ~
 CMP/EQ R1,R2
 BT ?0002 ;Branches to ?0002 of local block 1
 BRA ?0001 ;Branches to ?0001 of local block 1
?0002:
 ~
LABEL2: ;Local block 2 start
?0001: ~
 CMP/GE R1,R2
 BT ?0002 ;Branches to ?0002 of local block 2
 BRA ?0001 ;Branches to ?0001 of local block 2
?0002:
LABEL3: ;Local block 3 start

```

## (2) Naming Local Labels

### — First Character:

A local label is a string starting with a question mark (?).

### — Usable Characters:

The following ASCII characters can be used in a local label, except for the first character:

- Alphabetical uppercase and lowercase letters (A to Z, a to z)
- Numbers (0 to 9)
- Underscore (\_)
- Dollar sign (\$)

The assembler distinguishes uppercase letters from lowercase ones in local labels.

### — Maximum Length:

The length of local label characters is 2 to 16 characters. If 17 or more characters are specified, the assembler will not recognize them as a local label.

## (3) Scope of Local Labels

The scope of a local label is called a local block. Local blocks are separated by address symbols, or by `.SECTION`.

The local label defined within a local block can be referenced in that local block.

A local label belonging to a local block is interpreted as being unique even if its spelling is the same as local labels in other local blocks; it does not cause an error.

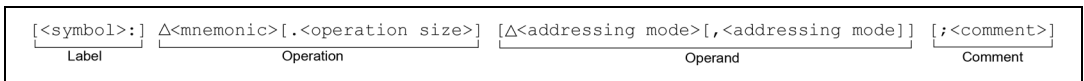
**Note:** The address symbols defined by `.ASSIGNA`, `.ASSIGNC`, `.EQU`, `.ASSIGN`, `.REG`, or `.FREG` are not interpreted as delimiters for the local block.

## 11.2 Executable Instructions

### 11.2.1 Overview of Executable Instructions

The executable instructions are the instructions of microprocessor. The microprocessor interprets and executes the executable instructions in the object code stored in memory.

An executable instruction source statement has the following basic form.



This section describes the mnemonic, operation size, and addressing mode.

#### (1) Mnemonic

The mnemonic expresses the executable instruction. Abbreviations that indicate the type of processing are provided as mnemonics for microprocessor instructions.

The assembler does not distinguish uppercase and lowercase letters in mnemonics.

#### (2) Operation Size

The operation size is the unit for processing data. The operation sizes vary with the executable instruction. The assembler does not distinguish uppercase and lowercase letters in the operation size.

| Specifier | Data Size                  |
|-----------|----------------------------|
| B         | Byte (1 byte)              |
| W         | Word (2 bytes)             |
| L         | Longword (4 bytes)         |
| S         | Single precision (4 bytes) |
| D         | Double precision (8 bytes) |

#### (3) Addressing Mode

The addressing mode specifies the data area accessed, and the destination address. The addressing modes vary with the executable instruction.

Table 11.8 lists the addressing modes.

**Table 11.8 Addressing Modes**

| Addressing Mode | Name                                  | Description                                                                                                                                                                                                              |
|-----------------|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Rn              | Register direct                       | The contents of the specified register.                                                                                                                                                                                  |
| @Rn             | Register indirect                     | A memory location. The value in Rn gives the start address of the memory accessed.                                                                                                                                       |
| @Rn+            | Register indirect with post-increment | A memory location. The value in Rn (before being incremented*1) gives the start address of the memory accessed.<br>The microprocessor first uses the value in Rn for the memory reference, and increments Rn afterwards. |
| @-Rn            | Register indirect with pre-decrement  | A memory location. The value in Rn (after being decremented*2) gives the start address of the memory accessed.<br>The microprocessor first decrements Rn, and then uses that value for the memory reference.             |
| @(disp,Rn)      | Register indirect with displacement*3 | A memory location. The start address of the memory access is given by: the value of Rn plus the displacement (disp).<br>The value of Rn is not changed.                                                                  |
| @(R0,Rn)        | Register indirect with index          | A memory location. The start address of the memory access is given by: the value of R0 plus the value of Rn.<br>The values of R0 and Rn are not changed.                                                                 |
| @(disp,GBR)     | GBR indirect with displacement        | A memory location. The start address of the memory access is given by: the value of GBR plus the displacement (disp).<br>The value of GBR is not changed.                                                                |
| @(R0,GBR)       | GBR indirect with index               | A memory location. The start address of the memory access is given by: the value of GBR plus the value of R0.<br>The values of GBR and R0 are not changed.                                                               |
| @(disp,PC)      | PC relative with displacement         | A memory location. The start address of the memory access is given by: the value of the PC plus the displacement (disp).                                                                                                 |

Notes 1 to 3: See next page.

**Table 11.8 Addressing Modes (cont)**

| Addressing Mode | Name                                     | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------------|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| @@(disp,TBR)    | TBR duplicate indirect with displacement | A memory location. The start address of the memory access is given by: the contents of the location indicated by the value of TBR plus the displacement (disp).<br>The value of TBR is not changed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| symbol          | PC relative specified with symbol        | [When used as the operand of a branch instruction]<br>The symbol directly indicates the destination address.<br>The assembler derives a displacement (disp) from the symbol and the value of the PC, using the formula: $disp = symbol - PC$ .<br>[When used as the operand of a data move instruction]<br>A memory location. The symbol indicates the start address of the memory accessed.<br>The assembler derives a displacement (disp) from the symbol and the value of the PC, using the formula: $disp = symbol - PC$ .<br>[When used as the operand of an instruction that specifies the RS or RE register (LDRS or LDRE instruction)]<br>A memory location. The symbol indicates the start address of the memory accessed.<br>The assembler derives a displacement (disp) from the symbol and the value of the PC, using the formula: $disp = symbol - PC$ . |
| #imm            | Immediate                                | Indicates a constant.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

Notes: 1. Increment

The amount of the increment is 1 when the operation size is a byte, 2 when the operation size is a word (two bytes), and 4 when the operation size is a longword (four bytes).

2. Decrement

The amount of the decrement is 1 when the operation size is a byte, 2 when the operation size is a word, and 4 when the operation size is a longword.

3. Displacement

A displacement is the distance between two points. In this assembly language, the unit of displacement values is in bytes.

The values that can be used for the displacement vary with the addressing mode and the operation size.

**Table 11.9 Allowed Displacement Values**

| Addressing Mode | Displacement*                                                                                                                        |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------|
| @ (disp,Rn)     | When the operation size is byte (B):<br>H'00000000 to H'0000000F (0 to 15)                                                           |
|                 | When the operation size is word (W):<br>H'00000000 to H'0000001E (0 to 30)                                                           |
|                 | When the operation size is longword (L):<br>H'00000000 to H'0000003C (0 to 60)                                                       |
| @ (disp:12,Rn)  | When the operation size is byte (B):<br>H'00000000 to H'00000FFF (0 to 4095)                                                         |
|                 | When the operation size is word (W):<br>H'00000000 to H'00001FFE (0 to 8190)                                                         |
|                 | When the operation size is longword (L):<br>H'00000000 to H'00003FFC (0 to 16380)                                                    |
| @ (disp,GBR)    | When the operation size is byte (B):<br>H'00000000 to H'000000FF (0 to 255)                                                          |
|                 | When the operation size is word (W):<br>H'00000000 to H'000001FE (0 to 510)                                                          |
|                 | When the operation size is longword (L):<br>H'00000000 to H'000003FC (0 to 1020)                                                     |
| @ (disp,PC)     | [When used as an operand of a move instruction]                                                                                      |
|                 | When the operation size is word (W):<br>H'00000000 to H'000001FE (0 to 510)                                                          |
|                 | When the operation size is longword (L):<br>H'00000000 to H'000003FC (0 to 1020)                                                     |
|                 | [When used as an operand of an instruction that sets the RS or RE register (LDRS or LDRE)]<br>H'FFFFFF00 to H'000000FE (-256 to 254) |
| @@ (disp,TBR)   | H'00000000 to H'000003FC (0 to 1020)                                                                                                 |

Note: Units are bytes, and numbers in parentheses are decimal.



**Table 11.9 Allowed Displacement Values (cont)**

| Addressing Mode | Displacement*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| symbol          | [When used as a branch instruction operand]<br>When used as an operand for a conditional branch instruction (BT, BF, BF/S, or BT/S):<br>$\left\{ \begin{array}{ll} \text{H'00000000 to H'000000FF} & (0 \text{ to } 255) \\ \text{H'FFFFFF00 to H'FFFFFFF} & (-256 \text{ to } -1) \end{array} \right.$ When used as an operand for an unconditional branch instruction (BRA or BSR)<br>$\left\{ \begin{array}{ll} \text{H'00000000 to H'00000FFF} & (0 \text{ to } 4095) \\ \text{H'FFFFFF00 to H'FFFFFFF} & (-4096 \text{ to } -1) \end{array} \right.$ [When used as the operand of a data move instruction]<br>When the operation size is word (W):<br>H'00000000 to H'000001FE (0 to 510)<br>When the operation size is longword (L):<br>H'00000000 to H'000003FC (0 to 1020)<br>[When used as an operand of an instruction that sets the RS or RE register (LDRS or LDRE)]<br>H'FFFFFF00 to H'000000FE (-256 to 254) |

Note: Units are bytes, and numbers in parentheses are decimal.

The values that can be used for immediate values vary with the executable instruction.

**Table 11.10 Allowed Immediate Values**

| Executable Instruction        | Immediate Value                                       |                                |
|-------------------------------|-------------------------------------------------------|--------------------------------|
| TST, AND, OR, XOR             | H'00000000 to H'000000FF                              | (0 to 255)                     |
| MOV                           | { H'00000000 to H'000000FF<br>H'FFFFFF80 to H'FFFFFFF | { (0 to 255)<br>(-128 to -1)*1 |
| ADD, CMP/EQ                   | { H'00000000 to H'000000FF<br>H'FFFFFF80 to H'FFFFFFF | { (0 to 255)<br>(-128 to -1)*1 |
| TRAPA                         | H'00000000 to H'000000FF                              | (0 to 255)                     |
| SETRC, LDRC                   | H'00000001 to H'000000FF                              | (1 to 255)*2                   |
| MOVI20                        | H'00000000 to H'000FFFFF                              | (0 to 1048575)                 |
| MOVI20S*3                     | H'00000000 to H'0FFFFFF00                             | (0 to 268435200)               |
| Bit manipulation instructions | H'00000000 to H'00000007                              | (0 to 7)                       |

Notes: 1. Values in the range H'FFFFFF80 to H'FFFFFFF can be written as positive decimal values.

2. When zero is set as the immediate values of the SETRC or LDRC instruction, warning number 835 occurs and the object code is output as zero. In this case, the range to be repeated is executed once.

When an externally referenced symbol is set as the immediate values of the SETRC or LDRC instruction, the linkage editor checks the range from H'00000000 to H'000000FF (0 to 255).

3. When the lower eight bits of immediate data are not 0, warning 845 is generated and the lower eight bits are rounded down to 0.

Note: The assembler corrects the value of displacements under certain conditions.

**Condition**

When the operation size is a word and the displacement is not a multiple of 2

**Type of Correction**

The lowest bit of the displacement is discarded, resulting in the value being a multiple of 2.

When the operation size is a longword and the displacement is not a multiple of 4



The lower 2 bits of the displacement are discarded, resulting in the value being a multiple of 4.

When the displacement of the branch instruction is not a multiple of 2



The lowest bit of the displacement is discarded, resulting in the value being a multiple of 2.

Be sure to take this correction into consideration when using operands of the mode @(disp,Rn), @(disp,GBR), @@(disp,TBR), and @(disp,PC).

— Example:

```
MOV.L @(63,PC),R0
```

The assembler corrects the 63 to be 60, and generates object code identical to that for the statement `MOV.L @(60,PC),R0`, and warning 870 occurs.

## 11.2.2 Notes on Executable Instructions

### (1) Notes on the Operation Size

The operation size that can be specified vary with the mnemonic and the addressing mode combination.

#### (a) SH-1 Executable Instruction and Operation Size Combinations:

Table 11.11 shows the SH-1 allowable executable instruction and operation size combinations.

Symbol meanings:

|            |                                                                                                                        |
|------------|------------------------------------------------------------------------------------------------------------------------|
| Rn, Rm     | A general register (R0 to R15)                                                                                         |
| R0         | General register R0                                                                                                    |
| SR         | Status register                                                                                                        |
| GBR        | Global base register                                                                                                   |
| VBR        | Vector base register                                                                                                   |
| MACH, MACL | High-order and Low-Order Multiplication and accumulation registers                                                     |
| PR         | Procedure register                                                                                                     |
| PC         | Program counter                                                                                                        |
| imm        | An immediate value                                                                                                     |
| disp       | A displacement value                                                                                                   |
| symbol     | A symbol                                                                                                               |
| B          | Byte                                                                                                                   |
| W          | Word (2 bytes)                                                                                                         |
| L          | Longword (4 bytes)                                                                                                     |
| μ          | Valid specification                                                                                                    |
| ×          | Invalid specification:<br>The assembler regards instructions with this combination as the specification being omitted. |
| Δ          | The assembler regards them as extended instructions.                                                                   |

**Table 11.11 SH-1 Executable Instruction and Operation Size Combinations (Part 1)**

| Data Transfer Instructions |                 | Operation Sizes |   |   |                      |    |
|----------------------------|-----------------|-----------------|---|---|----------------------|----|
| Mnemonic                   | Addressing Mode | B               | W | L | Default when Omitted |    |
| MOV                        | #imm,Rn         | O               | Δ | Δ | B                    | *1 |
| MOV                        | @(disp,PC),Rn   | ×               | O | O | L                    |    |
| MOV                        | symbol,Rn       | ×               | O | O | L                    |    |
| MOV                        | Rn,Rm           | ×               | × | O | L                    |    |
| MOV                        | Rn,@Rm          | O               | O | O | L                    |    |
| MOV                        | @Rn,Rm          | O               | O | O | L                    |    |
| MOV                        | Rn,@-Rm         | O               | O | O | L                    |    |
| MOV                        | @Rn+,Rm         | O               | O | O | L                    |    |
| MOV                        | R0,@(disp,Rn)   | O               | O | O | L                    |    |
| MOV                        | Rn,@(disp,Rm)   | ×               | × | O | L                    | *2 |
| MOV                        | @(disp,Rn),R0   | O               | O | O | L                    |    |
| MOV                        | @(disp,Rn),Rm   | ×               | × | O | L                    | *3 |
| MOV                        | Rn,@(R0,Rm)     | O               | O | O | L                    |    |
| MOV                        | @(R0,Rn),Rm     | O               | O | O | L                    |    |
| MOV                        | R0,@(disp,GBR)  | O               | O | O | L                    |    |
| MOV                        | @(disp,GBR),R0  | O               | O | O | L                    |    |
| MOVA                       | #imm,R0         | ×               | × | Δ | L                    |    |
| MOVA                       | @(disp,PC),R0   | ×               | × | O | L                    |    |
| MOVA                       | symbol,R0       | ×               | × | O | L                    |    |
| MOVT                       | Rn              | ×               | × | O | L                    |    |
| SWAP                       | Rn,Rm           | O               | O | × | W                    |    |
| XTRCT                      | Rn,Rm           | ×               | × | O | L                    |    |

Notes: 1. In size selection mode, the assembler selects the operation size according to the imm value.

2. In this case, Rn must be one of R1 to R15.

3. In this case, Rm must be one of R1 to R15.

**Table 11.11 SH-1 Executable Instruction and Operation Size Combinations (Part 2)**

| Arithmetic Operation Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                          | Addressing Mode | B               | W | L | Default when Omitted |
| ADD                               | Rn,Rm           | ×               | × | ○ | L                    |
| ADD                               | #imm,Rn         | ×               | × | ○ | L                    |
| ADDC                              | Rn,Rm           | ×               | × | ○ | L                    |
| ADDV                              | Rn,Rm           | ×               | × | ○ | L                    |
| CMP/EQ                            | #imm,R0         | ×               | × | ○ | L                    |
| CMP/EQ                            | Rn,Rm           | ×               | × | ○ | L                    |
| CMP/HS                            | Rn,Rm           | ×               | × | ○ | L                    |
| CMP/GE                            | Rn,Rm           | ×               | × | ○ | L                    |
| CMP/HI                            | Rn,Rm           | ×               | × | ○ | L                    |
| CMP/GT                            | Rn,Rm           | ×               | × | ○ | L                    |
| CMP/PZ                            | Rn              | ×               | × | ○ | L                    |
| CMP/PL                            | Rn              | ×               | × | ○ | L                    |
| CMP/STR                           | Rn,Rm           | ×               | × | ○ | L                    |
| DIV1                              | Rn,Rm           | ×               | × | ○ | L                    |
| DIV0S                             | Rn,Rm           | ×               | × | ○ | L                    |
| DIV0U                             | (no operands)   | ×               | × | × | —                    |
| EXTS                              | Rn,Rm           | ○               | ○ | × | W                    |
| EXTU                              | Rn,Rm           | ○               | ○ | × | W                    |
| MAC                               | @Rn+,@Rm+       | ×               | ○ | × | W                    |
| MULS                              | Rn,Rm           | ×               | ○ | ○ | L*                   |
| MULU                              | Rn,Rm           | ×               | ○ | ○ | L*                   |
| NEG                               | Rn,Rm           | ×               | × | ○ | L                    |
| NEGC                              | Rn,Rm           | ×               | × | ○ | L                    |
| SUB                               | Rn,Rm           | ×               | × | ○ | L                    |
| SUBC                              | Rn,Rm           | ×               | × | ○ | L                    |
| SUBV                              | Rn,Rm           | ×               | × | ○ | L                    |

Note: The object code generated when W is specified is the same as that generated when L is specified.

**Table 11.11 SH-1 Executable Instruction and Operation Size Combinations (Part 3)**

| Logic Operation Instructions |                 | Operation Sizes |   |   |                      |
|------------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                     | Addressing Mode | B               | W | L | Default when Omitted |
| AND                          | Rn,Rm           | ×               | × | ○ | L                    |
| AND                          | #imm,R0         | ×               | × | ○ | L                    |
| AND                          | #imm,@(R0,GBR)  | ○               | × | × | B                    |
| NOT                          | Rn,Rm           | ×               | × | ○ | L                    |
| OR                           | Rn,Rm           | ×               | × | ○ | L                    |
| OR                           | #imm,R0         | ×               | × | ○ | L                    |
| OR                           | #imm,@(R0,GBR)  | ○               | × | × | B                    |
| TAS                          | @Rn             | ○               | × | × | B                    |
| TST                          | Rn,Rm           | ×               | × | ○ | L                    |
| TST                          | #imm,R0         | ×               | × | ○ | L                    |
| TST                          | #imm,@(R0,GBR)  | ○               | × | × | B                    |
| XOR                          | Rn,Rm           | ×               | × | ○ | L                    |
| XOR                          | #imm,R0         | ×               | × | ○ | L                    |
| XOR                          | #imm,@(R0,GBR)  | ○               | × | × | B                    |

**Table 11.11 SH-1 Executable Instruction and Operation Size Combinations (Part 4)**

| Shift Instructions |                 | Operation Sizes |   |   |                      |
|--------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic           | Addressing Mode | B               | W | L | Default when Omitted |
| ROTL               | Rn              | ×               | × | ○ | L                    |
| ROTR               | Rn              | ×               | × | ○ | L                    |
| ROTCL              | Rn              | ×               | × | ○ | L                    |
| ROTCR              | Rn              | ×               | × | ○ | L                    |
| SHAL               | Rn              | ×               | × | ○ | L                    |
| SHAR               | Rn              | ×               | × | ○ | L                    |
| SHLL               | Rn              | ×               | × | ○ | L                    |
| SHLR               | Rn              | ×               | × | ○ | L                    |
| SHLL2              | Rn              | ×               | × | ○ | L                    |
| SHLR2              | Rn              | ×               | × | ○ | L                    |
| SHLL8              | Rn              | ×               | × | ○ | L                    |
| SHLR8              | Rn              | ×               | × | ○ | L                    |
| SHLL16             | Rn              | ×               | × | ○ | L                    |
| SHLR16             | Rn              | ×               | × | ○ | L                    |

**Table 11.11 SH-1 Executable Instruction and Operation Size Combinations (Part 5)**

| Branch Instructions |                 | Operation Sizes |   |   |                      |
|---------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic            | Addressing Mode | B               | W | L | Default when Omitted |
| BF                  | symbol          | ×               | × | × | —                    |
| BT                  | symbol          | ×               | × | × | —                    |
| BRA                 | symbol          | ×               | × | × | —                    |
| BSR                 | symbol          | ×               | × | × | —                    |
| JMP                 | @Rn             | ×               | × | × | —                    |
| JSR                 | @Rn             | ×               | × | × | —                    |
| RTS                 | (no operands)   | ×               | × | × | —                    |

Table 11.11 SH-1 Executable Instruction and Operation Size Combinations (Part 6)

| System Control Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | Default when Omitted |
| CLRT                        | (no operands)   | x               | x | x | —                    |
| CLRMAC                      | (no operands)   | x               | x | x | —                    |
| LDC                         | Rn,SR           | x               | x | O | L                    |
| LDC                         | Rn,GBR          | x               | x | O | L                    |
| LDC                         | Rn,VBR          | x               | x | O | L                    |
| LDC                         | @Rn+,SR         | x               | x | O | L                    |
| LDC                         | @Rn+,GBR        | x               | x | O | L                    |
| LDC                         | @Rn+,VBR        | x               | x | O | L                    |
| LDS                         | Rn,MACH         | x               | x | O | L                    |
| LDS                         | Rn,MACL         | x               | x | O | L                    |
| LDS                         | Rn,PR           | x               | x | O | L                    |
| LDS                         | @Rn+,MACH       | x               | x | O | L                    |
| LDS                         | @Rn+,MACL       | x               | x | O | L                    |
| LDS                         | @Rn+,PR         | x               | x | O | L                    |
| NOP                         | (no operands)   | x               | x | x | —                    |
| RTE                         | (no operands)   | x               | x | x | —                    |
| SETT                        | (no operands)   | x               | x | x | —                    |
| SLEEP                       | (no operands)   | x               | x | x | —                    |
| STC                         | SR,Rn           | x               | x | O | L                    |
| STC                         | GBR,Rn          | x               | x | O | L                    |
| STC                         | VBR,Rn          | x               | x | O | L                    |
| STC                         | SR,@-Rn         | x               | x | O | L                    |
| STC                         | GBR,@-Rn        | x               | x | O | L                    |
| STC                         | VBR,@-Rn        | x               | x | O | L                    |
| STS                         | MACH,Rn         | x               | x | O | L                    |
| STS                         | MACL,Rn         | x               | x | O | L                    |
| STS                         | PR,Rn           | x               | x | O | L                    |
| STS                         | MACH,@-Rn       | x               | x | O | L                    |
| STS                         | MACL,@-Rn       | x               | x | O | L                    |
| STS                         | PR,@-Rn         | x               | x | O | L                    |
| TRAPA                       | #imm            | x               | x | O | L                    |



(b) SH-2 Executable Instruction and Operation Size Combinations:

Table 11.12 lists the combination of executable instructions added to SH-2 from SH-1 and the operation size.

**Table 11.12 SH-2 Executable Instruction and Operation Size Combinations (Part 1)**

| Arithmetic Operation Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                          | Addressing Mode | B               | W | L | Default when Omitted |
| MAC                               | @Rn+,@Rm+       | ×               | ○ | ○ | W                    |
| MUL                               | Rn,Rm           | ×               | × | ○ | L                    |
| DMULS                             | Rn,Rm           | ×               | × | ○ | L                    |
| DMULU                             | Rn,Rm           | ×               | × | ○ | L                    |
| DT                                | Rn              | ×               | × | × | —                    |

**Table 11.12 SH-2 Executable Instruction and Operation Size Combinations (Part 2)**

| Branch Instructions |                 | Operation Sizes |   |   |                      |
|---------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic            | Addressing Mode | B               | W | L | Default when Omitted |
| BF/S                | symbol          | ×               | × | × | —                    |
| BT/S                | symbol          | ×               | × | × | —                    |
| BRAF                | Rn              | ×               | × | × | —                    |
| BSRF                | Rn              | ×               | × | × | —                    |

## (c) SH-2E Executable Instruction and Operation Size Combinations:

Table 11.13 lists the combination of executable instructions added to SH-2E from SH-2 and the operation size.

Symbol meanings:

FRm,FRn Floating-point register

FR0 FR0 floating-point register

FPUL Floating-point communication register

FPSCR Floating-point status control register

S Single precision (4 bytes)

**Table 11.13 SH-2E Executable Instruction and Operation Size Combinations (Part 1)**

| Data Transfer Instructions |                 | Operation Sizes |   |   |   |                      |
|----------------------------|-----------------|-----------------|---|---|---|----------------------|
| Mnemonic                   | Addressing Mode | B               | W | L | S | Default when Omitted |
| FLDI0                      | FRn             | x               | x | x | O | S                    |
| FLDI1                      | FRn             | x               | x | x | O | S                    |
| FMOV                       | @Rm,FRn         | x               | x | x | O | S                    |
| FMOV                       | FRn,@Rm         | x               | x | x | O | S                    |
| FMOV                       | @Rm+,FRn        | x               | x | x | O | S                    |
| FMOV                       | FRn,@-Rm        | x               | x | x | O | S                    |
| FMOV                       | @(R0,Rm),FRn    | x               | x | x | O | S                    |
| FMOV                       | FRm,@(R0,Rm)    | x               | x | x | O | S                    |
| FMOV                       | FRm,FRn         | x               | x | x | O | S                    |

**Table 11.13 SH-2E Executable Instruction and Operation Size Combinations (Part 2)**

| Arithmetic Operation Instructions |                 | Operation Sizes |   |   |   |   | Default when Omitted |
|-----------------------------------|-----------------|-----------------|---|---|---|---|----------------------|
| Mnemonic                          | Addressing Mode | B               | W | L | S |   |                      |
| FABS                              | FRn             | ×               | × | × | ○ | S |                      |
| FADD                              | FRm,FRn         | ×               | × | × | ○ | S |                      |
| FCMP/EQ                           | FRm,FRn         | ×               | × | × | ○ | S |                      |
| FCMP/GT                           | FRm,FRn         | ×               | × | × | ○ | S |                      |
| FDIV                              | FRm,FRn         | ×               | × | × | ○ | S |                      |
| FMAC                              | FR0,FRm,FRn     | ×               | × | × | ○ | S |                      |
| FMUL                              | FRm,FRn         | ×               | × | × | ○ | S |                      |
| FNEG                              | FRn             | ×               | × | × | ○ | S |                      |
| FSUB                              | FRm,FRn         | ×               | × | × | ○ | S |                      |

**Table 11.13 SH-2E Executable Instruction and Operation Size Combinations (Part 3)**

| System Control Instructions |                 | Operation Sizes |   |   |   |   | Default when Omitted |
|-----------------------------|-----------------|-----------------|---|---|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | S |   |                      |
| FLDS                        | FRm,FPUL        | ×               | × | × | ○ | S |                      |
| FLOAT                       | FPUL,FRn        | ×               | × | × | ○ | S |                      |
| FSTS                        | FPUL,FRn        | ×               | × | × | ○ | S |                      |
| FTRC                        | FRm,FPUL        | ×               | × | × | ○ | S |                      |
| LDS                         | Rm,FPUL         | ×               | × | ○ | × | L |                      |
| LDS                         | @Rm+,FPUL       | ×               | × | ○ | × | L |                      |
| LDS                         | Rm,FPSCR        | ×               | × | ○ | × | L |                      |
| LDS                         | @Rm+,FPSCR      | ×               | × | ○ | × | L |                      |
| STS                         | FPUL,Rn         | ×               | × | ○ | × | L |                      |
| STS                         | FPUL,@-Rn       | ×               | × | ○ | × | L |                      |
| STS                         | FPSCR,Rn        | ×               | × | ○ | × | L |                      |
| STS                         | FPSCR,@-Rn      | ×               | × | ○ | × | L |                      |

## (d) SH-3 Executable Instruction and Operation Size Combinations:

Table 11.14 lists the combination of executable instructions added to SH-3 from SH-2 and the operation size.

Symbol meanings:

|         |                       |
|---------|-----------------------|
| Rn_BANK | Bank general register |
| SSR     | Saved status register |
| SPC     | Saved program counter |

**Table 11.14 SH-3 Executable Instruction and Operation Size Combinations (Part 1)**

| Data Transfer Instructions |                 | Operation Sizes |   |   |                      |
|----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                   | Addressing Mode | B               | W | L | Default when Omitted |
| PREF                       | @Rn             | x               | x | x | —                    |

**Table 11.14 SH-3 Executable Instruction and Operation Size Combinations (Part 2)**

| Shift Instructions |                 | Operation Sizes |   |   |                      |
|--------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic           | Addressing Mode | B               | W | L | Default when Omitted |
| SHAD               | Rn,Rm           | x               | x | O | L                    |
| SHLD               | Rn,Rm           | x               | x | O | L                    |

**Table 11.14 SH-3 Executable Instruction and Operation Size Combinations (Part 3)**

| System Control Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | Default when Omitted |
| CLRS                        | (no operands)   | ×               | × | × | —                    |
| SETS                        | (no operands)   | ×               | × | × | —                    |
| LDC                         | Rm,SSR          | ×               | × | ○ | L                    |
| LDC                         | Rm,SPC          | ×               | × | ○ | L                    |
| LDC                         | Rm,Rn_BANK      | ×               | × | ○ | L                    |
| LDC                         | @Rm+,SSR        | ×               | × | ○ | L                    |
| LDC                         | @Rm+,SPC        | ×               | × | ○ | L                    |
| LDC                         | @Rm+,Rn_BANK    | ×               | × | ○ | L                    |
| STC                         | SSR,Rn          | ×               | × | ○ | L                    |
| STC                         | SPC,Rn          | ×               | × | ○ | L                    |
| STC                         | Rm_BANK,Rn      | ×               | × | ○ | L                    |
| STC                         | SSR,@-Rn        | ×               | × | ○ | L                    |
| STC                         | SPC,@-Rn        | ×               | × | ○ | L                    |
| STC                         | Rm_BANK,@-Rn    | ×               | × | ○ | L                    |
| LDTLB                       | (no operands)   | ×               | × | × | —                    |

## (e) SH-4 Executable Instruction and Operation Size Combinations:

Table 11.15 lists the combination of executable instructions added to SH-4 from SH-3 and the operation size.

Symbol meanings:

|         |                                                          |
|---------|----------------------------------------------------------|
| DRm,DRn | Double-precision floating-point register                 |
| XDm,XDn | Extended double-precision floating-point register        |
| FVm,FVn | Single-precision floating-point vector register          |
| XMTRX   | Single-precision floating-point extended register matrix |
| DBR     | Debug vector base register                               |
| SGR     | Save general register 15                                 |
| D       | Double precision (8 bytes)                               |

**Table 11.15 SH-4 Executable Instruction and Operation Size Combinations (Part 1)**

| Data Transfer Instructions |                 | Operation Sizes |   |   |   |   | Default when Omitted |
|----------------------------|-----------------|-----------------|---|---|---|---|----------------------|
| Mnemonic                   | Addressing Mode | B               | W | L | S | D |                      |
| FLDI0                      | FRn             | x               | x | x | 0 | x | S                    |
| FLDI1                      | FRn             | x               | x | x | 0 | x | S                    |
| FMOV                       | FRm,FRn         | x               | x | x | 0 | x | S                    |
| FMOV                       | FRn,@Rm         | x               | x | x | 0 | x | S                    |
| FMOV                       | FRn,@-Rn        | x               | x | x | 0 | x | S                    |
| FMOV                       | FRn,@(R0,Rm)    | x               | x | x | 0 | x | S                    |
| FMOV                       | @Rm,FRn         | x               | x | x | 0 | x | S                    |
| FMOV                       | @Rm+,FRn        | x               | x | x | 0 | x | S                    |
| FMOV                       | @(R0,Rm),FRn    | x               | x | x | 0 | x | S                    |
| FMOV                       | DRm,DRn         | x               | x | x | x | 0 | D                    |
| FMOV                       | DRm,@Rn         | x               | x | x | x | 0 | D                    |
| FMOV                       | DRm,@-Rn        | x               | x | x | x | 0 | D                    |
| FMOV                       | DRm,@(R0,Rn)    | x               | x | x | x | 0 | D                    |
| FMOV                       | @Rm,DRn         | x               | x | x | x | 0 | D                    |
| FMOV                       | @Rm+,DRn        | x               | x | x | x | 0 | D                    |
| FMOV                       | @(R0,Rm),DRn    | x               | x | x | x | 0 | D                    |
| FMOV                       | DRm,XDn         | x               | x | x | x | 0 | D                    |
| FMOV                       | XDm,DRn         | x               | x | x | x | 0 | D                    |
| FMOV                       | XDm,XDn         | x               | x | x | x | 0 | D                    |
| FMOV                       | XDm,@Rn         | x               | x | x | x | 0 | D                    |
| FMOV                       | XDm,@-Rn        | x               | x | x | x | 0 | D                    |
| FMOV                       | XDm,@(R0,Rn)    | x               | x | x | x | 0 | D                    |
| FMOV                       | @Rm,XDn         | x               | x | x | x | 0 | D                    |
| FMOV                       | @Rm,XDn         | x               | x | x | x | 0 | D                    |
| FMOV                       | @(R0,Rm),XDn    | x               | x | x | x | 0 | D                    |

**Table 11.15 SH-4 Executable Instruction and Operation Size Combinations (Part 2)**

| Arithmetic Operation Instructions |                 | Operation Sizes |   |   |   |   | Default when Omitted |
|-----------------------------------|-----------------|-----------------|---|---|---|---|----------------------|
| Mnemonic                          | Addressing Mode | B               | W | L | S | D |                      |
| FABS                              | FRn             | x               | x | x | O | x | S                    |
| FABS                              | DRn             | x               | x | x | x | O | D                    |
| FADD                              | FRm,FRn         | x               | x | x | O | x | S                    |
| FADD                              | DRm,DRn         | x               | x | x | x | O | D                    |
| FCMP/EQ                           | FRm,FRn         | x               | x | x | O | x | S                    |
| FCMP/EQ                           | DRm,DRn         | x               | x | x | x | O | D                    |
| FCMP/GT                           | FRm,FRn         | x               | x | x | O | x | S                    |
| FCMP/GT                           | DRm,DRn         | x               | x | x | x | O | D                    |
| FDIV                              | FRm,FRn         | x               | x | x | O | x | S                    |
| FDIV                              | DRm,DRn         | x               | x | x | x | O | D                    |
| FIPR                              | FVm,FVn         | x               | x | x | O | x | S                    |
| FMAC                              | FR0,FRm,FRn     | x               | x | x | O | x | S                    |
| FMUL                              | FRm,FRn         | x               | x | x | O | x | S                    |
| FMUL                              | DRm,DRn         | x               | x | x | x | O | D                    |
| FNEG                              | FRn             | x               | x | x | O | x | S                    |
| FNEG                              | DRn             | x               | x | x | x | O | D                    |
| FSQRT                             | FRn             | x               | x | x | O | x | S                    |
| FSQRT                             | DRn             | x               | x | x | x | O | D                    |
| FSUB                              | FRm,FRn         | x               | x | x | O | x | S                    |
| FSUB                              | DRm,DRn         | x               | x | x | x | O | D                    |
| FTRV                              | XMTRX,FVn       | x               | x | x | O | x | S                    |



**Table 11.15 SH-4 Executable Instruction and Operation Size Combinations (Part 3)**

| System Control Instructions |                 | Operation Sizes |   |   |   |   | Default when Omitted |
|-----------------------------|-----------------|-----------------|---|---|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | S | D |                      |
| FCNVDS                      | DRm,FPUL        | x               | x | x | x | O | D                    |
| FCNVSD                      | FPUL,DRn        | x               | x | x | x | O | D                    |
| FLDS                        | FRm,FPUL        | x               | x | x | O | x | S                    |
| FLOAT                       | FPUL,FRn        | x               | x | x | O | x | S                    |
| FLOAT                       | FPUL,DRn        | x               | x | x | x | O | D                    |
| FRCHG                       | (no operands)   | x               | x | x | x | x | —                    |
| FSCHG                       | (no operands)   | x               | x | x | x | x | —                    |
| FSTS                        | FPUL,FRn        | x               | x | x | O | x | S                    |
| FTRC                        | FRm,FPUL        | x               | x | x | O | x | S                    |
| FTRC                        | DRm,FPUL        | x               | x | x | x | O | D                    |
| LDC                         | Rm,DBR          | x               | x | O | x | x | L                    |
| LDC                         | @Rm+,DBR        | x               | x | O | x | x | L                    |
| LDS                         | Rm,FPUL         | x               | x | O | x | x | L                    |
| LDS                         | @Rm+,FPUL       | x               | x | O | x | x | L                    |
| LDS                         | Rm,FPSCR        | x               | x | O | x | x | L                    |
| LDS                         | @Rm+,FPSCR      | x               | x | O | x | x | L                    |
| OCBI                        | @Rn             | x               | x | x | x | x | —                    |
| OCBP                        | @Rn             | x               | x | x | x | x | —                    |
| OCBWB                       | @Rn             | x               | x | x | x | x | —                    |
| STC                         | DBR,Rn          | x               | x | O | x | x | L                    |
| STC                         | DBR,@-Rn        | x               | x | O | x | x | L                    |
| STC                         | SGR,Rn          | x               | x | O | x | x | L                    |
| STC                         | SGR,@-Rn        | x               | x | O | x | x | L                    |
| STS                         | FPUL,Rm         | x               | x | O | x | x | L                    |
| STS                         | FPUL,@-Rm       | x               | x | O | x | x | L                    |
| STS                         | FPSCR,Rm        | x               | x | O | x | x | L                    |
| STS                         | FPSCR,@-Rm      | x               | x | O | x | x | L                    |

## (f) SH2-DSP, SH3-DSP Executable Instruction and Operation Size Combinations:

Table 11.16 shows the executable instruction and operation size combinations for the SH2-DSP and SH3-DSP instructions added to those of the SH-2 and SH-3, respectively.

Symbol meanings:

|     |                                                                 |
|-----|-----------------------------------------------------------------|
| MOD | Modulo register                                                 |
| RS  | Repeat start register                                           |
| RE  | Repeat end register                                             |
| DSR | DSP status register                                             |
| A0  | DSP data register (A0, A1, X0, X1, Y0, or Y1 can be specified.) |

**Table 11.16 SH2-DSP, SH3-DSP Executable Instruction and Operation Size Combinations (Part 1)**

| Repeat Control Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | Default when Omitted |
| LDRS                        | @(disp,PC)      | ×               | × | ○ | L                    |
| LDRS                        | symbol          | ×               | × | ○ | L                    |
| LDRE                        | @(disp,PC)      | ×               | × | ○ | L                    |
| LDRE                        | symbol          | ×               | × | ○ | L                    |
| SETRC                       | Rn              | ×               | × | × | —                    |
| SETRC                       | #imm            | ×               | × | × | —                    |

**Table 11.16 SH2-DSP, SH3-DSP Executable Instruction and Operation Size Combinations  
(Part 2)**

| System Control Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | Default when Omitted |
| LDC                         | Rn,MOD          | ×               | × | ○ | L                    |
| LDC                         | Rn,RS           | ×               | × | ○ | L                    |
| LDC                         | Rn,RE           | ×               | × | ○ | L                    |
| LDC                         | @Rn+,MOD        | ×               | × | ○ | L                    |
| LDC                         | @Rn+,RS         | ×               | × | ○ | L                    |
| LDC                         | @Rn+,RE         | ×               | × | ○ | L                    |
| LDS                         | Rn,DSR          | ×               | × | ○ | L                    |
| LDS                         | Rn,A0           | ×               | × | ○ | L                    |
| LDS                         | @Rn+,DSR        | ×               | × | ○ | L                    |
| LDS                         | @Rn+,A0         | ×               | × | ○ | L                    |
| STC                         | MOD,Rn          | ×               | × | ○ | L                    |
| STC                         | RS,Rn           | ×               | × | ○ | L                    |
| STC                         | RE,Rn           | ×               | × | ○ | L                    |
| STC                         | MOD,@-Rn        | ×               | × | ○ | L                    |
| STC                         | RS,@-Rn         | ×               | × | ○ | L                    |
| STC                         | RE,@-Rn         | ×               | × | ○ | L                    |
| STS                         | DSR,Rn          | ×               | × | ○ | L                    |
| STS                         | A0,Rn           | ×               | × | ○ | L                    |
| STS                         | DSR,@-Rn        | ×               | × | ○ | L                    |
| STS                         | A0,@-Rn         | ×               | × | ○ | L                    |

## (g) SH4AL-DSP Executable Instruction and Operation Size Combinations:

Table 11.17 shows the executable instruction and operation size combinations for the SH4AL-DSP instructions added to those of the SH3-DSP.

**Table 11.17 SH4AL-DSP Executable Instruction and Operation Size Combinations  
(Part 1)**

| Data Transfer Instructions |                 | Operation Sizes |   |   |                      |
|----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                   | Addressing Mode | B               | W | L | Default when Omitted |
| CLRDMXY                    | (no operands)   | ×               | × | × | —                    |
| MOVCA                      | R0,@Rn          | ×               | × | ○ | L                    |
| MOVCO                      | R0,@Rn          | ×               | × | ○ | L                    |
| MOVLI                      | @Rn,R0          | ×               | × | ○ | L                    |
| MOVUA                      | @Rn,R0          | ×               | × | ○ | L                    |
| MOVUA                      | @Rn+,R0         | ×               | × | ○ | L                    |
| PREFI                      | (no operands)   | ×               | × | × | —                    |
| SETDMX                     | (no operands)   | ×               | × | × | —                    |
| SETDMY                     | (no operands)   | ×               | × | × | —                    |

**Table 11.17 SH4AL-DSP Executable Instruction and Operation Size Combinations  
(Part 2)**

| System Control Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | Default when Omitted |
| ICBI                        | @Rn             | x               | x | O | L                    |
| LDC                         | Rn,DBR          | x               | x | O | L                    |
| LDC                         | @Rn+,DBR        | x               | x | O | L                    |
| LDC                         | Rn,SGR          | x               | x | O | L                    |
| LDC                         | @Rn+,SGR        | x               | x | O | L                    |
| OCBI                        | @Rn             | x               | x | x | —                    |
| OCBP                        | @Rn             | x               | x | x | —                    |
| OCBWB                       | @Rn             | x               | x | x | —                    |
| STC                         | DBR,Rn          | x               | x | O | L                    |
| STC                         | DBR,@-Rn        | x               | x | O | L                    |
| STC                         | SGR,Rn          | x               | x | O | L                    |
| STC                         | SGR,@-Rn        | x               | x | O | L                    |
| SYNCO                       | @Rn             | x               | x | O | L                    |

**Table 11.17 SH4AL-DSP Executable Instruction and Operation Size Combinations  
(Part 3)**

| Repeat Control Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | Default when Omitted |
| LDRC                        | Rn              | x               | x | x | —                    |

## (h) SH-4A Executable Instruction and Operation Size Combinations:

Table 11.18 shows the executable instruction and operation size combinations for the SH-4A instructions added to those of the SH-4.

**Table 11.18 SH-4A Executable Instruction and Operation Size Combinations (Part 1)**

| Data Transfer Instructions |                 | Operation Sizes |   |   |                      |
|----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                   | Addressing Mode | B               | W | L | Default when Omitted |
| MOVCO                      | R0,@Rn          | ×               | × | O | L                    |
| MOVLI                      | @Rn,R0          | ×               | × | O | L                    |
| MOVUA                      | @Rn,R0          | ×               | × | O | L                    |
| MOVUA                      | @Rn+,R0         | ×               | × | O | L                    |
| PREFI                      | (no operands)   | ×               | × | × | —                    |

**Table 11.18 SH-4A Executable Instruction and Operation Size Combinations (Part 2)**

| System Control Instructions |                 | Operation Sizes |   |   |   |   | Default when Omitted |
|-----------------------------|-----------------|-----------------|---|---|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | S | D |                      |
| FPCHG                       | (no operands)   | ×               | × | × | × | × | —                    |
| ICBI                        | @Rn             | ×               | × | × | × | × | —                    |
| LDC                         | Rn,SGR          | ×               | × | O | × | × | L                    |
| LDC                         | @Rn+,SGR        | ×               | × | O | × | × | L                    |
| FSCA                        | FPUL,DRn        | ×               | × | × | O | × | S                    |
| FSRRA                       | FRn             | ×               | × | × | O | × | S                    |
| SYNCO                       | @Rn             | ×               | × | × | × | × | —                    |

## (i) SH-2A Executable Instruction and Operation Size Combinations:

Table 11.19 shows the executable instruction and operation size combinations for the SH-2A instructions added to those of the SH-2.

Symbol meanings:

TBR      Jump table register

**Table 11.19 SH-2A Executable Instruction and Operation Size Combinations (Part 1)**

| Data Transfer Instructions |                  | Operation Sizes |   |   |                      |
|----------------------------|------------------|-----------------|---|---|----------------------|
| Mnemonic                   | Addressing Mode  | B               | W | L | Default when Omitted |
| MOV                        | R0,@Rn+          | O               | O | O | L                    |
| MOV                        | @-Rm,R0          | O               | O | O | L                    |
| MOV                        | Rm,@(disp:12,Rn) | O               | O | O | L                    |
| MOV                        | @(disp:12,Rm),Rn | O               | O | O | L                    |
| MOVI20                     | #imm20,Rn        | ×               | × | O | L                    |
| MOVI20S                    | #imm20,Rn        | ×               | × | O | L                    |
| MOVML                      | Rm,@-R15         | ×               | × | O | L                    |
| MOVML                      | @R15+,Rn         | ×               | × | O | L                    |
| MOVMU                      | Rm,@-R15         | ×               | × | O | L                    |
| MOVMU                      | @R15+,Rn         | ×               | × | O | L                    |
| MOVRT                      | Rn               | ×               | × | O | L                    |
| MOVU                       | @(disp:12,Rm),Rn | O               | O | × | W                    |
| NOTT                       | (no operands)    | ×               | × | × | —                    |
| PREF                       | @Rn              | ×               | × | × | —                    |

**Table 11.19 SH-2A Executable Instruction and Operation Size Combinations (Part 2)**

| Arithmetic Operation Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                          | Addressing Mode | B               | W | L | Default when Omitted |
| CLIPS                             | Rn              | O               | O | × | W                    |
| CLIPU                             | Rn              | O               | O | × | W                    |
| DIVS                              | R0,Rn           | ×               | × | O | L                    |
| DIVU                              | R0,Rn           | ×               | × | O | L                    |
| MULR                              | R0,Rn           | ×               | × | O | L                    |

**Table 11.19 SH-2A Executable Instruction and Operation Size Combinations (Part 3)**

| Shift Instructions |                 | Operation Sizes |   |   |                      |
|--------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic           | Addressing Mode | B               | W | L | Default when Omitted |
| SHAD               | Rn, Rm          | ×               | × | O | L                    |
| SHLD               | Rn, Rm          | ×               | × | O | L                    |

**Table 11.19 SH-2A Executable Instruction and Operation Size Combinations (Part 4)**

| Branch Instructions |                 | Operation Sizes |   |   |                      |
|---------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic            | Addressing Mode | B               | W | L | Default when Omitted |
| JSR/N               | @Rn             | ×               | × | × | —                    |
| JSR/N               | @@(disp,TBR)    | ×               | × | × | —                    |
| RTS/N               | (no operands)   | ×               | × | × | —                    |
| RTV/N               | Rn              | ×               | × | × | —                    |

**Table 11.19 SH-2A Executable Instruction and Operation Size Combinations (Part 5)**

| System Control Instructions |                 | Operation Sizes |   |   |                      |
|-----------------------------|-----------------|-----------------|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | Default when Omitted |
| LDBANK                      | @Rm,R0          | ×               | × | O | L                    |
| LDC                         | Rm,TBR          | ×               | × | O | L                    |
| RESBANK                     | (no operands)   | ×               | × | × | —                    |
| STBANK                      | R0,@Rn          | ×               | × | O | L                    |
| STC                         | TBR,Rn          | ×               | × | O | L                    |



**Table 11.19 SH-2A Executable Instruction and Operation Size Combinations (Part 6)**

| Bit Manipulation Instructions |                    | Operation Sizes |   |   |                      |
|-------------------------------|--------------------|-----------------|---|---|----------------------|
| Mnemonic                      | Addressing Mode    | B               | W | L | Default when Omitted |
| BAND                          | #imm,@(disp:12,Rn) | O               | × | × | B                    |
| BANDNOT                       | #imm,@(disp:12,Rn) | O               | × | × | B                    |
| BCLR                          | #imm,@(disp:12,Rn) | O               | × | × | B                    |
| BCLR                          | #imm,Rn            | ×               | × | O | L                    |
| BLD                           | #imm,@(disp:12,Rn) | O               | × | × | B                    |
| BLD                           | #imm,Rn            | ×               | × | O | L                    |
| BLDNOT                        | #imm,@(disp:12,Rn) | O               | × | × | B                    |
| BOR                           | #imm,@(disp:12,Rn) | O               | × | × | B                    |
| BORNOT                        | #imm,@(disp:12,Rn) | O               | × | × | B                    |
| BSET                          | #imm,@(disp:12,Rn) | O               | × | × | B                    |
| BSET                          | #imm,Rn            | ×               | × | O | L                    |
| BST                           | #imm,@(disp:12,Rn) | O               | × | × | B                    |
| BST                           | #imm,Rn            | ×               | × | O | L                    |
| BXOR                          | #imm,@(disp:12,Rn) | O               | × | × | B                    |

(j) SH2A-FPU Executable Instruction and Operation Size Combinations:

Table 11.20 shows the executable instruction and operation size combinations for the SH2A-FPU instructions added to those of the SH-2E and SH-2A.

**Table 11.20 SH2A-FPU Executable Instruction and Operation Size Combinations  
(Part 1)**

| Data Transfer Instructions |                   | Operation Sizes |   |   |   |   |                      |
|----------------------------|-------------------|-----------------|---|---|---|---|----------------------|
| Mnemonic                   | Addressing Mode   | B               | W | L | S | D | Default when Omitted |
| FMOV                       | DRm,DRn           | ×               | × | × | × | O | D                    |
| FMOV                       | DRm,@Rn           | ×               | × | × | × | O | D                    |
| FMOV                       | DRm@-Rn           | ×               | × | × | × | O | D                    |
| FMOV                       | DRm,@(R0,Rn)      | ×               | × | × | × | O | D                    |
| FMOV                       | @Rm,DRn           | ×               | × | × | × | O | D                    |
| FMOV                       | @Rm+,DRn          | ×               | × | × | × | O | D                    |
| FMOV                       | @(R0,Rm),DRn      | ×               | × | × | × | O | D                    |
| FMOV                       | @(disp:12,Rm),FRn | ×               | × | × | O | × | S                    |
| FMOV                       | @(disp:12,Rm),DRn | ×               | × | × | × | O | D                    |
| FMOV                       | FRm,@(disp:12,Rn) | ×               | × | × | O | × | S                    |
| FMOV                       | DRm,@(disp:12,Rn) | ×               | × | × | × | O | D                    |

**Table 11.20 SH2A-FPU Executable Instruction and Operation Size Combinations  
(Part 2)**

| Arithmetic Operation Instructions |                 | Operation Sizes |   |   |   |   |                      |
|-----------------------------------|-----------------|-----------------|---|---|---|---|----------------------|
| Mnemonic                          | Addressing Mode | B               | W | L | S | D | Default when Omitted |
| FABS                              | DRn             | ×               | × | × | × | O | D                    |
| FADD                              | DRm,DRn         | ×               | × | × | × | O | D                    |
| FCMP/EQ                           | DRm,DRn         | ×               | × | × | × | O | D                    |
| FCMP/GT                           | DRm,DRn         | ×               | × | × | × | O | D                    |
| FDIV                              | DRm,DRn         | ×               | × | × | × | O | D                    |
| FMUL                              | DRm,DRn         | ×               | × | × | × | O | D                    |
| FNEG                              | DRn             | ×               | × | × | × | O | D                    |
| FSQRT                             | FRn             | ×               | × | × | O | × | S                    |
| FSQRT                             | DRn             | ×               | × | × | × | O | D                    |
| FSUB                              | DRm,DRn         | ×               | × | × | × | O | D                    |

**Table 11.20 SH2A-FPU Executable Instruction and Operation Size Combinations  
 (Part 3)**

| System Control Instructions |                 | Operation Sizes |   |   |   |   | Default when Omitted |
|-----------------------------|-----------------|-----------------|---|---|---|---|----------------------|
| Mnemonic                    | Addressing Mode | B               | W | L | S | D |                      |
| FCNVDS                      | DRm,FPUL        | ×               | × | × | × | ○ | D                    |
| FCNVSD                      | FPUL,DRn        | ×               | × | × | × | ○ | D                    |
| FLOAT                       | FPUL,DRn        | ×               | × | × | × | ○ | D                    |
| FSCHG                       | (no operands)   | ×               | × | × | × | × | —                    |
| FTRC                        | DRm,FPUL        | ×               | × | × | × | ○ | D                    |

## (2) Notes on Delayed Branch Instructions

The unconditional branch instructions are delayed branch instructions. The microprocessors execute the delay slot instruction (the instruction directly following a branch instruction in memory) before executing the delayed branch instruction.

If an instruction inappropriate for a delay slot is specified, the assembler issues error 150 or 151.

Table 11.21 shows the relationship between the delayed branch instructions and the delay slot instructions.

**Table 11.21 Relationship between Delayed Branch Instructions and Delay Slot Instructions**

| Delay Slot Instruction | Delayed Branch Instruction |      |      |      |     |     |     |     |     |     |    |
|------------------------|----------------------------|------|------|------|-----|-----|-----|-----|-----|-----|----|
|                        | BF/S                       | BT/S | BRAF | BSRF | BRA | BSR | JMP | JSR | RTS | RTE |    |
| BF                     | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| BT                     | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| BF/S                   | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| BT/S                   | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| BRAF                   | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| BSRF                   | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| BRA                    | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| BSR                    | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| JMP                    | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| JSR                    | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| JSR/N                  | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| RTS                    | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| RTS/N                  | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| RTE                    | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| RTV/N                  | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| TRAPA                  | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| DIVS                   | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| DIVU                   | ×                          | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   |    |
| LDC                    | Rn,SR                      | *1   | *1   | *1   | *1  | *1  | *1  | *1  | *1  | *1  | *1 |
|                        | @Rn+,SR                    | *1   | *1   | *1   | *1  | *1  | *1  | *1  | *1  | *1  | *1 |
| MOV                    | @(disp,PC),Rn              | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   | ×  |
|                        | symbol,Rn                  | ×    | ×    | ×    | ×   | ×   | ×   | ×   | ×   | ×   | ×  |

**Table 11.21 Relationship between Delayed Branch Instructions and Delay Slot Instructions (cont)**

| Delay Slot Instruction               |               | Delayed Branch Instruction |      |      |      |     |     |     |     |     |     |
|--------------------------------------|---------------|----------------------------|------|------|------|-----|-----|-----|-----|-----|-----|
|                                      |               | BF/S                       | BT/S | BRAF | BSRF | BRA | BSR | JMP | JSR | RTS | RTE |
| MOVA                                 | @(disp,PC),R0 | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
|                                      | symbol,R0     | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
| LDRS                                 | @(disp,PC)    | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
|                                      | symbol        | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
| LDRE                                 | @(disp,PC)    | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
|                                      | symbol        | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
| Extended instructions                | MOV.L #imm,Rn | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
|                                      | MOV.W #imm,Rn | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
|                                      | MOVA #imm,R0  | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
| 32-bit instructions*2                |               | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
| Register bank-related instructions*3 |               | x                          | x    | x    | x    | x   | x   | x   | x   | x   | x   |
| Any other instructions               |               | O                          | O    | O    | O    | O   | O   | O   | O   | O   | O   |

Symbol meanings:

O: Normal, i.e., the assembler generates the specified object code.

x: Error 150 or 151

The instruction specified is inappropriate as a delay slot instruction.

The assembler generates object code with a NOP instruction (H'0009).

Notes: 1. Operates normally when the CPU type is SH-1, SH-2, SH-2E, SH2-DSP, SH-2A, or SH2A-FPU.

Any other CPU type will cause error 150 or 151 to occur.

2. 32-bit instructions:

Instructions that accept a register-indirect address with 12-bit displacement or 20-bit immediate data as an operand: MOV120 and MOV120S instructions.

3. Register bank-related instructions: RESBANK, LDBANK, and STBANK instructions.

Note: If the delayed branch instruction and the delay slot instruction are coded in different sections, the assembler does not check the validity of the delay slot instruction.

(3) Notes on Address Calculations

When the operand addressing mode is PC relative with displacement, i.e.,  $@(disp,PC)$ , the value of PC must be taken into account in coding. The value of PC can vary depending on certain conditions.

(a) Normal Case

The value of PC is the first address in the currently executing instruction plus 4 bytes.

Example:

(Consider the state when a MOV instruction is being executed at absolute address H'00001000.)

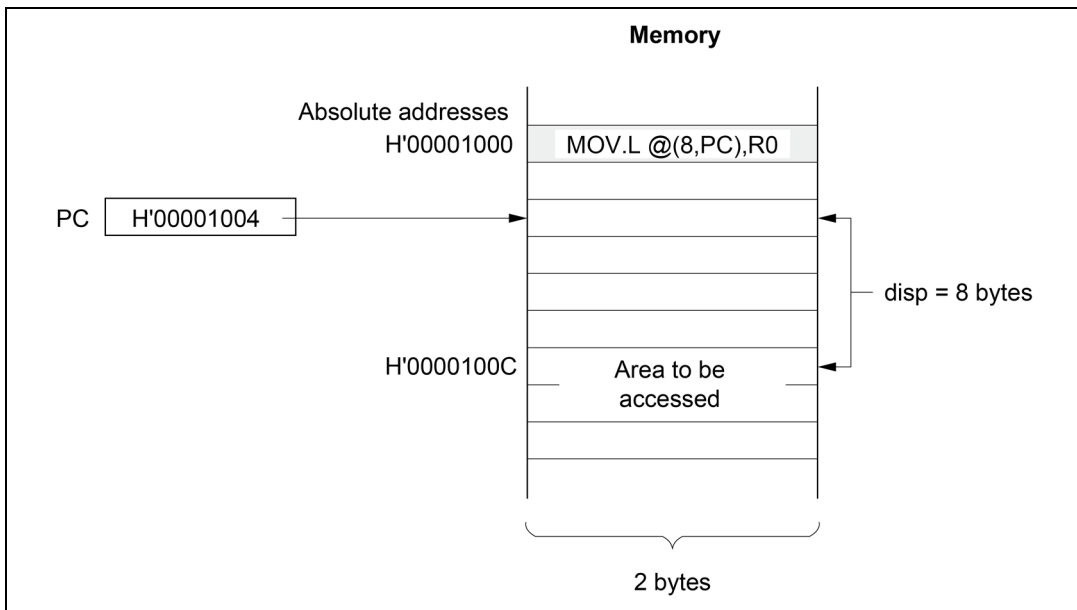


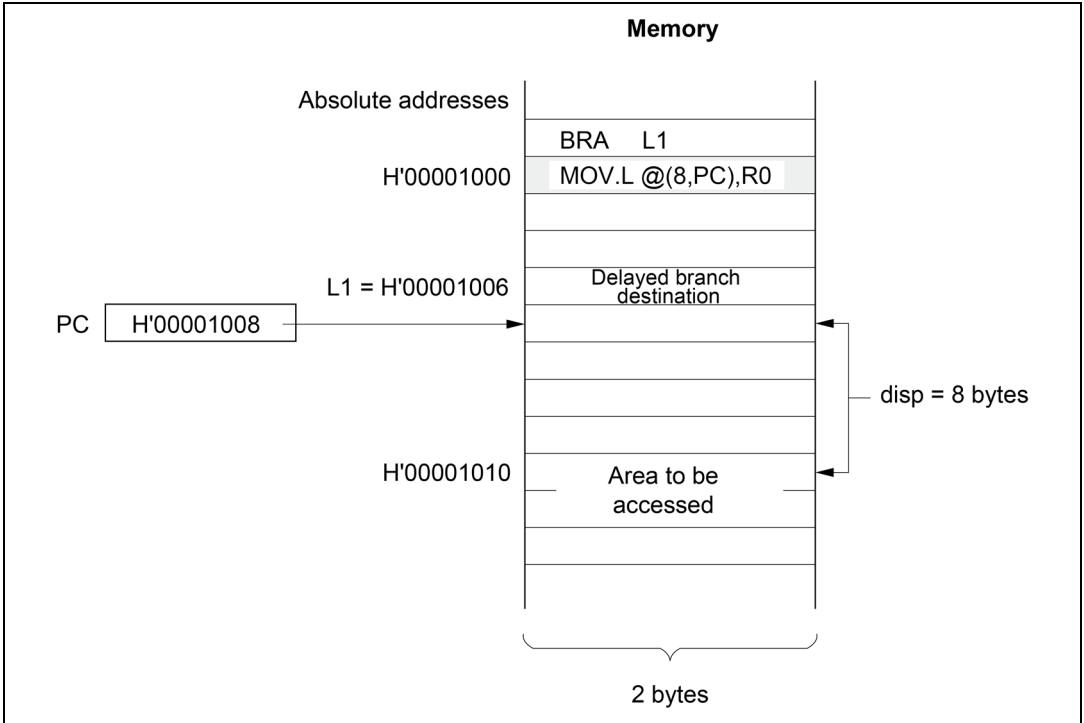
Figure 11.1 Address Calculation Example (Normal Case)

(b) During the Delay Slot Instruction

The value of PC is destination address for the delayed branch instruction plus 2 bytes.

Example:

(Consider the state when a MOV instruction is being executed at absolute address H'00001000.)



**Figure 11.2 Address Calculation Example (When the Value of PC Differs Due to a Branch)**

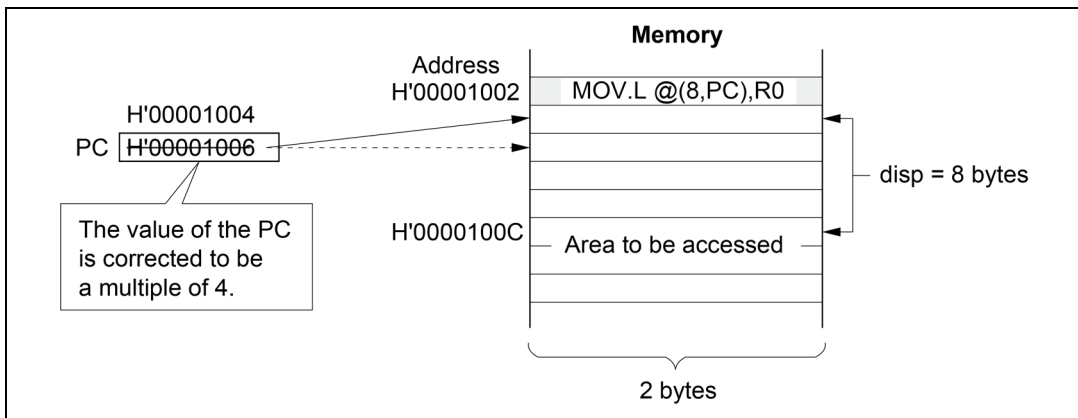
Supplement: When the operand is the PC relative specified with the symbol, the assembler derives the displacement taking account of the value of PC when generating the object code.

- (c) During the Execution of Either a `MOV.L @(disp,PC),Rn` or a `MOVA @(disp,PC),R0`  
 When the value of PC is not a multiple of 4, microprocessors correct the value by discarding the lower 2 bits when calculating addresses.

Example 1:

When the microprocessor corrects the value of PC

(Consider the state when a `MOV` instruction is being executed at address `H'00001002`.)

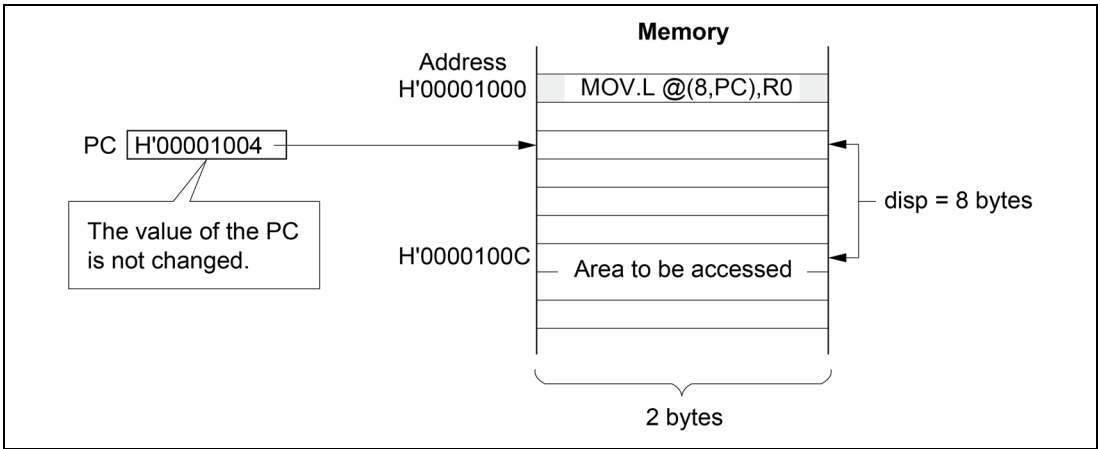


**Figure 11.3 Address Calculation Example (When Microprocessor Corrects the Value of PC)**



Example 2:

When the microprocessor does not correct the value of PC  
 (Consider the state when a MOV instruction is being executed at address H'00001000.)



**Figure 11.4 Address Calculation Example (When Microprocessor Does Not Correct the Value of PC)**

Supplement: When the operand is the PC relative specified with the symbol, the assembler derives the displacement taking account of the value of PC when generating the object code.

## 11.3 DSP Instructions

### 11.3.1 Program Contents

#### (1) Source Statements

The SH2-DSP, SH3-DSP, and SH4AL-DSP instructions are classified into two types: executable instructions and DSP instructions. The DSP instructions manipulate DSP registers. The instruction set and description format of DSP instructions are different from those of the executable instructions. For the DSP instructions, many operations can be included in one statement. The DSP instruction operation is as follows:

— DSP operation:

Specifies operations between DSP registers.

PABS, PADD, PADDC, PAND, PCLR, PCMP, PCOPY, PDEC, PDMSB, PINC, PLDS, PMULS, PNEG, POR, PRND, PSHA, PSHL, PSTS, PSUB, PSUBC, PSWAP, PXOR

— X data transfer operation:

Specifies data transfer between a DSP register and X data memory.

MOVX, NOPX

— Y data transfer operation:

Specifies data transfer between a DSP register and Y data memory.

MOVY, NOPY

— Single data transfer operation:

Specifies data transfer between a DSP register and memory.

MOVS

## (2) Parallel Operation Instructions

Parallel operation instructions specify DSP operations as well as data transfer between a DSP register and X or Y data memory at the same time. The instruction size is 32 bits. The description format is as follows:

[<label>][Δ<DSP operation part>][Δ<data transfer part>][<comment>]

### (a) DSP Operation Part Description Format:

[<condition>Δ]<DSP operation>Δ<operand>[Δ...]

- Condition:

Specifies how parallel operation instruction is executed as follows:

DCT: The instruction is executed when the DC bit is 1.

DCF: The instruction is executed when the DC bit is 0.

- DSP operation:

Specifies DSP operation.

PADD and PMULS, PCLR and PMULS, and PSUB and PMULS can be specified in combination.

### (b) Data Transfer Part Description Format:

[<X data transfer operation>[Δ<operand>]] [Δ<Y data transfer operation>[Δ<operand>]]

Be sure to specify X data transfer and Y data transfer in this order. Inputting an instruction is not required when the data move instruction is NOPX or NOPY.

### Example:

|                       |                                      |                                      |                         |
|-----------------------|--------------------------------------|--------------------------------------|-------------------------|
| <u>LABEL1:</u>        | <u>PADD A0,M0,A0 PMULS X0,Y0,M0</u>  | <u>MOVX.W @R4+,X0 MOVY.W @R6+,Y0</u> | <u>;DSP Instruction</u> |
| Label                 | DSP operation part                   | Data transfer part                   | Comment                 |
| <u>DCT PINC X1,A1</u> | <u>MOVX.W @R4,X0 MOVY.W @R6+, Y0</u> |                                      |                         |
| DSP operation part    | Data transfer part                   |                                      |                         |
| <u>PCMP X1, M0</u>    | <u>MOVX.W @R4, X0</u>                | <u>;Y Memory transfer is omitted</u> |                         |
| DSP operation part    | Data transfer part                   | Comment                              |                         |

## (3) Data Transfer Instructions

Two types of data move instructions are available: combination of X data memory transfer and Y data memory transfer, and single data transfer. The description formats are as follows:

## (a) Combination of X Data Memory Transfer and Y Data Memory Transfer Instructions:

```
[<label>][Δ<X data transfer operation>[Δ<operand>]]
[Δ<Y data transfer operation>[Δ<operand>]][<comment>]
```

Be sure to specify X data memory transfer and Y data memory transfer in this order.

Inputting an instruction is not required when the data move instruction is NOPX or NOPY.

Note that both X data memory and Y data memory cannot be omitted, unlike the parallel operation instruction.

Example:

```
LABEL2: MOVX.W @R4,X0 ;Data move instruction
 (Y data memory transfer is omitted)

 MOVX.W @R4,X0 MOVY.W @R6+, Y0
```

## (b) Single Data Transfer Instruction:

```
[<label>][Δ<single data transfer operation>Δ<operand>][<comment>]
```

Specifies the MOVS instruction.

Example:

```
LABEL3: MOVS.W @-R2,A0 ;Single data transfer
```

#### (4) Coding of Source Statements Across Multiple Lines

For the DSP instructions, many operations can be included in one statement, and therefore, source statements become long and complicated. To make programs easy to read, source statements for DSP instructions can be written across multiple lines by separating between an operand and an operation, in addition to separating at a comma between operands.

Write source statements across multiple lines using the following procedure.

- Insert a new line between an operand and an operation.
- Insert a plus sign (+) in the first column of the new line.
- Continue writing the source statement following the plus sign.

Spaces and tabs can be inserted following the plus sign.

Example:

```
 PADD A0,M0,X0
+
 PMULS A1,Y1,M0
+
 MOVX @R4,X0
+
 MOVY @R6,Y1
```

; A single source statement is written across four lines.

### 11.3.2 DSP Instructions

#### (1) DSP Operation Instructions

Table 11.22 lists DSP instructions in mnemonic.

**Table 11.22 DSP Instructions in Mnemonic**

| Specifications                        | Mnemonic                                                                                                                                               |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| DSP arithmetic operation instructions | PADD, PSUB, PCOPY, PDMSB, PINC, PNEG, PMULS, PADD, PSUB, PCOPY, PDMSB, PINC, PNEG, PMULS, PADD, PSUB, PCOPY, PDEC, PABS, PRND, PCLR, PLDS, PSTS, PSWAP |
| DSP logic operation instructions      | POR, PAND, PXOR                                                                                                                                        |
| DSP shift operation instructions      | PSHA, PSHL                                                                                                                                             |

#### (a) Operation Size:

For the DSP operation instructions, operation size cannot be specified.

#### (b) Addressing Mode:

Table 11.23 lists addressing modes for the DSP operation instructions.

**Table 11.23 Addressing Modes for DSP Operation Instructions**

| Addressing Mode     | Description Format     |
|---------------------|------------------------|
| DSP register direct | Dp (DSP register name) |
| Immediate data      | #imm                   |

- DSP register direct

Table 11.24 lists registers that can be specified in DSP register direct addressing mode.

For Sx, Sy, Dz, Du, Se, Sf, and Dg, refer to table 11.26, DSP Operation Instructions.

**Table 11.24 Registers that Can Be Specified in DSP Register Direct Addressing Mode**

|    |    | DSP Register |     |     |     |     |     |     |     |
|----|----|--------------|-----|-----|-----|-----|-----|-----|-----|
|    |    | A0           | A1  | M0  | M1  | X0  | X1  | Y0  | Y1  |
| Dp | Sx | Yes          | Yes |     |     | Yes | Yes |     |     |
|    | Sy |              |     | Yes | Yes |     |     | Yes | Yes |
|    | Dz | Yes          | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
|    | Du | Yes          | Yes |     |     | Yes |     | Yes |     |
|    | Se |              | Yes |     |     | Yes | Yes | Yes |     |
|    | Sf |              | Yes |     |     | Yes |     | Yes | Yes |
|    | Dg | Yes          | Yes | Yes | Yes |     |     |     |     |

- Immediate data

Immediate data can only be specified for the first operand of the PSHA and PSHL instructions. The following items can be specified:

— Value type

Constants, symbols, or expressions can be specified.

— Symbol type

Symbols including relative and externally defined symbols can be specified as immediate data.

— Value range

Table 11.25 lists the specifiable value ranges.

**Table 11.25 Ranges of Immediate Data**

| Immediate Data | Range                                |
|----------------|--------------------------------------|
| PSHA           | H'FFFFFFE0 to H'00000020 (−32 to 32) |
| PSHL           | H'FFFFFFF0 to H'00000010 (−16 to 16) |

## (c) Combination of Multiple DSP Operation Instructions:

The PADD instruction and the PMULS instruction, the PCLR instruction and the PMULS instruction, or the PSUB instruction and the PMULS instruction can be specified in combination. Each of these two combinations is basically one DSP instruction. The PADD, PCLR, or PSUB operand and a PMULS operand are separately described so that programs can be read easily.

Example:

```
PADD A0,M0,A0 PMULS X0,Y0,M0 NOPX MOVY.W @R6+,Y0
PCLR A1 PMULS X0,Y0,M0 NOPX MOVY.W @R6+,Y0
PSUB A1,M1,A1 PMULS X1,Y1,M1 MOVX @R4+,X0 NOPY
```

Note: Warning 701 is displayed if the same register is specified as the destination registers when multiple DSP operation instructions are specified in combination.

PADD A0,M0,A0 PMULS X0,Y0,A0 ; Warning 701 will occur.

## (d) Conditional DSP Operation Instructions:

Conditional DSP operation instructions specify if the program is executed according to the DC bit of the DSR register.

DCT: When the DC bit is 1, the instruction is executed.

DCF: When the DC bit is 0, the instruction is executed.

Conditional DSP operation instructions are the following:

PABS, PADD, PAND, PCLR, PCOPY, PDEC, PDMSB, PINC, PLDS, PNEG, POR, PRND, PSHA, PSHL, PSTS, PSUB, PSWAP, PXOR

## (e) DSP Operation Instruction List:

Table 11.26 lists DSP operation instructions for the SH2-DSP and SH3-DSP. Table 11.27 lists DSP operation instructions for the SH4AL-DSP added to those of the SH2-DSP and SH3-DSP. For the registers that can be specified as Sx, Sy, Dz, Du, Se, Sf, and Dg, refer to table 11.24, Registers that Can Be Specified in DSP Register Direct Addressing Mode.



**Table 11.26 DSP Operation Instructions**

| <b>Mnemonic</b> | <b>Addressing Mode</b> | <b>Mnemonic</b> | <b>Addressing Mode</b> |
|-----------------|------------------------|-----------------|------------------------|
| PABS            | Sx, Dz                 |                 |                        |
| PABS            | Sy, Dz                 |                 |                        |
| PADD            | Sx, Sy, Dz             |                 |                        |
| PADD            | Sx, Sy, Du             | PMULS           | Se, Sf, Dg             |
| PADDC           | Sx, Sy, Dz             |                 |                        |
| PAND            | Sx, Sy, Dz             |                 |                        |
| PCLR            | Dz                     |                 |                        |
| PCMP            | Sx, Sy                 |                 |                        |
| PCOPY           | Sx, Dz                 |                 |                        |
| PCOPY           | Sy, Dz                 |                 |                        |
| PDEC            | Sx, Dz                 |                 |                        |
| PDEC            | Sy, Dz                 |                 |                        |
| PDMSB           | Sx, Dz                 |                 |                        |
| PDMSB           | Sy, Dz                 |                 |                        |
| PINC            | Sx, Dz                 |                 |                        |
| PINC            | Sy, Dz                 |                 |                        |
| PLDS            | Dz, MACH               |                 |                        |
| PLDS            | Dz, MACL               |                 |                        |
| PMULS           | Se, Sf, Dg             |                 |                        |
| PNEG            | Sx, Dz                 |                 |                        |
| PNEG            | Sy, Dz                 |                 |                        |
| POR             | Sx, Sy, Dz             |                 |                        |
| PRND            | Sx, Dz                 |                 |                        |
| PRND            | Sy, Dz                 |                 |                        |
| PSHA            | #imm, Dz               |                 |                        |
| PSHA            | Sx, Sy, Dz             |                 |                        |
| PSHL            | #imm, Dz               |                 |                        |
| PSHL            | Sx, Sy, Dz             |                 |                        |
| PSTS            | MACH, Dz               |                 |                        |
| PSTS            | MACL, Dz               |                 |                        |

**Table 11.27 DSP Operation Instructions**

| <b>Mnemonic</b> | <b>Addressing Mode</b> | <b>Mnemonic</b> | <b>Addressing Mode</b> |
|-----------------|------------------------|-----------------|------------------------|
| PSUB            | Sx, Sy, Dz             |                 |                        |
| PSUB            | Sx, Sy, Du             | PMULS           | Se, Sf, Dg             |
| PSUBC           | Sx, Sy, Dz             |                 |                        |
| PXOR            | Sx, Sy, Dz             |                 |                        |
| PCLR            | Du                     | PMULS           | Se,Sf,Dg               |
| PSUB            | Sy,Sx,Dz               |                 |                        |
| PSWAP           | Sx,Dz                  |                 |                        |
| PSWAP           | Sy,Dz                  |                 |                        |

**(2) Data Transfer Instructions****(a) Mnemonics:**

Two types of data transfer instructions are available: dual memory transfer instructions and single memory transfer instructions.

Dual memory transfer instructions specify data transfer, at the same time, between X memory and a DSP register, and between Y memory and a DSP register.

Single memory transfer instructions specify data transfer between arbitrary memory and a DSP register. Table 11.28 lists data transfer instructions in mnemonic.

**Table 11.28 Data Transfer Instructions in Mnemonic**

| <b>Classification</b>  |                   | <b>Mnemonic</b> |
|------------------------|-------------------|-----------------|
| Dual memory transfer   | X memory transfer | NOPX<br>MOVX    |
|                        | Y memory transfer | NOPY<br>MOVY    |
| Single memory transfer |                   | MOVS            |

**(b) Operation Size:**

NOPX and NOPY instructions: Operation size cannot be specified.

MOVX and MOVY instructions: Word size (W) or longword size (L) can be specified. If omitted, word size is assumed.

MOVS instruction: Word size (W) or longword size (L) can be specified. If omitted, longword size is assumed.

(c) Addressing Mode:

Table 11.29 lists addressing modes that can be specified for the data transfer instructions.

**Table 11.29 Addressing Modes of Data Transfer Instructions**

| Addressing mode                             | Description |
|---------------------------------------------|-------------|
| DSP register direct                         | Dz          |
| Register indirect                           | @Az         |
| Register indirect with post-increment       | @Az+        |
| Register indirect with index/post-increment | @Az+Iz      |
| Register indirect with pre-decrement        | @-Az        |

Register indirect with index/post-increment is a special addressing mode for the DSP data transfer instructions. In this mode, after referring to the contents indicated by register Az, register Az contents are incremented by the value of the Iz register.

(d) Registers that Can Be Specified in Addressing Modes:

Table 11.30 lists registers that can be specified in the DSP register direct, register indirect, register indirect with post-increment, register indirect with index/post-increment, and register indirect with pre-decrement addressing modes. For Dx, Dy, Dxy, Ds, Da, Ax, Ax2, Ay, Ay2, As, Ix, Iy, and Is, refer to table 11.31, Data Transfer Instructions.

**Table 11.30 Registers that Can Be Specified in Addressing Modes for Data Transfer Instructions**

|    | General Registers |     |     |     |     |     |     |     |     | DSP Registers |     |     |     |     |     |     |     |     |     |     |     |
|----|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|    | R0                | R1  | R2  | R3  | R4  | R5  | R6  | R7  | R8  | R9            | A0  | A1  | M0  | M1  | X0  | X1  | Y0  | Y1  | A0G | A1G |     |
| Dz | Dx                |     |     |     |     |     |     |     |     |               |     |     |     |     |     | Yes | Yes |     |     |     |     |
|    | Dy                |     |     |     |     |     |     |     |     |               |     |     |     |     |     |     |     | Yes | Yes |     |     |
|    | Dxy               |     |     |     |     |     |     |     |     |               |     |     |     |     |     | Yes | Yes | Yes | Yes |     |     |
|    | Ds                |     |     |     |     |     |     |     |     |               | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
|    | Da                |     |     |     |     |     |     |     |     |               | Yes | Yes |     |     |     |     |     |     |     |     |     |
| Az | Ax                |     |     |     | Yes | Yes |     |     |     |               |     |     |     |     |     |     |     |     |     |     |     |
|    | Ax2               | Yes | Yes |     | Yes | Yes |     |     |     |               |     |     |     |     |     |     |     |     |     |     |     |
|    | Ay                |     |     |     |     |     | Yes | Yes |     |               |     |     |     |     |     |     |     |     |     |     |     |
|    | Ay2               |     |     | Yes | Yes |     | Yes | Yes |     |               |     |     |     |     |     |     |     |     |     |     |     |
|    | As                |     |     | Yes | Yes | Yes | Yes |     |     |               |     |     |     |     |     |     |     |     |     |     |     |
| Iz | Ix                |     |     |     |     |     |     |     | Yes |               |     |     |     |     |     |     |     |     |     |     |     |
|    | Iy                |     |     |     |     |     |     |     |     | Yes           |     |     |     |     |     |     |     |     |     |     |     |
|    | Is                |     |     |     |     |     |     |     |     | Yes           |     |     |     |     |     |     |     |     |     |     |     |

Note: Warning 703 is displayed if the destination register for the DSP instruction and the destination register for the data transfer instruction are the same register in the same statement.

Example:

```
PADD A0,M0,Y0 NOPX MOVY.W @R6+,Y0 → Warning 703
```

(e) Data Transfer Instruction List:

Table 11.31 lists data transfer instructions for the SH2-DSP and SH3-DSP. Table 11.32 lists data transfer instructions for the SH4AL-DSP added to those of the SH2-DSP and SH3-DSP. For registers that can be specified for Dx, Dy, Dxy, Ds, Da, Ax, Ax2, Ay, Ay2, As, Ix, Iy, and Is, refer to table 11.30, Registers that Can Be Specified in Addressing Modes for Data Transfer Instructions.

**Table 11.31 Data Transfer Instructions**

| <b>Classification</b>             | <b>Mnemonic</b> | <b>Addressing Mode</b> |
|-----------------------------------|-----------------|------------------------|
| X data transfer instructions      | NOPX            |                        |
|                                   | MOVX.W          | @Ax, Dx                |
|                                   | MOVX.W          | @Ax+, Dx               |
|                                   | MOVX.W          | @Ax+lx, Dx             |
|                                   | MOVX.W          | Da, @Ax                |
|                                   | MOVX.W          | Da, @Ax+               |
|                                   | MOVX.W          | Da, @Ax+lx             |
| Y data transfer instructions      | NOPY            |                        |
|                                   | MOVY.W          | @Ay, Dy                |
|                                   | MOVY.W          | @Ay+, Dy               |
|                                   | MOVY.W          | @Ay+ly, Dy             |
|                                   | MOVY.W          | Da, @Ay                |
|                                   | MOVY.W          | Da, @Ay+               |
|                                   | MOVY.W          | Da, @Ay+ly             |
| Single data transfer instructions | MOVS.W          | @-As, Ds               |
|                                   | MOVS.W          | @As, Ds                |
|                                   | MOVS.W          | @As+, Ds               |
|                                   | MOVS.W          | @As+ls, Ds             |
|                                   | MOVS.W          | Ds, @-As               |
|                                   | MOVS.W          | Ds, @As                |
|                                   | MOVS.W          | Ds, @As+               |
|                                   | MOVS.W          | Ds, @As+ls             |
|                                   | MOVS.L          | @-As, Ds               |
|                                   | MOVS.L          | @As, Ds                |
|                                   | MOVS.L          | @As+, Ds               |
|                                   | MOVS.L          | @As+ls, Ds             |
|                                   | MOVS.L          | Ds, @-As               |
|                                   | MOVS.L          | Ds, @As                |
|                                   | MOVS.L          | Ds, @As+               |
|                                   | MOVS.L          | Ds, @As+ls             |

**Table 11.32 Data Transfer Instructions**

| <b>Classification</b>        | <b>Mnemonic</b> | <b>Addressing Mode</b> |
|------------------------------|-----------------|------------------------|
| X data transfer instructions | MOVX.W          | @Ax2,Dxy               |
|                              | MOVX.W          | @Ax2+,Dxy              |
|                              | MOVX.W          | @Ax2+R8,Dxy            |
|                              | MOVX.L          | @Ax2,Dxy               |
|                              | MOVX.L          | @Ax2+,Dxy              |
|                              | MOVX.L          | @Ax2+R8,Dxy            |
| Y data transfer instructions | MOVY.W          | @Ay2,Dxy               |
|                              | MOVY.W          | @Ay2+,Dxy              |
|                              | MOVY.W          | @Ay2+R9,Dxy            |
|                              | MOVY.L          | @Ay2,Dxy               |
|                              | MOVY.L          | @Ay2+,Dxy              |
|                              | MOVY.L          | @Ay2+R9,Dxy            |

## 11.4 Assembler Directives

The assembler directives are instructions that the assembler interprets and executes. The underlines indicate the default. Table 11.33 lists the assembler directives provided by this assembler.

**Table 11.33 Assembler Directives**

| Type                             | Mnemonic                                                  | Function                                                                              |
|----------------------------------|-----------------------------------------------------------|---------------------------------------------------------------------------------------|
| Target CPU                       | .CPU                                                      | Specifies the target CPU.                                                             |
| Section and the location counter | .SECTION                                                  | Declares a section.                                                                   |
|                                  | .ORG                                                      | Sets the value of the location counter.                                               |
|                                  | .ALIGN                                                    | Corrects the value of the location counter to a multiple of boundary alignment value. |
| Symbols                          | .EQU                                                      | Sets a symbol value.                                                                  |
|                                  | .ASSIGN                                                   | Sets or resets a symbol value.                                                        |
|                                  | .REG                                                      | Defines the alias of a register name.                                                 |
|                                  | .FREG                                                     | Defines a floating-point register name.                                               |
| Data and data area reservation   | .DATA                                                     | Reserves integer data.                                                                |
|                                  | .DATAB                                                    | Reserves an integer data block.                                                       |
|                                  | .SDATA                                                    | Reserves string literal data.                                                         |
|                                  | .SDATAB                                                   | Reserves a string literal data block.                                                 |
|                                  | .SDATAC                                                   | Reserves string literal data (with length).                                           |
|                                  | .SDATAZ                                                   | Reserves string literal data (with zero terminator).                                  |
|                                  | .FDATA                                                    | Reserves floating-point data.                                                         |
|                                  | .FDATAB                                                   | Reserves a floating-point data block.                                                 |
|                                  | .XDATA                                                    | Reserves fixed-point data.                                                            |
|                                  | .RES                                                      | Reserves data area.                                                                   |
|                                  | .SRES                                                     | Reserves string literal data area.                                                    |
|                                  | .SRESC                                                    | Reserves string literal data area (with length).                                      |
| .SRESZ                           | Reserves string literal data area (with zero terminator). |                                                                                       |
|                                  | .FRES                                                     | Reserves floating-point data area.                                                    |

**Table 11.33 Assembler Directives (cont)**

| <b>Type</b>                                         | <b>Mnemonic</b> | <b>Function</b>                                                                    |
|-----------------------------------------------------|-----------------|------------------------------------------------------------------------------------|
| Externally defined and externally referenced symbol | .EXPORT         | Declares externally defined symbols.                                               |
|                                                     | .IMPORT         | Declares externally referenced symbols.                                            |
|                                                     | .GLOBAL         | Declares externally defined and externally referenced symbols.                     |
| Object modules                                      | .OUTPUT         | Controls object module and debugging information output.                           |
|                                                     | .DEBUG          | Controls the output of symbolic debugging information.                             |
|                                                     | .ENDIAN         | Selects big endian or little endian.                                               |
|                                                     | .LINE           | Changes line number.                                                               |
| Assemble listing                                    | .PRINT          | Controls assemble listing output.                                                  |
|                                                     | .LIST           | Controls the output of the source program listing.                                 |
|                                                     | .FORM           | Sets the number of lines and columns in the assemble listing.                      |
|                                                     | .HEADING        | Sets the header for the source program listing.                                    |
|                                                     | .PAGE           | Inserts a new page in the source program listing.                                  |
|                                                     | .SPACE          | Outputs blank lines to the source program listing.                                 |
| Other directives                                    | .PROGRAM        | Sets the name of the object module.                                                |
|                                                     | .RADIX          | Sets the radix in which integer constants with no radix specifier are interpreted. |
|                                                     | .END            | Specifies an entry point and the end of the source program.                        |
|                                                     | .STACK          | Defines the stack value for the specified symbol.                                  |

Note: .FILE is only used as a descriptor for assembly source code that is output by the compiler, and is only valid for such code. Do not use .FILE in your own assembly programs.



**.CPU**

Description Format:  $\Delta$ .CPU $\Delta$ <target CPU>

| Specification | Target CPU                      |
|---------------|---------------------------------|
| SH1           | Assembles program for SH-1      |
| SH2           | Assembles program for SH-2      |
| SH2E          | Assembles program for SH-2E     |
| SH2A          | Assembles program for SH-2A     |
| SH2AFPU       | Assembles program for SH2A-FPU  |
| SHDSP         | Assembles program for SH2-DSP   |
| SH3           | Assembles program for SH-3      |
| SH3DSP        | Assembles program for SH3-DSP   |
| SH4           | Assembles program for SH-4      |
| SH4A          | Assembles program for SH-4A     |
| SH4ALDSP      | Assembles program for SH4AL-DSP |

The label field is not used.

Description: .CPU specifies the target CPU for which the source program is assembled.

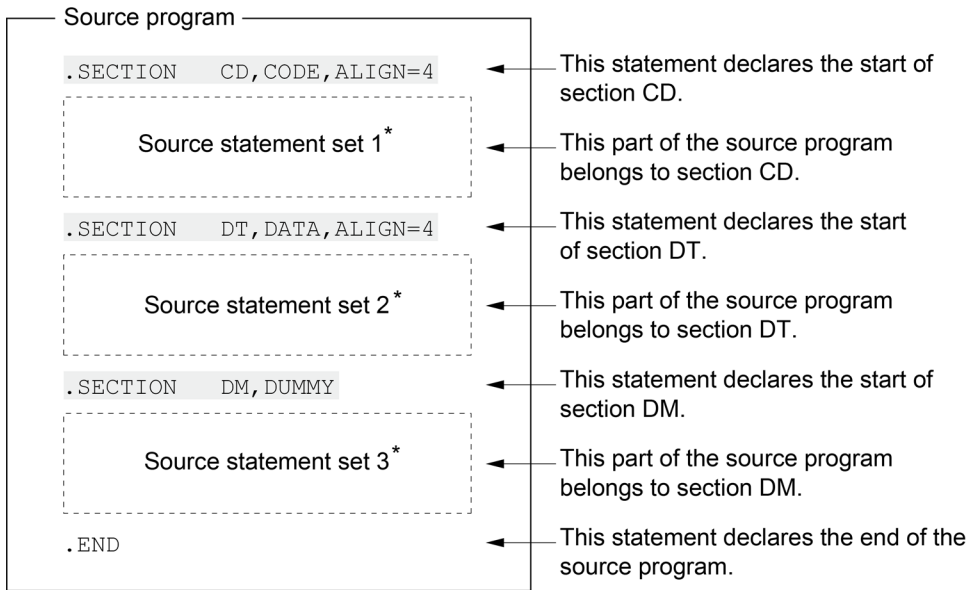
Specify this directive at the beginning of the source program. If it is not specified at the beginning, an error will occur. However, directives related to assembly listing can be written before this directive.

When several .CPUs are specified, only the first specification becomes valid.

The assembler gives priority to target CPU specification in the order of **cpu** option, .CPU, and the SHCPU environment variable.

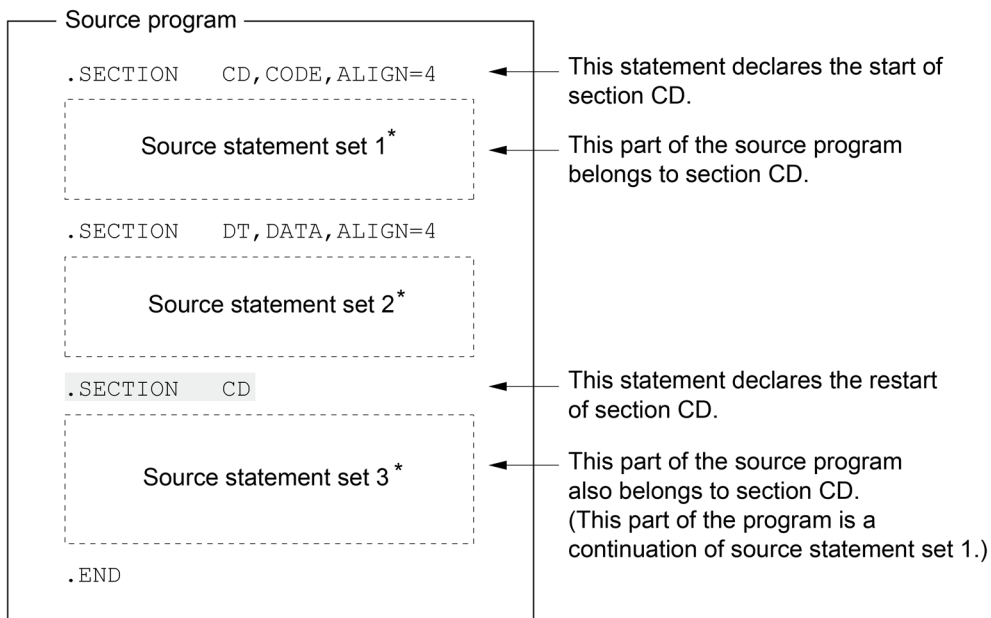
If the directive is not specified, the CPU selected by the environment variable SHCPU becomes valid.





Note: This example assumes that the `.SECTION` directive does not appear in any of the source statement sets 1 to 3.

It is possible to redeclare (and thus restart,) a section that was previously declared in the same file. The following is a simple example of section restart.



Note: This example assumes that the `.SECTION` directive does not appear in any of the source statement sets 1 to 3.

When using `.SECTION` to restart a section, the second and third operands must be omitted. (The original specifications when first declaring the section remain valid.)

Use `LOCATE = <start address>` as the third operand when starting an absolute address section. The start address is the absolute address of the start of that section.

The symbol value must be specified as follows:

- The specification must be a constant value, and
- Forward reference symbols must not appear in the specification.

The values allowed for the start address are from `H'00000000` to `H'FFFFFFF`. (From 0 to 4,294,967,295 in decimal.)

Use `ALIGN = <boundary alignment value>` to start a relative address section. The optimizing linkage editor will adjust the start address of the section to be the multiple of the boundary alignment value.

The boundary alignment value must be specified as follows:

- The specification must be a constant value, and
- Forward reference symbols must not appear in the specification.

The values allowed for the boundary alignment value are powers of 2, e.g. 2<sup>0</sup>, 2<sup>1</sup>, 2<sup>2</sup>, ..., 2<sup>31</sup>. For code sections, the values must be 4 or larger powers of 2, e.g. 2<sup>2</sup>, 2<sup>3</sup>, 2<sup>4</sup>, ..., 2<sup>31</sup>.

The assembler provides a default section for the following cases:

- The use of executable, extended, or DSP instructions when no section has been declared.
- The use of data reservation assembler directives when no section has been declared.
- The use of .ALIGN when no section has been declared.
- The use of .ORG when no section has been declared.
- Reference to the location counter when no section has been declared.
- The use of statements consisting of only the label field when no section has been declared.

The default section is the following section:

- Section name: P
- Section type: Code section  
Relative address section (with a boundary alignment value of 4)

Example:

```

 .ALIGN 4 ; This section of the program belongs to the default section P.
 .DATA.L H'11111111 ; The default section P is a code section, and is a relative
        ~~~~~~                    ; address section with a boundary alignment value of 4.

        .SECTION   CD, CODE, ALIGN=4

        MOV       R0, R1           ; This section of the program belongs to the section CD.
        MOV       R0, R2           ; The section CD is a code section, and is a relative
        ~~~~~~                    ; section with a boundary alignment value of 4.

 .SECTION DT, DATA, LOCATE=H'00001000

X1: .DATA.L H'22222222 ; This section of the program belongs to the section DT.
 .DATA.L H'33333333 ; The section DT is a data section, and is an absolute address
        ~~~~~~                    ; section with a start address of H'00001000.

        .END
    
```

Note: This example assumes .SECTION does not appear in the parts indicated by "~~~~".

## .ORG

Description Format:  $\Delta$ .ORG $\Delta$ <location-counter value>

The label field is not used.

Description: .ORG sets the value of the location counter. .ORG is used to place executable instructions or data at a specific address.

The location-counter value must be specified as follows:

- The specification must be a constant value or an address within the section, and,
- Forward reference symbols must not appear in the specification.

The values allowed for the location-counter value are from H'00000000 to H'FFFFFFF. (From 0 to 4,294,967,295 in decimal.)

When the location-counter value is specified with an absolute address value, the following condition must be satisfied:

<location-counter value>  $\geq$  <section start address> (when compared as unsigned values)

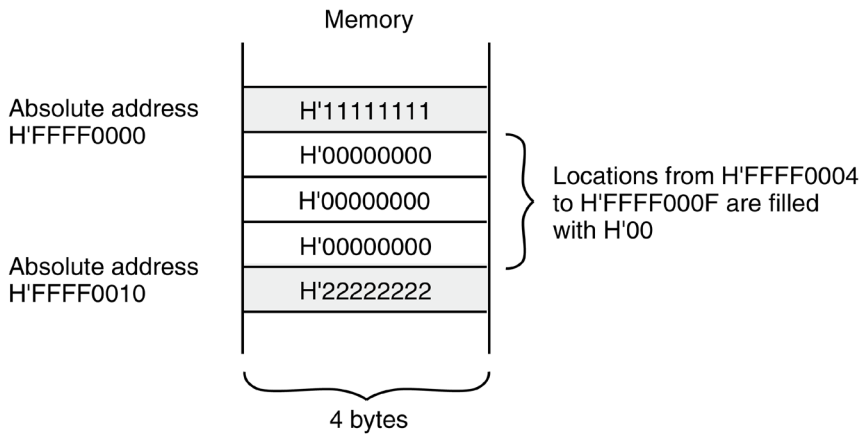
The assembler handles the value of the location counter as follows:

- An absolute address value within an absolute address section.
- A relative address value (relative distance from the section head) within a relative address section.

Example:     .SECTION DT,DATA,LOCATE=H'FFFF0000  
              .DATA.L H'11111111  
              .ORG H'FFFF0010 ; This statement sets the value of the location  
                                  ; counter.  
              .DATA.L H'22222222 ; The integer data H'22222222 is stored at  
                                  ; absolute address H'FFFF0010.

~

Explanatory Figure for the Coding Example



**.ALIGN**

Description Format:  $\Delta$ .ALIGN $\Delta$ <boundary alignment value>

The label field is not used.

Description: .ALIGN corrects the location-counter value to be a multiple of the boundary alignment value. Executable instructions and data can be allocated on specific boundary values (address multiples) by using .ALIGN.

The location counter value must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

The values allowed for the boundary alignment value are powers of 2, e.g.  $2^0, 2^1, 2^2, \dots, 2^{31}$ .

When .ALIGN is used in a relative section the following must be satisfied:

Boundary alignment value specified by .SECTION  $\geq$  Boundary alignment value specified by .ALIGN

When .ALIGN is used in a code or data section, the assembler inserts NOP instructions in the object code\* to adjust the value of the location counter. Odd byte size areas are filled with H'09.

Note: This object code is not displayed in the assemble listing.



```

Example: .SECTION P,CODE,ALIGN=4
         .DATA.B H'11
         .DATA.B H'22
         .DATA.B H'33

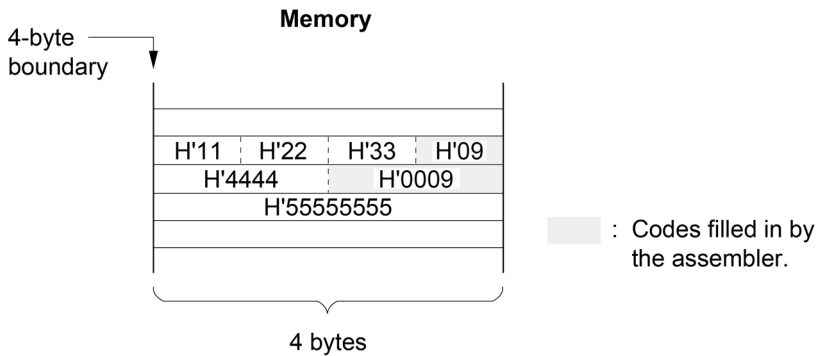
         .ALIGN 2 ; This statement adjusts the value of the location
         .DATA.W H'4444 ; counter to be a multiple of 2.

         .ALIGN 4 ; This statement adjusts the value of the location
         .DATA.L H'55555555 ; counter to be a multiple of 4.

         ~
    
```

Explanatory Figure for the Coding Example

This example assumes that the byte-sized integer data H'11 is originally located at the 4-byte boundary address. The assembler will insert the filler data as shown in the figure below.



**.EQU**

Description Format: <symbol>[:] $\Delta$ .EQU $\Delta$ <symbol value>

## Description:

.EQU sets a value to a symbol.

Symbols defined with .EQU cannot be redefined.

The symbol value must be specified as follows:

- The specification must be a constant value, an address value, or an externally referenced symbol value\* and,
- Forward reference symbols must not appear in the specification.

The values allowed for the symbol value are from H'00000000 to H'FFFFFFF.

(From -2,147,483,648 to 4,294,967,295 in decimal.)

Note: An externally referenced symbol, externally referenced symbol + constant, or externally referenced symbol – constant can be specified.

## Example:

~

X1: **.EQU** 10 ;The value 10 is set to X1.

X2: **.EQU** 20 ;The value 20 is set to X2.

CMP/EQ #X1,R0 ;This is the same as CMP/EQ #10,R0.

BT LABEL1

CMP/EQ #X2,R0 ;This is the same as CMP/EQ #20,R0.

BT LABEL2

~

**.ASSIGN**

Description Format: <symbol>[:]Δ.ASSIGNΔ<symbol value>

Description:

.ASSIGN sets a value to a symbol.

Symbols defined with .ASSIGN can be redefined with .ASSIGN.

The symbol value must be specified as follows:

- The specification must be a constant value or an address value, and,
- Forward reference symbols must not appear in the specification.

The values allowed for the symbol value are from H'00000000 to H'FFFFFFF. (From -2,147,483,648 to 4,294,967,295 in decimal.)

Definitions with .ASSIGN are valid from the point of the definition forward in the program.

Symbols defined with .ASSIGN have the following limitations:

- They cannot be used as externally defined or externally referenced symbols.
- They cannot be referenced from the debugger.

Example:

```

~

X1: .ASSIGN 1
X2: .ASSIGN 2
    CMP/EQ #X1,R0      ;This is the same as CMP/EQ #1,R0.
    BT LABEL1
    CMP/EQ #X2,R0      ;This is the same as CMP/EQ #2,R0.
    BT LABEL2

~

X1: .ASSIGN 3
X2: .ASSIGN 4
    CMP/EQ #X1,R0      ; This is the same as CMP/EQ #3,R0.
    BT LABEL3
    CMP/EQ #X2,R0      ; This is the same as CMP/EQ #4,R0.
    BF LABEL4

~
    
```

**.REG**

Description Format: <symbol>[:]Δ.REGΔ<register name>  
 or  
 <symbol>[:]Δ.REGΔ(<register name>)

Description: .REG defines the alias of a register name.  
 The alias of a register name defined with .REG can be used in exactly the same manner as the original register name.  
 The alias of a register name defined with .REG cannot be redefined.  
 The alias of a register name can only be defined for the general registers (R0 to R15, and SP).  
 Definitions with .REG are valid from the point of the definition forward in the program.  
 Symbols defined with .REG have the following limitations:  
 They cannot be used as externally referenced or externally defined symbols.

Example:

```

~
MIN: .REG    R10
MAX: .REG    R11
MOV    #0,MIN ;This is the same as MOV #1,R10.
MOV    #99,MAX ;This is the same as MOV #99,R11.

CMP/HS MIN,R1
BF     LABEL
CMP/HS R1,MAX
BF     LABEL

~

```

**.FREG**

Description Format: <symbol>[:]Δ.FREGΔ<floating-point register name>  
 or  
 <symbol>[:]Δ.FREGΔ(<floating-point register name>)

Description: .FREG defines the alias of a floating-point register name.  
 The alias of a floating-point register name defined with .FREG can be used in exactly the same manner as the original register name.  
 The alias of a floating-point register name defined with .FREG cannot be redefined.  
 The alias can only be defined for the floating-point registers FRm (m = 0 to 15), DRn (n = 0, 2, 4, 6, 8, 10, 12, 14), XDn (n = 0, 2, 4, 6, 8, 10, 12, 14), and FVi (i = 0, 4, 8, 12).  
 Definitions with the .FREG are valid from the point of the definition forward in the program.  
 Symbols defined with .FREG have the following limitations:  
 They cannot be used as externally referenced or externally defined symbols.  
 .FREG is valid only when SH2E, SH4, SH4A, or SH2AFPU is selected as the CPU type.

Example:

```

~
MAX: .FREG    FR11
      FMOV    FR1,MAX ; This is the same as
                       ; FMOV FR1,FR11.

      FCMP/EQ MAX,FR2 ; This is the same as
                       ; FCMP/EQ FR11,FR2.

      BF      LABEL

~
    
```

**.DATA**

Description Format: [<symbol>[:]] $\Delta$ .[<operation size>] $\Delta$ <integer data>[,...]

<operation size>: { B | W | L }

Description:

.DATA reserves integer data in memory.

The specifier determines the size of the reserved data.

The longword size is used when the operation size is omitted.

Arbitrary values, including relative values, forward referenced symbols and externally referenced symbols, can be used to specify the integer data.

The operation size and the range of integer data are as follows:

| <b>Operation Size</b>        | <b>Integer Data Range*</b> |                        |
|------------------------------|----------------------------|------------------------|
| B (Byte)                     | H'00000000 to H'000000FF   | (0 to 255)             |
|                              | H'FFFFFF80 to H'FFFFFFF    | (-128 to -1)           |
| W (Word, 2 bytes)            | H'00000000 to H'0000FFFF   | (0 to 65,535)          |
|                              | H'FFF8000 to H'FFFFFFF     | (-32,768 to -1)        |
| <u>L</u> (Longword, 4 bytes) | H'00000000 to H'7FFFFFFF   | (0 to 4,294,967,295)   |
|                              | H'80000000 to H'FFFFFFF    | (-2,147,483,648 to -1) |

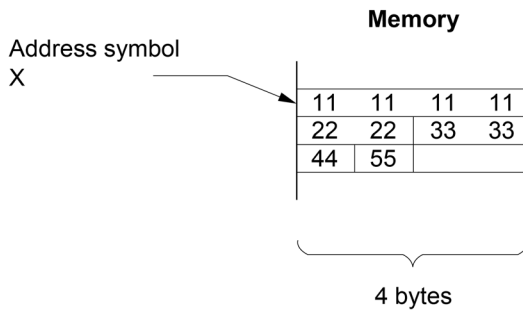
Note: Numbers in parentheses are decimal.

Example:

```

~
      .ALIGN 4
X:    .DATA.L H'11111111 ;
      .DATA.W H'2222,H'3333; These statements reserve integer
                                ; data.
      .DATA.B H'44,H'55 ;
~
    
```

Explanatory Figure for the Coding Example



Note: The data in this figure is hexadecimal.

**.DATAB**

Description Format: [`<symbol>[:]`]`Δ.DATAB[.<operation range>]Δ<block count>,<integer data>`

`<operation size>`: { B | W | L }

Description: .DATAB reserves the specified number of integer data items consecutively in memory.

The operation size determines the size of the reserved data.

The longword size is used when the operation size is omitted.

The block count must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

Arbitrary values, including relative values forward reference symbols, and externally referenced symbols, can be used to specify the integer data.

The operation size and the range of block size are as follows:

| Operation Size               | Block Size Range*                             |
|------------------------------|-----------------------------------------------|
| B (Byte)                     | H'00000001 to H'FFFFFFFF (1 to 4,294,967,295) |
| W (Word, 2 bytes)            | H'00000001 to H'7FFFFFFF (1 to 2,147,483,647) |
| <u>L</u> (Longword, 4 bytes) | H'00000001 to H'3FFFFFFF (1 to 1,073,741,823) |

| Operation Size | Integer Data Range*                                                                             |
|----------------|-------------------------------------------------------------------------------------------------|
| B              | H'00000000 to H'000000FF (0 to 255)<br>H'FFFFFFF80 to H'FFFFFFF (–128 to –1)                    |
| W              | H'00000000 to H'0000FFFF (0 to 65,535)<br>H'FFFFF8000 to H'FFFFFFF (–32,768 to –1)              |
| <u>L</u>       | H'00000000 to H'7FFFFFFF (0 to 4,294,967,295)<br>H'80000000 to H'FFFFFFF (–2,147,483,648 to –1) |

Note: Numbers in parentheses are decimal.

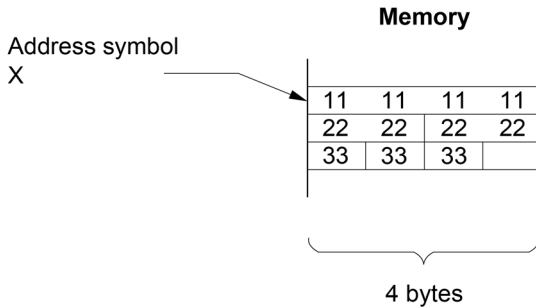


Example:

```

~
        .ALIGN      4
X:      .DATAB.L   1,H'11111111 ;
        .DATAB.W   2,H'2222     ; This statement reserves two blocks
        .DATAB.B   3,H'33       ; of integer data.
~
    
```

Explanatory Figure for the Coding Example



Note: The data in this figure is hexadecimal.

**.SDATA**

Description Format: [<symbol>[:]]Δ.SDATAΔ"<string literal>"[,...]

Description: .SDATA reserves string literal data in memory.  
A control character can be appended to a string literal.  
The syntax for this notation is as follows:

"<string literal>"<ASCII code for a control character>

The ASCII code for a control character must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

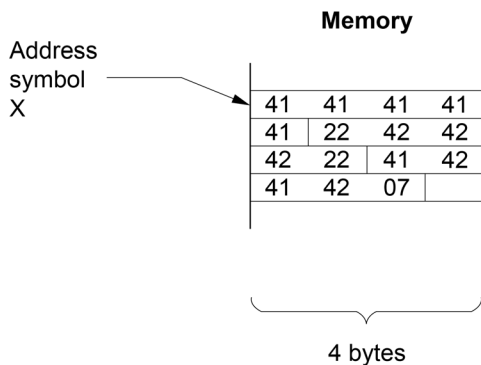
Example: ~

```

.ALIGN      4
X: .SDATA   "AAAAA"      ; This statement reserves string
                                ; literal data.
     .SDATA   """"BBB"""" ; The string literal in this example
                                ; includes double quotation marks.
     .SDATA   "ABAB"<H'07> ; The string literal in this example
                                ; has a control character appended.
  
```

~

Explanatory Figure for the Coding Example



- Notes: 1. The data in this figure is hexadecimal.
2. The ASCII code for "A" is: H'41.  
The ASCII code for "B" is: H'42.  
The ASCII code for "" is: H'22.

## .SDATAB

Description Format: [<symbol>[:]]Δ.SDATABΔ<block count>,"<string literal>"

Description: .SDATAB reserves the specified number of string literals consecutively in memory.

The <block count> must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

A value of 1 or larger must be specified as the block count.

The maximum value of the block count depends on the length of the string literal data.

(The length of the string literal data multiplied by the block count must be less than or equal to H'FFFFFFFF (4,294,967,295) bytes.)

A control character can be appended to a string literal.

The syntax for this notation is as follows:

|                                                        |
|--------------------------------------------------------|
| "<string literal>"<ASCII code for a control character> |
|--------------------------------------------------------|

The ASCII code for a control character must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

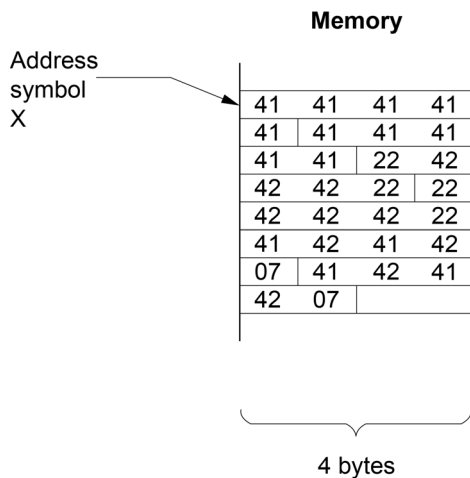
Example:

```

~
.ALIGN      4
X:
.SDATAB    2,"AAAAA"      ; This statement reserves two
                          ; string literal data blocks.
.SDATAB    2,"""BBB""""   ; The string literal in this
                          ; example includes double quotation
                          ; marks.
.SDATAB    2,"ABAB"<H'07> ; The string literal in this
                          ; example has a control character
                          ; appended.
~

```

Explanatory Figure for the Coding Example



- Notes: 1. The data in this figure is hexadecimal.
2. The ASCII code for "A" is: H'41.  
The ASCII code for "B" is: H'42.  
The ASCII code for "" is: H'22.

## .SDATAC

Description Format: [<symbol>[:]]Δ.SDATACΔ"<string literal>"[,...]

Description: .SDATAC reserves string literal data (with length) in memory.  
A string literal with length is a string literal with an inserted leading byte that indicates the length of the string.  
The length indicates the size of the string literal (not including the length) in bytes.  
A control character can be appended to a string literal.  
The syntax for this notation is as follows:

|                                  |
|----------------------------------|
| "<string literal>"<control code> |
|----------------------------------|

The ASCII code for a control character must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

Example:

~

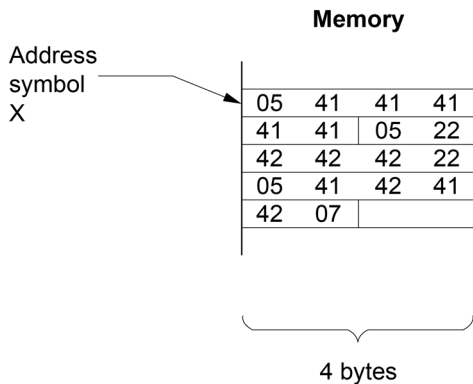
```

.ALIGN 4
X:
.SDATAAC      "AAAAA" ; This statement reserves character
                ; string data (with length).
.SDATAAC      """"BBB"""" ; The string literal in this example
                ; includes double quotation marks.
.SDATAAC      "ABAB"<H'07>; The string literal in this example
                ; has a control character appended.

```

~

Explanatory Figure for the Coding Example



Notes: 1. The data in this figure is hexadecimal.

2. The ASCII code for "A" is: H'41.  
 The ASCII code for "B" is: H'42.  
 The ASCII code for "" is: H'22.

## .SDATAZ

Description Format: [<symbol>[:]]Δ.SDATAZΔ"<string literal>"[,...]

Description: .SDATAZ reserves string literal data (with zero terminator) in memory. A string literal with zero terminator is a string literal with an appended trailing byte (with the value H'00) that indicates the end of the string. A control character can be appended to a string literal. The syntax for this notation is as follows:

|                                                        |
|--------------------------------------------------------|
| "<string literal>"<ASCII code for a control character> |
|--------------------------------------------------------|

The ASCII code for a control character must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

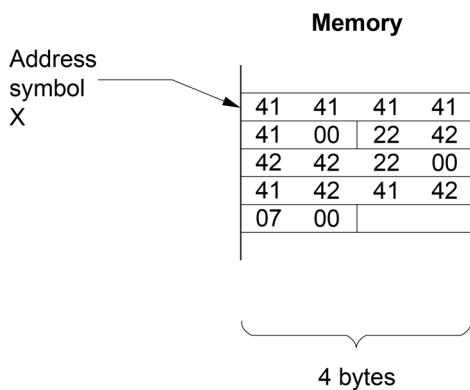
Example: ~

```
.ALIGN 4

X: .SDATAZ "AAAAA" ; This statement reserves character
; string data (with zero terminator).
.SDATAZ """"BBB"""" ; The string literal in this example
; includes double quotation marks.
.SDATAZ "ABAB"<H'07> ; The string literal in this example
; has a control character appended.
```

~

Explanatory Figure for the Coding Example



Notes: 1. The data in this figure is hexadecimal.

2. The ASCII code for "A" is: H'41.  
The ASCII code for "B" is: H'42.  
The ASCII code for "" is: H'22.



## **.FDATA**

Description Format: [<symbol>[:]]Δ.FDATA[.<operation size>]Δ<floating-point data>[,...]

<operation size>: { S | D }

Description: .FDATA reserves floating-point data in memory.  
The operation size determines the size of the reserved data.  
Single precision is used when the operation size is omitted.  
Operation size is as follows:

| <b>Operation Size</b> | <b>Data Size</b>           |
|-----------------------|----------------------------|
| <u>S</u>              | Single precision (4 bytes) |
| D                     | Double precision (8 bytes) |

Example: ~

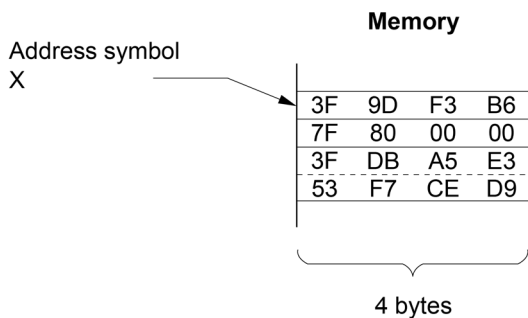
```

.ALIGN      4
X:  .FDATA.S  F'1.234          ; This statement reserves a 4-byte
    ; area 3F9DF3B6 (F'1.234S).
    .FDATA.S  H'7F800000.S   ; This statement reserves a 4-byte
    ; area 7F800000 (H'7F800000.S).
    .FDATA.D  F'4.32D-1     ; This statement reserves an 8-byte
    ; area 3FDBA5E353F7CED9
    ; (F'4.32D-1).

```

~

Explanatory Figure for the Coding Example



**.FDATAB**

Description Format: [<symbol>[:]]Δ.FDATAB[.<operation size>]Δ<block count>,  
 <floating-point data>  
 <operation size>: { S | D }

Description: .FDATAB reserves the specified number of floating-point data items consecutively in memory.

The operation size determines the size of the reserved data.  
 Single precision is used when the operation size is omitted.

The block count must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols, externally defined symbols, and relative symbols must not appear in specification.

The range of values that can be specified as the block count varies with the operation size.

| <b>Operation Size</b>                | <b>Block Size Range*</b>                         |
|--------------------------------------|--------------------------------------------------|
| <u>S</u> (single precision, 4 bytes) | H'00000001 to H'3FFFFFFF<br>(1 to 1,073,741,823) |
| D (double precision, 8 bytes)        | H'00000001 to H'1FFFFFFF<br>(1 to 536,870,911)   |

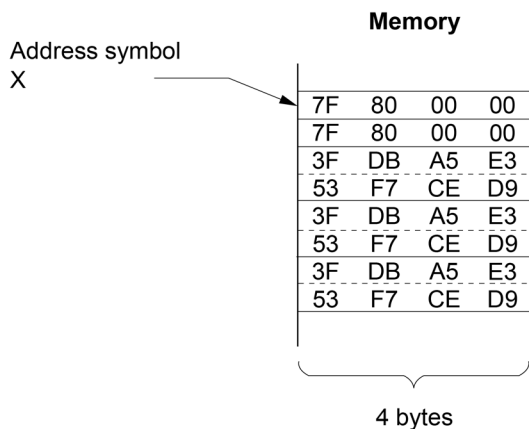
Note: Numbers in parentheses are decimal.

Example: ~

```
.ALIGN          4
X: .FDATAB.S 2,H'7F800000.S ; This statement reserves two blocks
; of 4-byte areas 7F800000
; (H'7F800000.S).
.FDATAB.D 3,F'4.32D-1 ; This statement reserves three
; blocks of 8-byte areas
; 3FDBA5E353F7CED9 (F'4.32D-1).
```

~

Explanatory Figure for the Coding Example



**.XDATA**

Description Format: [<symbol>[:]]Δ.XDATA[.<operation size>]Δ<fixed-point data>[,...]  
 <operation size>: { W | L }

Description: .XDATA reserves fixed-point data in memory.  
 The operation size determines the size of the reserved data.  
 The longword size is used when the operation range is omitted.

The operation size is as follows:

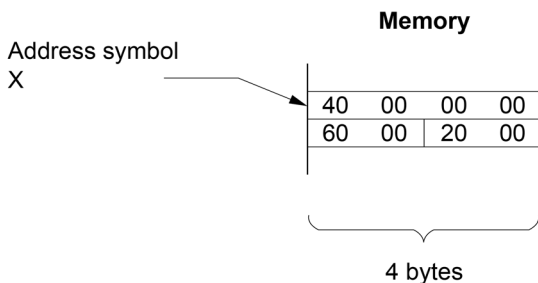
| Operation Size | Data Size          |
|----------------|--------------------|
| W              | Word (2 bytes)     |
| <u>L</u>       | Longword (4 bytes) |

Example:

```

~
.ALIGN 4
X:
.XDATA.L 0.5 ; This statement reserves 4-byte
; area (H'40000000).
.XDATA.W 0.75,0.25 ; This statement reserves 2-byte
; areas (H'6000) and (H'2000).
~
    
```

Explanatory Figure for the Coding Example



**.RES**

Description Format: [<symbol>[:]]Δ.RES[.<operation size>]Δ<area count>  
 <operation size>: { B | W | L }

Description: .RES reserves data areas in memory.  
 The operation size determines the size of one area.  
 The longword size is used when the specifier is omitted.  
 The area count must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

The range of values that can be specified as the area count varies with the operation size.

The data size and the range of area count are as follows:

| <b>Operation Size</b>        | <b>Area Count Range*</b>                      |
|------------------------------|-----------------------------------------------|
| B (byte)                     | H'00000001 to H'FFFFFFFF (1 to 4,294,967,295) |
| W (word, 2 bytes)            | H'00000001 to H'7FFFFFFF (1 to 2,147,483,647) |
| <u>L</u> (longword, 4 bytes) | H'00000001 to H'3FFFFFFF (1 to 1,073,741,823) |

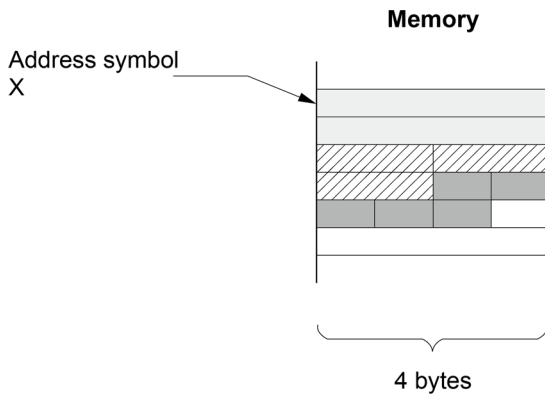
Note: Numbers in parentheses are decimal.

Example:

```

~
X:  .ALIGN  4
    .RES.L  2  ; This statement reserves two-longword-size
           ; areas.
    .RES.W  3  ; This statement reserves three-word-size
           ; areas.
    .RES.B  5  ; This statement reserves five-byte-size
           ; areas.
~
    
```

Explanatory Figure for the Coding Example



**.SRES**

Description Format: [<symbol>[:]]Δ.SRESΔ<string literal area size>[,...]

Description: .SRES reserves string literal data areas.  
The string literal area size must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

The values that are allowed for the string literal area size are from H'00000001 to H'FFFFFFF (from 1 to 4,294,967,295 in decimal).

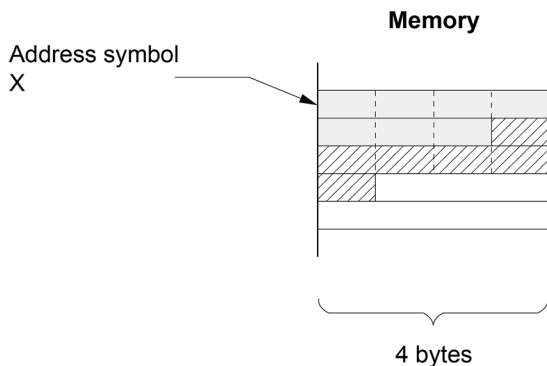
Example:

```

~
.ALIGN 4
X:
.SRES 7 ; This statement reserves a 7-byte area.
.SRES 6 ; This statement reserves a 6-byte area.
~

```

Explanatory Figure for the Coding Example





## .SRESC

Description Format: [<symbol>[:]]Δ.SRESCΔ<string literal area size>[,...]

Description: .SRESC reserves string literal data areas (with length) in memory. A string literal with length is a string literal with an inserted leading byte that indicates the length of the string. The length indicates the size of the string literal (not including the length) in bytes. The string literal area size must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

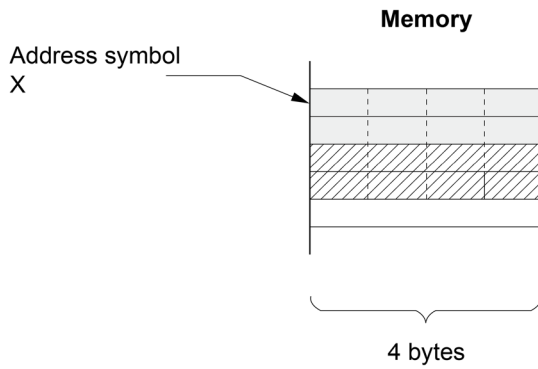
The values that are allowed for the string literal area size are from H'00000000 to H'000000FF (from 0 to 255 in decimal).

The size of the area reserved in memory is the size of the string literal area itself plus 1 byte for the count.

Example:

```
~  
  
X:  .ALIGN  4  
    .SRESC 7 ; This statement reserves 7 bytes plus 1 byte  
    ; for the count.  
    .SRESC 6 ; This statement reserves 6 bytes plus 1 byte  
    ; for the count.  
  
~
```

## Explanatory Figure for the Coding Example



## .SRESZ

Description Format: [<symbol>[:]]Δ.SRESZΔ<string literal area size>[,...]

Description: .SRESZ allocates string literal data areas (with zero termination). A string literal with zero termination is a string literal with an appended trailing byte (with the value H'00) that indicates the end of the string. The string literal area size must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

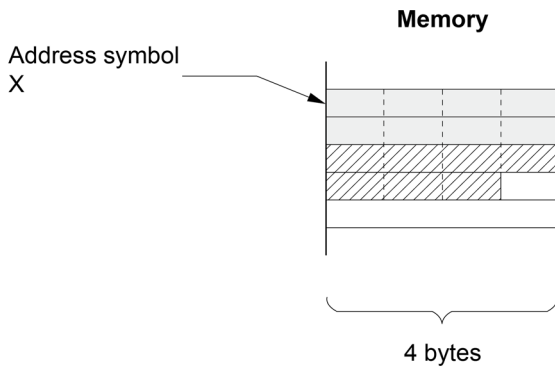
The values that are allowed for the string literal area size are from H'00000000 to H'000000FF (from 0 to 255 in decimal).

The size of the area reserved in memory is the size of the string literal area itself plus 1 byte for the terminating zero.

Example:

```
~  
  
X:  .ALIGN  4  
    .SRESZ 7 ; This statement reserves 7 bytes plus 1 byte  
      ; for the terminating byte.  
    .SRESZ 6 ; This statement reserves 6 bytes plus 1 byte  
      ; for the terminating byte.  
  
~
```

## Explanatory Figure for the Coding Example



**.FRES**

Description Format: [`<symbol>[:]`]`Δ.FRES[.<operation size>]Δ<area count>`

`<operation size> = { S | D }`

Description:

.FRES reserves floating-point data areas in memory.

The operation size determines the size of the reserved data.

Single precision is used when the specifier is omitted.

The area count must be specified as follows:

The specification must be a constant value,

- The specification must be a constant value, and,
- Forward reference symbols, externally referenced symbols, and relative symbols must not appear in the specification.

Operation size is as follows:

| Operation Size | Data Size                  |
|----------------|----------------------------|
| <u>S</u>       | Single precision (4 bytes) |
| D              | Double precision (8 bytes) |

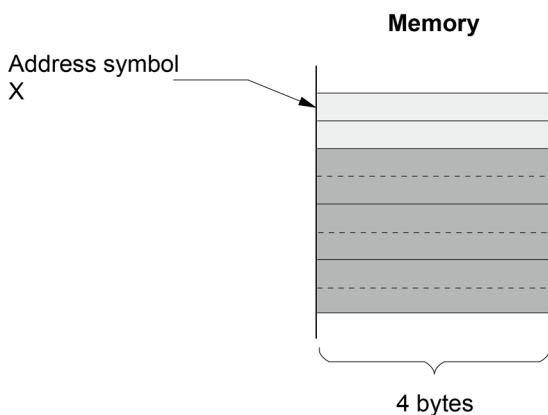
Example:

```

~
      .ALIGN    4
X:    .FRES.S   2      ; This statement reserves two areas.
      .FRES.D   3      ; This statement reserves three areas.
~

```

Explanatory Figure for the Coding Example

**.EXPORT**

Description Format:  $\Delta$ .EXPORT $\Delta$ <symbol>[,<...>]

The label field is not used.

Description:

.EXPORT declares externally defined symbols.

An externally defined symbol declaration is required to reference symbols defined in the current file from other files.

The following can be declared to be externally defined symbols.

- Constant symbols (other than those defined with .ASSIGN)
- Absolute address symbols (other than address symbols in a dummy section)
- Relative address symbols

To reference a symbol as an externally referenced symbol, it is necessary to declare it to be an externally defined symbol, and also to declare it to be an externally referenced symbol.

Externally referenced symbols are declared in the file in which they are referenced using either `.IMPORT` or `.GLOBAL`.

Example: (In this example, a symbol defined in file A is referenced from file B.)  
 File A:

```
.EXPORT      X      ; This statement declares X to be an
                  ; externally defined symbol.
```

~

```
X: .EQU      H'10000000 ; This statement defines X.
```

~

File B:

```
.IMPORT      X      ; This statement declares X to be an
                  ; externally referenced symbol.
```

~

```
.ALIGN      4
.DATA.L     X      ; This statement references X.
```

~

**.IMPORT**

Description Format:  $\Delta$ .IMPORT $\Delta$ <symbol>[,<symbol>...]

The label field is not used.

## Description:

.IMPORT declares externally referenced symbols.

An externally referenced symbol declaration is required to reference symbols defined in another file.

Symbols defined in the current file cannot be declared to be externally referenced symbols.

To reference a symbol as an externally referenced symbol, it is necessary to declare it to be an externally referenced symbol, and also to declare it to be an externally defined symbol.

Externally defined symbols are declared in the file in which they are defined using either .EXPORT or .GLOBAL.

## Example:

(In this example, a symbol defined in file A is referenced from file B.)  
File A:

```
.EXPORT X           ; This statement declares X to be an
                    ; externally defined symbol.
```

~

```
X: .EQU H'10000000 ; This statement defines X.
```

~

File B:

```
.IMPORT X           ; This statement declares X to be an
                    ; externally referenced symbol.
```

~

```
.ALIGN 4           ;
.DATA.L X           ; This statement references X.
```

~



## **.GLOBAL**

Description Format:  $\Delta$ .GLOBAL $\Delta$ <symbol>[,<symbol>...]

The label field is not used.

### Description:

.GLOBAL declares symbols to be either externally defined symbols or externally referenced symbols.

An externally defined symbol declaration is required to reference symbols defined in the current file from other files. An externally referenced symbol declaration is required to reference symbols defined in another file.

A symbol defined within the current file is declared to be an externally defined symbol by a .GLOBAL declaration.

A symbol that is not defined within the current file is declared to be an externally referenced symbol by a .GLOBAL declaration.

The following can be declared to be externally defined symbols.

- Constant symbols (other than those defined with .ASSIGN)
- Absolute address symbols (other than address symbols in a dummy section)
- Relative address symbols

To reference a symbol as an externally referenced symbol, it is necessary to declare it to be an externally defined symbol, and also to declare it to be an externally referenced symbol.

Externally defined symbols are declared in the file in which they are defined using either .EXPORT or .GLOBAL.

Externally referenced symbols are declared in the file in which they are referenced using either .IMPORT or .GLOBAL.

Example: (In this example, a symbol defined in file A is referenced from file B.)

File A:

```
.GLOBAL X ; This statement declares X to be an  
; externally defined symbol.
```

~

```
X: .EQU H'10000000 ; This statement defines X.
```

~

File B:

```
.GLOBAL X ; This statement declares X to be an  
; externally referenced symbol.
```

~

```
.ALIGN 4 ;  
.DATA.L X ; This statement references X.
```

~

**.OUTPUT**

Description Format: Δ.OUTPUTΔ<output specifier>[,...]

<output specifier> = { OBJ | NOOBJ |  
 DBG | NODBG }

The label field is not used.

Description: .OUTPUT controls object module and debugging information output.

(1) Output of object module

Controls the output of the object module.

**Output Specifier    Output Control**

---

OBJ                    An object module is output.

---

NOOBJ                  No object module is output.

---

(2) Output of debugging information

Controls the output of the debugging information.

**Output Specifier    Output Control**

---

DBG                    Debugging information is output in the object module.

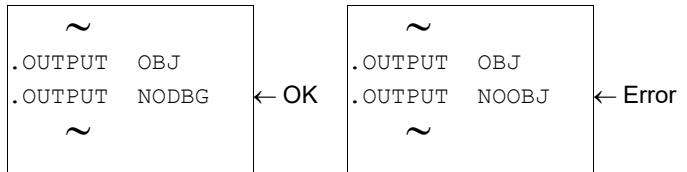
---

NODBG                No debugging information is output in the object module.

---

If .OUTPUT is used two or more times in a program with inconsistent output specifiers, an error occurs.

Example:



Specifications concerning debugging information output are only valid when an object module is output.

The assembler gives priority to command line option specifications concerning the object module and debugging information output.

Example: This example and its description assume that no command line options concerning object module or debugging information output were specified.

Example 1: **.OUTPUT** OBJ ; An object module is output.  
; No debugging information is output.  
~

Example 2: **.OUTPUT** OBJ,DBG ; Both an object module and debugging  
; information is output.  
~

Example 3: **.OUTPUT** OBJ,NODBG ; An object module is output.  
; No debugging information is output.  
~

Supplement: Debugging information is required when debugging a program using the debugger, and is part of the object module.  
Debugging information includes information about source statements and information about symbols.

**.DEBUG**

Description Format:  $\Delta$ .DEBUG $\Delta$ <output specifier>

<output specifier>= { ON | OFF }  
 The label field is not used.

Description: .DEBUG controls the output of symbolic debugging information. This directive allows assembly time to be reduced by restricting the output of symbolic debugging information to only those symbols required in debugging. The specification of .DEBUG is only valid when both an object module and debugging information are output.

| Output Specifier | Output Control                               |
|------------------|----------------------------------------------|
| <u>ON</u>        | Symbolic debugging information is output.    |
| OFF              | No symbolic debugging information is output. |

Example:

```

~

.DEBUG   OFF      ; Starting with the next statement, the
                ; assembler does not output symbolic
                ; debugging information.

~

.DEBUG   ON       ; Starting with the next statement, the
                ; assembler outputs symbolic debug
                ; information.

~
    
```

Supplement: The term "symbolic debugging information" refers to the parts of debugging information concerned with symbols.

**.ENDIAN**

Description Format:  $\Delta$ .ENDIAN $\Delta$ <endian>

<endian>: { BIG | LITTLE }

The label field is not used.

Description: .ENDIAN specifies whether the byte order of the target microcomputer is in big endian or little endian.

Enter .ENDIAN at the beginning of the source program.

The endian type takes priority for option specifications.

| <b>Endian</b> | <b>Output Control</b>              |
|---------------|------------------------------------|
| <u>BIG</u>    | Assembles program in big endian    |
| LITTLE        | Assembles program in little endian |

```

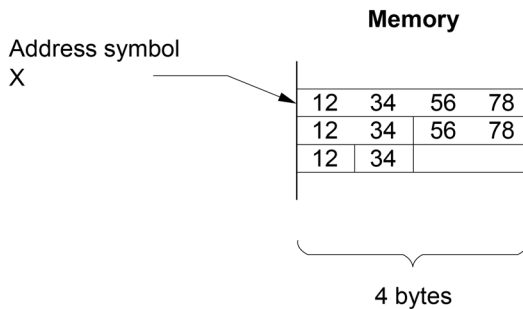
Example:      1. When the big endian is selected
               .CPU      SH3
               .ENDIAN  BIG           ; This statement selects the big endian.

               ~

X: .DATA.L  H'12345678   ;
   .DATA.W  H'1234,H'5678 ; These statements reserve integer
                           ; data.
   .DATA.B  H'12,H'34   ;

               ~
    
```

Explanatory Figure for the Coding Example



Note: The data in this figure is hexadecimal.

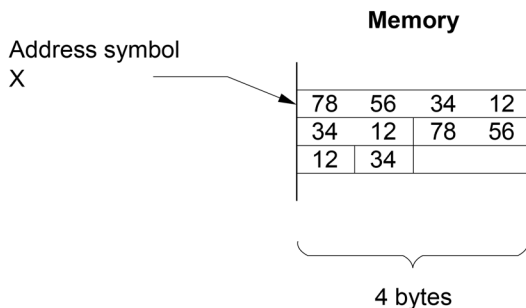
Example:                   2. When the little endian is selected  
                               .CPU        SH3  
                               .ENDIAN LITTLE        ; This statement selects the little endian.

~

X:  
   .DATA.L H'12345678        ;  
   .DATA.W H'1234,H'5678   ; These statements reserve integer  
                               ; data.  
   .DATA.B H'12,H'34        ;

~

Explanatory Figure for the Coding Example



Note: The data in this figure is hexadecimal.



## .LINE

Description Format:  $\Delta$ .LINE $\Delta$  ["<file name>",<line number>

The label field is not used.

Description: .LINE changes the file name and line number referred to at error message output or at debugging.

The line number and the file name specified with .LINE is valid until the next .LINE.

The compiler (version 3.0 or later) generates .LINE corresponding to the line in the C source file when the debugging option is specified and the assembly source program is output.

If the file name is omitted, the file name is not changed, but only the line number is changed.

Example:

```
shc -code=asmcode -debug test.c
```

C source program (test.c)

```
int    func()
{
    int    i,j;

    j=0;
    for (i=1;i<=10;i++){
        j+=i;
    }
    return(j);
}
```

→

Assembly source program (test.src)

```
.FILE        "C:\asm\test.c"
.EXPORT      _func
.SECTION     P,CODE,ALIGN=4
_func:
                ; function: func
                ; frame size=0
.LINE        "C:\asm\test.c",5
MOV          #0,R5 ; H'00000000
.LINE        "C:\asm\test.c",6
MOV          #1,R2 ; H'00000001
MOV          #10,R6 ; H'0000000A

L11:
ADD          #-1,R6
TST         R6,R6
.LINE        "C:\asm\test.c",7
ADD          R2,R5
ADD          #1,R2
BF          L11
RTS
MOV          R5,R0
.END
```

**.PRINT**

Description Format:  $\Delta.PRINT\Delta$ <output specifier>[,...]

<output specifier>= { LIST | NOLIST | SRC | NOSRC |  
CREF | NOCREF | SCT | NOSCT }

The label field is not used.

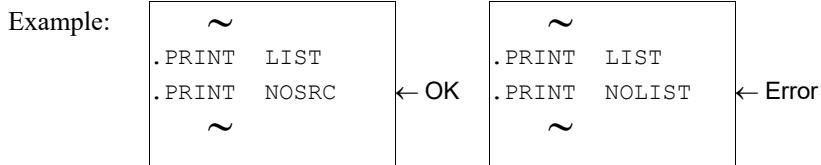
Description: .PRINT controls the following output.

- (1) Assemble listing
- (2) Source program listing
- (3) Cross-reference listing
- (4) Section information listing

| Item | Output Specifier*1 | Assembler Action                                                      |
|------|--------------------|-----------------------------------------------------------------------|
| (1)  | LIST               | An assemble listing is output.*2                                      |
|      | <u>NOLIST</u>      | No assemble listing is output.*2                                      |
| (2)  | <u>SRC</u>         | A source program listing is output in the assemble listing.*3*4       |
|      | NOSRC              | No source program listing is output in the assemble listing.*3*4      |
| (3)  | <u>CREF</u>        | A cross-reference listing is output in the assemble listing.*3*5      |
|      | NOCREF             | No cross-reference listing is output in the assemble listing.*3*5     |
| (4)  | <u>SCT</u>         | A section information listing is output in the assemble listing.*3*6  |
|      | NOSCT              | No section information listing is output in the assemble listing.*3*6 |

- Notes:
1. This specification is valid only once.
  2. Valid when the **list** or **nolist** option is not specified.
  3. Valid when the assemble listing is output.
  4. Valid when the **source** or **nosource** option is not specified.
  5. Valid when the **cross\_reference** or **nocross\_reference** option is not specified.
  6. Valid when the **section** or **nosection** option is not specified.

If .PRINT is used two or more times in a program with inconsistent output specifiers, an error occurs.



Example: This example and its description assume that no options concerning assemble listing output are specified.

Example 1: **.PRINT LIST** ; All types of assemble listing are output.

~

Example 2: **.PRINT LIST,NOSRC,NOCREF**  
; Only a section information listing is output.

~

**.LIST**

Description Format:  $\Delta$ .LIST $\Delta$ <output specifier>[,...]

<output specifier>={ ON | OFF | COND | NOCOND | DEF | NODEF |  
CALL | NOCALL | EXP | NOEXP |  
CODE | NOCODE }

The label field is not used.

Description: .LIST controls output of the source program listing in the following three ways:

- (1) Selects whether or not to output source statements.
- (2) Selects whether or not to output source statements related to the preprocessor function.
- (3) Selects whether or not to output object code lines.

Output is controlled by output specifiers as follows:

**Output Specifier**

| Type | Output      | Not output | Object                          | Description                                                                                                   |
|------|-------------|------------|---------------------------------|---------------------------------------------------------------------------------------------------------------|
| (1)  | <u>ON</u>   | OFF        | Source statements               | The source statements following this directive                                                                |
| (2)  | <u>COND</u> | NOCOND     | Failed condition* <sup>1</sup>  | Condition-failed .AIF or .AIFDEF statements                                                                   |
|      | <u>DEF</u>  | NODEF      | Definition* <sup>1</sup>        | Macro definition statements<br>.AREPEAT and .AWHILE definition statements<br>.INCLUDE, .ASSIGNA, and .ASSIGNC |
|      | <u>CALL</u> | NOCALL     | Call* <sup>1</sup>              | Macro call statements,<br>.AIF, AIFDEF, and .AENDI                                                            |
| (3)  | <u>EXP</u>  | NOEXP      | Expansion* <sup>1</sup>         | Macro expansion statements<br>.AREPEAT and .AWHILE expansion statements                                       |
|      | <u>CODE</u> | NOCODE     | Object code lines* <sup>1</sup> | The object code lines exceeding the source statement lines                                                    |

Note: This specification is valid when the **show** or **noshow** option is not specified.

The specification of .LIST is only valid when an assemble listing is output. The assembler gives priority to option specifications concerning source program listing output.

.LIST statements themselves are not output on the source program listing.

Example: This example and its description assume that no options concerning assemble listing output are specified.

```

.LIST NOCOND,NODEF ----- This statement controls source program
.MACRO SHLRN COUNT,Rd ----- listing output.

SHIFT .ASSIGNA \COUNT

      .AIF \&SHIFT GE 16
      SHLR16 \Rd
SHIFT .ASSIGNA \&SHIFT-16
      .AENDI

      .AIF \&SHIFT GE 8
      SHLR8 \Rd
SHIFT .ASSIGNA \&SHIFT-8
      .AENDI

      .AIF \&SHIFT GE 4
      SHLR2 \Rd
      SHLR2 \Rd
SHIFT .ASSIGNA \&SHIFT-4
      .AENDI

      .AIF \&SHIFT GE 2
      SHLR2 \Rd
SHIFT .ASSIGNA \&SHIFT-2
      .AENDI

      .AIF \&SHIFT GE 1
      SHLR \Rd
      .AENDI
      .ENDM -----

SHLRN 23,R0 ----- Macro call
    
```

These statements define a general-Purpose multiple-bit shift procedure as a macro instruction.

Source Listing Output of Coding Example:

.LIST suppresses the output of the macro definition, .ASSIGNA and .ASSIGNC, and .AIF and .AIFDEF condition-failed statements.

|    |               |    |       |               |
|----|---------------|----|-------|---------------|
| 31 |               | 31 |       |               |
| 32 |               | 32 | SHLRN | 23,R0         |
| 33 |               |    | M     |               |
| 35 |               |    | M     |               |
| 36 |               |    | M     | .AIF 23 GE 16 |
| 37 | 00000000 4029 |    | C     | SHLR16 R0     |
| 39 |               |    | M     | .AENDI        |
| 40 |               |    | M     |               |
| 41 |               |    | M     | .AIF 7 GE 8   |
| 45 |               |    | M     |               |
| 46 |               |    | M     | .AIF 7 GE 4   |
| 47 | 00000002 4009 |    | C     | SHLR2 R0      |
| 48 | 00000004 4009 |    | C     | SHLR2 R0      |
| 50 |               |    | M     | .AENDI        |
| 51 |               |    | M     |               |
| 52 |               |    | M     | .AIF 3 GE 2   |
| 53 | 00000006 4009 |    | C     | SHLR2 R0      |
| 55 |               |    | M     | .AENDI        |
| 56 |               |    | M     |               |
| 57 |               |    | M     | .AIF 1 GE 1   |
| 58 | 00000008 4001 |    | C     | SHLR R0       |
| 59 |               |    | M     | .AENDI        |

## .FORM

Description Format:  $\Delta$ .FORM $\Delta$ <size specifier>[,...]

<size specifier> = { LIN = <line count> | COL = <column count> |  
TAB = {4 | 8} }

The label field is not used.

Description: .FORM sets the number of lines per page, columns per line, and tab size in the assemble listing.

The line count and column count must be specified as follows:

- The specifications must be constant values, and,
- Forward reference symbols must not appear in the specifications.

| Size Specifier        | Listing Size                                                    | Allowable Range | When Not Specified |
|-----------------------|-----------------------------------------------------------------|-----------------|--------------------|
| LIN=<line count>      | The specified value is set to the number of lines per page.*1   | 20 to 255*4     | 60                 |
| COL=<column count>    | The specified value is set to the number of columns per line.*2 | 79 to 255*4     | 132                |
| TAB = {4   <u>8</u> } | The specified value is set to the tab size.*3                   | 4 or 8*5        | 8                  |

- Notes: 1. Valid when the **lines** option is not specified.  
 2. Valid when the **columns** option is not specified.  
 3. Valid when the **tab** suboption is not specified in the **show** option.  
 4. When a value less than the minimum value is specified, the minimum value is assumed, and when a value larger than the maximum value is specified, the maximum value is assumed; no error is output.  
 5. When an invalid value is specified, 8 is assumed; no error is output.

The assembler gives priority to command line option specifications concerning the number of lines and columns in the assemble listing. .FORM can be used any number of times in a given source program.

Example: This example and its description assume that no options concerning the assemble listing line count, column count, and/or tab size are specified.

~

**.FORM** LIN=60, COL=200, TAB=4

; Starting with this page, the number of  
; lines per page in the assemble listing  
; is 60 lines.

; Starting with this line, the number  
; of columns per line in the assemble  
; listing is 200 columns.

; Outputs the assemble listing with  
; setting the tab size as 4.

~

~

**.FORM** LIN=55, COL=150

; Starting with this page, the number of  
; lines per page in the assemble listing is  
; 55 lines.

; Starting with this line, the number  
; of columns per line in the assemble  
; listing is 150 columns.

~



## .HEADING

Description Format:  $\Delta$ .HEADING $\Delta$ "<string literal>"

The label field is not used.

Description:

.HEADING sets the header for the source program listing.

A string literal of up to 60 characters can be specified as the header.

.HEADING can be used any number of times in a given source program.

The range of validity for a given use of .HEADING is as follows:

- When .HEADING is on the first line of a page, it is valid starting with that page.
- When .HEADING appears on the second or later line of a page, it is valid starting with the next page.

Example:

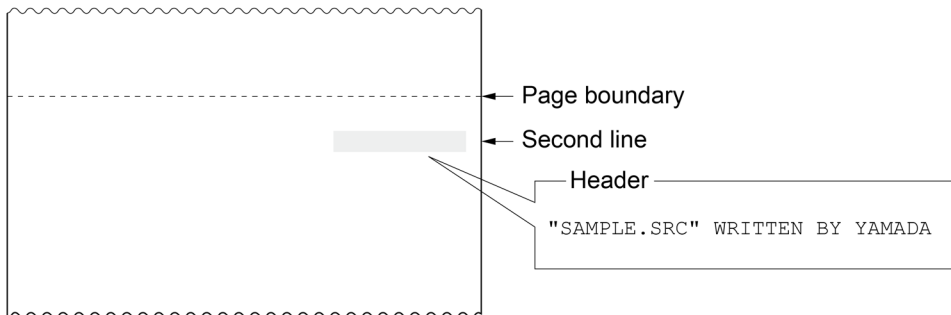
~

```
.HEADING ""SAMPLE.SRC"" WRITTEN BY YAMADA"
```

~

Explanatory Figure for the Coding Example

### Source program listing



**.PAGE**

Description Format: Δ.PAGE

The label field is not used.

Description: .PAGE inserts a new page in the source program listing at an arbitrary point.  
 .PAGE is ignored if it is used on the first line of a page.  
 .PAGE statements themselves are not output to the source program listing.

Example:

```

~
MOV          R0,R1
RTS
MOV          R0,R2
.PAGE        ;A new page is specified here since the section changes at
             this point.
.SECTION     DT,DATA,ALIGN=4
.DATA.L      H'11111111
.DATA.L      H'22222222
.DATA.L      H'33333333
~

```

Explanatory Figure for the Coding Example

Source program listing

```
18 00000022 6103          18      MOV      R0,R1
19 00000024 000B          19      RTS
20 00000026 6203          20      MOV      R0,R2
```

```
*** SuperH RISC engine ASSEMBLER Ver. 5.1 ***      06/01/01 10:15:30
PROGRAM NAME =
```

```
22 00000000          22      .SECTION DT,DATA,ALIGN
23 00000000 11111111      23      .DATA.L  H'11111111
24 00000004 22222222      24      .DATA.L  H'22222222
25 00000008 33333333      25      .DATA.L  H'33333333
```

← New  
page

**.SPACE**

Description Format:  $\Delta$ .SPACE[ $\Delta$ <line count>]

The label field is not used.

Description: .SPACE outputs the specified number of blank lines to the source program listing.

The line count must be specified as follows:

- The specification must be a constant value, and,
- Forward reference symbols must not appear in the specification.

Values from 1 to 50 can be specified as the line count.

When a new page occurs as the result of blank lines output by .SPACE, any remaining blank lines are not output on the new page.

.SPACE statements themselves are not output to the source program listing.

Example:

```
.SECTION DT1,DATA,ALIGN=4
.DATA.L H'11111111
.DATA.L H'22222222
.DATA.L H'33333333
.DATA.L H'44444444           ;Inserts five blank lines at the point
.SPACe 5                     ; where the section changes.
.SECTION DT2,DATA,ALIGN=4
~
```

## Explanatory Figure for the Coding Example

### Source program listing

```
*** SuperH RISC engine ASSEMBLER Ver. 5.1 ***      06/01/01 10:15:30
PROGRAM NAME =

  1  00000000                                1          .SECTION   DT1, DATA, ALIGN=4
  2  00000000  11111111                      2          .DATA.L    H'11111111
  3  00000004  22222222                      3          .DATA.L    H'22222222
  4  00000008  33333333                      4          .DATA.L    H'33333333
  5  0000000C  44444444                      5          .DATA.L    H'44444444

                                     ~

  7  00000000                                7          .SECTION   DT2, DATA, ALIGN=4
```

**.PROGRAM**

Description Format:  $\Delta$ .PROGRAM $\Delta$ <object module name>

The label field is not used.

Description:

.PROGRAM sets the object module name.

The object module name is a name that is required by the optimizing linkage editor to identify the object module.

Object module naming conventions are the same as symbol naming conventions.

The assembler distinguishes uppercase and lowercase letter in object module names.

Setting the object module name with .PROGRAM is valid only once in a given program. (The assembler ignores the second and later specifications of .PROGRAM.)

If there is no .PROGRAM specification of the object module name, the assembler will set a default (implicit) object module name.

The default object module name is the file name of the object file (the object module output destination).

Example: Object file name ..... PROG .obj

||           ||

File name   File type

↓

Object module name ..... PROG

The object module name can be the same as a symbol used in the program.

Example: **.PROGRAM** PROG1   ; This statement sets the object module  
                                  ; name to be  
                                  ; PROG1.

~

**.RADIX**

Description Format: Δ.RADIXΔ<radix specifier>

<radix specifier> = { B | Q | D | H }

The label field is not used.

Description:

.RADIX sets the radix (base) for integer constants with no radix specification.

This specifier sets the radix (base) for integer constants with no radix specification.

When there is no radix specification with .RADIX in a program, integer constants with no radix specification are interpreted as decimal constants.

If hexadecimal (radix specifier H) is specified as the radix for integer constants with no radix specification, integer constants whose first digit is A through F must be prefixed with a 0 (zero). (The assembler interprets expressions that begin with A through F to be symbols.)

Specifications with .RADIX are valid from the point of specification forward in the program.

| Radix Specifier | Integer Constant with no Radix |
|-----------------|--------------------------------|
| B               | Binary                         |
| Q               | Octal                          |
| <u>D</u>        | Decimal                        |
| H               | Hexadecimal                    |

Example: 1.

```

~
X: .RADIX D
   .EQU      100 ;This 100 is decimal.

```

```

~
Y: .RADIX H
   .EQU      64 ;This 64 is hexadecimal.

```

2.

```

~
.RADIX H

```





Example:

```
~  
.STACK    SYMBOL=H'100  
~
```

## 11.5 File Inclusion Function

The file inclusion function allows source files to be included into other source files at assembly. The file included into another file is called an include file.

This assembler provides `.INCLUDE` to perform file inclusion.

The file specified with `.INCLUDE` is inserted at the location of `.INCLUDE`.

Example:

Source program

```
.INCLUDE "FILE.H"

.SECTION CD1, CODE, ALIGN=4
MOV #ON, R0

~
```

Include file FILE.H

```
ON: .EQU 1
OFF: .EQU 0
```

↓ ↓ ↓ ↓ ↓ ↓ ↓

File included result (source list)

```
.INCLUDE "FILE.H"
ON: .EQU 1
OFF: .EQU 0

.SECTION CD1, CODE, ALIGN=4
MOV #ON, R0

~
```

## .INCLUDE

Description Format:  $\Delta$ .INCLUDE  $\Delta$ "<file name>"

The label field is not used.

Description:

.INCLUDE is the file inclusion assembler directive. If no file type is specified, only the file name is used as specified (the assembler does not assume any default file type).

The file name can include the directory. The directory can be specified either by the absolute path (path from the root directory) or by the relative path (path from the current directory).

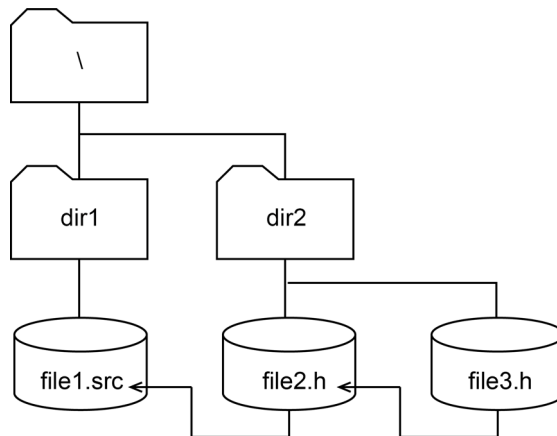
Include files can include other files. The nesting depth for file inclusion is limited to 30 levels.

The current directory for .INCLUDE in a source file is the directory where the assembler is invoked. The current directory for .INCLUDE in an include file is the directory where the include file exits.

The directory name of the filenames specified by .INCLUDE can be changed by the **include** option.

Example:

This example assumes the following directory configuration and operations:



- Starts the assembler from the root directory (\)
- Inputs source file \dir1\file1.src
- Makes file2.h included in file1.src
- Makes file3.h included in file2.h

The start command is as follows:

```
>asmsh \dir1\file1.src (RET)
```

file1.src must have the following include directive:

```
.INCLUDE "dir2\file2.h"      ;    \ is the current directory  
                             ;    (relative path  
                             ;    specification).
```

or

```
.INCLUDE "\dir2\file2.h"    ;    Absolute path  
                             ;    specification
```

file2.h must have the following inclusion directive:

```
.INCLUDE "file3.h"         ;    \dir2 is the current  
                             ;    directory  
                             ;    (relative path  
                             ;    specification).
```

or

```
.INCLUDE "\dir2\file3.h"   ;    Absolute path  
                             ;    specification
```

## 11.6 Conditional Assembly Function

### 11.6.1 Overview of the Conditional Assembly Function

The conditional assembly function provides the following assembly operations:

- Replaces a string literal in the source program with another string literal.
- Selects whether or not to assemble a specified part of a source program according to the condition.
- Iteratively assembles a specified part of a source program.

#### (1) Preprocessor variables

Preprocessor variables are used to write assembly conditions. Preprocessor variables are of either integer or character type.

##### (a) Integer preprocessor variables

Integer preprocessor variables are defined by `.ASSIGNA` (these variables can be redefined).

When referencing integer preprocessor variables, insert a backslash (\) and an ampersand (&) in front of them.

A coding example is shown below:

Example:

```
FLAG: .ASSIGNA 1
      ~
      .AIF \&FLAG EQ 1           ; MOV R0,R1 is assembled
      MOV R0,R1                 ; when FLAG is 1.
      .AENDI
      ~
```

##### (b) Character preprocessor variables

Character preprocessor variables are defined by `.ASSIGNC` (these variables can be redefined).

When referencing character preprocessor variables, insert a backslash (\) and an ampersand (&) in front of them.

A coding example is shown below:

Example:

```
FLAG: .ASSIGNC "ON"  
~  
.AIF "&FLAG" EQ "ON" ; MOV R0,R1 is assembled  
MOV R0,R1 ; when FLAG is "ON".  
.AENDI  
~
```

## (2) Replacement Symbols

.DEFINE specifies symbols that will be replaced with the corresponding string literals at assembly. A coding example is shown below.

Example:

```
SYM1: .DEFINE "R1"  
~  
MOV.L SYM1,R0 ; Replaced with MOV.L R1,R0.  
~
```

### (3) Conditional Assembly

The conditional assembly function determines whether or not to assemble a specified part of a source program according to the (specified) conditions. Conditional assembly is classified into two types: conditional assembly with comparison using relational operators and conditional assembly with definition of replacement symbols.

#### (a) Conditional Assembly with Comparison

Selects the part of program to be assembled according to whether or not the specified condition is satisfied. A coding example is as follows:

```

    ~
    .AIF <comparison condition 1>
        <Statements to be assembled when condition 1 is satisfied>
    .AELIF <comparison condition 2>
        <Statements to be assembled when condition 2 is satisfied>
    .AELSE
        <Statements to be assembled when both conditions are not satisfied>
    .AENDI
    ~
    
```

--- This part can be omitted.

Example:

```

    ~
    .AIF  "\&FLAG" EQ "ON"
        MOV  R0,R10           ; Assembled when FLAG
        MOV  R1,R11           ; is ON.
        MOV  R2,R12           ;
    .AELSE
        MOV  R10,R0           ; Assembled when FLAG
        MOV  R11,R1           ; is not ON.
        MOV  R12,R2           ;
    .AENDI
    ~
    
```

## (b) Conditional Assembly with Definition

Selects the part of program to be assembled by whether or not the specified replacement symbol has been defined. A coding example is as follows:

```

~
.AIFDEF <definition condition>
  <Statements to be assembled when the specified replacement symbol is defined>
~-----~
.AELSE
  <Statements to be assembled when the specified replacement symbol is not defined>
~-----~
.AENDI
~

```

---This part can be omitted.

Example:

```

~
.AIFDEF FLAG
MOV R0,R10 ; Assembled when FLAG is defined with
MOV R1,R11 ; .DEFINE before .AIFDEF
MOV R2,R12 ; in the program.
.AELSE
MOV R10,R0 ; Assembled when FLAG is not defined with
MOV R11,R1 ; .DEFINE before the .AIFDEF
MOV R12,R2 ; in the program.
.AENDI
~

```



#### (4) Iterated Expansion

A part of a source program can be iteratively assembled the specified number of times. A coding example is shown below.

Example:

```

    ~
    .AREPEAT <count>
        <Statements to be iterated>
    .AENDR
    ~
    
```

Example:

```

    TST     R0,R0           ; This example is a division of 64-bit data by 32-bit data.
    BT      zero_div       ; R1:R2 (64 bits) ÷ R0 (32 bits) = R2 (32 bits): Unsigned
    CMP/HS  R0,R1         ; Zero divisor check
    BT      over_div       ; Overflow check
    DIV0U                    ; Flag initialization
    .AREPEAT 32
    ROTCL   R2             ; These statements are iteratively assembled 32 times.
    DIV1    R0,R1         ;
    .AENDR
    ROTCL   R2             ; R2 = quotient
    
```

## (5) Conditional Iterated Expansion

A part of a source program can be iteratively assembled while the specified condition is satisfied. A coding example is shown below.

```

~
.AWHILE <condition>
    <Statements to be iterated>
.AENDW
~

```

## Example:

```

; This example is a multiply and
; accumulate
; operation.
TblSiz: .ASSIGNA 50 ; TblSiz: Data table size
MOV A_Tbl1,R1 ; R1: Start address of data table 1
MOV A_Tbl2,R2 ; R2: Start address of data table 2
CLRMAC ; MAC register initialization
.AWHILE \&TblSiz GT 0 ; While TblSiz is larger than 0,
MAC.W @R1+,@R2+ ; this statement is iteratively assembled.
TblSiz: .ASSIGNA \&TblSiz-1 ; 1 is subtracted from TblSiz.
.AENDW
STS MACL,R0 ; The result is obtained in R0.

```

## 11.6.2 Conditional Assembly Directives

This assembler provides the following conditional assembly directives.

| Category            | Mnemonic | Function                                                                                                                                                                                                                                                                  |
|---------------------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Variable definition | .ASSIGNA | Defines an integer preprocessor variable. The defined variable can be redefined.                                                                                                                                                                                          |
|                     | .ASSIGNC | Defines a character preprocessor variable. The defined variable can be redefined.                                                                                                                                                                                         |
|                     | .DEFINE  | Defines a preprocessor replacement string literal. The defined variable cannot be redefined.                                                                                                                                                                              |
| Conditional branch  | .AIF     | Determines whether or not to assemble a part of a source program according to the specified condition. When the condition is satisfied, the statements after the .AIF are assembled. When not satisfied, the statements after the .AELIF or .AELSE are assembled.         |
|                     | .AELIF   |                                                                                                                                                                                                                                                                           |
|                     | .AELSE   |                                                                                                                                                                                                                                                                           |
|                     | .AENDI   |                                                                                                                                                                                                                                                                           |
|                     | .AIFDEF  | Determines whether or not to assemble a part of a source program according to the replacement symbol definition. When the replacement symbol is defined, the statements after the .AIFDEF are assembled. When not defined, the statements after the .AELSE are assembled. |
|                     | .AELSE   |                                                                                                                                                                                                                                                                           |
| .AENDI              |          |                                                                                                                                                                                                                                                                           |
| Iterated expansion  | .AREPEAT | Repeats assembly of a part of a source program (between .AREPEAT and .AENDR) the specified number of times.                                                                                                                                                               |
|                     | .AENDR   |                                                                                                                                                                                                                                                                           |
|                     | .AWHILE  | Assembles a part of a source program (between .AWHILE and .AENDW) iteratively while the specified condition is satisfied.                                                                                                                                                 |
|                     | .AENDW   |                                                                                                                                                                                                                                                                           |
|                     | .EXITM   | Terminates .AREPEAT or .AWHILE iterated expansion.                                                                                                                                                                                                                        |
| Others              | .AERROR  | Processes an error during preprocessor expansion.                                                                                                                                                                                                                         |
|                     | .ALIMIT  | Specifies the maximum count of .AWHILE expansion.                                                                                                                                                                                                                         |

## .ASSIGNA

Description Format: <preprocessor variable>[:] Δ.ASSIGNA Δ<value>

Description: .ASSIGNA defines a value for an integer preprocessor variable. The syntax of integer preprocessor variables is the same as that for symbols. An integer preprocessor variable can be defined with up to 32 characters, and uppercase and lowercase letters are distinguished.

The preprocessor variables defined with .ASSIGNA can be redefined with .ASSIGNA.

The value to be assigned has the following format:

- Constant (integer constant and character constant)
- Defined preprocessor variable
- Expression using the above as terms

Defined preprocessor variables are valid in the source statements following the directive.

Defined preprocessor variables can be referenced in the following locations:

- .ASSIGNA
- .ASSIGNC
- .AIF
- .AELIF
- .AREPEAT
- .AWHILE
- Macro body (source statements between .MACRO and .ENDM)

When referencing integer preprocessor variables, insert a backslash (\) and an ampersand (&) in front of them.

```
\&<preprocessor variable>[']
```

To clearly distinguish the preprocessor variable name from the rest of the source statement, an apostrophe (') can be added.

When a preprocessor string literal is defined by an option, .ASSIGNA specifying the preprocessor variable having the same name as the string literal is invalidated.

Example:

```

                                ; This example generates a general-purpose multiple-bit
                                ; shift instruction which shifts bits to the right by the
                                ; number of SHIFT.
RN:      .REG   R0              ; R0 is set to Rn.
SHIFT:   .ASSIGNA 27          ; 27 is set to SHIFT.

                                ;
                                ;
                                ; Condition: SHIFT ≥ 16
                                ; When the condition is satisfied, Rn is shifted to the right by 16 bits.
                                ; 16 is subtracted from SHIFT.
                                ;
                                ;
                                ; Condition: SHIFT ≥ 8
                                ; When the condition is satisfied, Rn is shifted to the right by 8 bits.
                                ; 8 is subtracted from SHIFT.
                                ;
                                ;
                                ; Condition: SHIFT ≥ 4
                                ; When the condition is satisfied, Rn is shifted to the right by 4 bits.
                                ;
                                ; 4 is subtracted from SHIFT.
                                ;
                                ;
                                ; Condition: SHIFT ≥ 2
                                ; When the condition is satisfied, Rn is shifted to the right by 2 bits.
                                ; 2 is subtracted from SHIFT.
                                ;
                                ;
                                ; Condition: SHIFT = 1
                                ; When the condition is satisfied, Rn is shifted to the right by 1 bit.
                                ;
                                ;

```

The expanded results are as follows:

```

SHLR16  R0      ; When the condition is satisfied, Rn is shifted to the right by 16 bits.
SHLR8   R0      ; When the condition is satisfied, Rn is shifted to the right by 8 bits.
SHLR2   R0      ; When the condition is satisfied, Rn is shifted to the right by 2 bits.
SHLR    R0      ; When the condition is satisfied, Rn is shifted to the right by 1 bit.

```

## .ASSIGNC

Description Format: `<preprocessor variable>[:] Δ.ASSIGNC Δ"<string literal>"`

Description: .ASSIGNC defines a string literal for a character preprocessor variable. The syntax of character preprocessor variables is the same as that for symbols. A character preprocessor variable can be defined with up to 32 characters, and uppercase and lowercase letters are distinguished.

The preprocessor variables defined with .ASSIGNC can be redefined with .ASSIGNC.

String literals are specified by characters or preprocessor variables enclosed with double quotation marks (").

Defined preprocessor variables are valid in the source statements following the directive.

Defined preprocessor variables can be referenced in the following locations:

- .ASSIGNA
- .ASSIGNC
- .AIF
- .AELIF
- .AREPEAT
- AWHILE
- Macro body (source statements between .MACRO and .ENDM)

When referencing character preprocessor variables, insert a backslash (\) and an ampersand (&) in front of them.

```
\&<preprocessor variable>[' ]
```

To clearly distinguish the preprocessor variable name from the rest of the source statement, an apostrophe (') can be added.

When a preprocessor string literal is defined by an option, .ASSIGNC specifying the preprocessor variable having the same name as the string literal is invalidated.

Example:

```
FLAG: .ASSIGNC "ON" ; "ON" is set to FLAG.
```

~

```
.AIF "\&FLAG" EQ "ON" ; MOV R0,R1 is assembled  
MOV R0,R1 ; when FLAG is "ON".
```

```
.AENDI
```

~

```
FLAG: .ASSIGNC "\&FLAG " ; A space (" ") is added to FLAG.
```

```
FLAGA: .ASSIGNC "OFF" ; "OFF" is added to FLAGA.
```

```
FLAG: .ASSIGNC "\&FLAG'AND \&FLAGA"
```

```
; An apostrophe (') is used to distinguish FLAG and  
; AND.
```

```
; FLAG finally becomes "ON AND OFF".
```

~

**.DEFINE**

Description Format: <symbol>[:] Δ.DEFINE Δ"<replacement string literal>"

Description: .DEFINE specifies that the symbol is replaced with the corresponding string literal.

The differences between .DEFINE and .ASSIGNC are as follows.

- The symbol defined by .ASSIGNC can only be used in the preprocessor statement; the symbol defined by .DEFINE can be used in any statement.
- The symbols defined by .ASSIGNA and .ASSIGNC are referenced by the "&symbol" format; the symbol defined by .DEFINE is referenced by the "symbol" format.

Defined symbols cannot be redefined. .DEFINE specifying a symbol is invalidated when the same replacement symbol has been defined by a option. This replacement is not applied to the .AENDI, .AENDR, .AENDW, .AIFDEF, .END, and .ENDM directives.

Example:

```
SYM1: .DEFINE "R1"
```

~

```
MOV.L SYM1,R0 ; Replaced with MOV.L R1,R0.
```

~

A hexadecimal number starting with an alphabetical character a to f or A to F will be replaced when the same string literal is specified as a replacement symbol by .DEFINE. Add 0 to the beginning of the number to stop replacing such number.

```
C0: .DEFINE "0"
    MOV.B #H'C0,R0 ; Replaced with MOV.B #H'0,R0.
    MOV.B #H'0C0,R0 ; Not replaced.
```

A radix indication (B', Q', D', or H') will also be replaced when the same string literal is specified as a replacement symbol by .DEFINE. When specifying a symbol having only one character, such as B, Q, D, H, b, q, d, or h, make sure that the corresponding radix indication is not used.

```
B: .DEFINE "H"
    MOV.B #B'10,R0 ; Replaced with MOV.H #H'10,R0.
```



## **.AIF, .AELIF, .AELSE, .AENDI**

Description Format:  $\Delta$ .AIF  $\Delta$ <term1>  $\Delta$ <relational operator>  $\Delta$ <term2>  
<Source statements assembled if the .AIF condition is satisfied>  
[ $\Delta$ .AELIF  $\Delta$ <term1>  $\Delta$ <relational operator>  $\Delta$ <term2>  
<Source statements assembled if the .AELIF condition is satisfied>]  
[ $\Delta$ .AELSE  
<Source statements assembled if all the conditions are not satisfied>]  
.AENDI

The label field is not used.

Description: .AIF, .AELIF, .AELSE, and .AENDI are the assembler directives that select whether or not to assemble source statements according to the condition specified. .AELIF and .AELSE can be omitted.

.AELIF can be specified repeatedly between .AIF and .AELSE.

The condition must be specified as follows:

.AIF: Condition to be compared.

.AELIF: Condition to be compared.

.ALESE: Operand field cannot be used.

.AENDI: Operand field cannot be used.

Terms are specified with numeric values or string literals. However, when a numeric value and a string literal are compared, the condition always fails.

Numeric values are specified by constants or preprocessor variables.

String literals are specified by characters or preprocessor variables enclosed with double quotation marks ("). To specify a double quotation mark in a string literal, enter two double quotation marks in succession.

The following relational operators can be used:

EQ:  $\text{term1} = \text{term2}$

NE:  $\text{term1} \neq \text{term2}$

GT:  $\text{term1} > \text{term2}$

LT:  $\text{term1} < \text{term2}$

GE:  $\text{term1} \geq \text{term2}$

LE:  $\text{term1} \leq \text{term2}$

Numeric values are handled as 32-bit signed integers. For string literals, only EQ and NE conditions can be used.

Example:

~

```
.AIF \&TYPE EQ 1
MOV R0,R3           ; These statements
MOV R1,R4           ; are assembled
MOV R2,R5           ; when TYPE is 1.
.AELIF \&TYPE EQ 2
MOV R0,R6           ; These statements
MOV R1,R7           ; are assembled
MOV R2,R8           ; when TYPE is 2.
.AELSE
MOV R0,R9           ; These statements
MOV R1,R10          ; are assembled
MOV R2,R11          ; when TYPE is not 1 nor 2.
.AENDI
```

~

## **.AIFDEF, .AELSE, .AENDI**

Description Format:  $\Delta$ .AIFDEF  $\Delta$ <replacement symbol>  
 <statements to be assembled when the specified replacement symbol is defined>  
 [ $\Delta$ .AELSE  
 <statements to be assembled when the specified replacement symbol is not defined>]  
 .AENDI  
 The label field is not used.

Description: .AIFDEF, .AELSE, and .AENDI are the assembler directives that select whether or not to assemble source statements according to the replacement symbol definition. .AELSE can be omitted  
 The condition must be specified as follows.  
 .AIFDEF: The condition to be defined.  
 .AELSE: The operand field cannot be used.  
 .AENDI: The operand field cannot be used.  
 The replacement symbol can be defined by .DEFINE  
 When the specified replacement symbol is defined by the option or defined before being referenced by these directives, the condition is regarded as satisfied. When the replacement symbol is defined after being referenced by these directives or is not defined, the condition is regarded as unsatisfied.

Example:

~

```
.AIFDEF    FLAG
MOV       R0,R3    ; These statements are assembled when
MOV       R1,R4    ; FLAG is defined by .DEFINE.
.AELSE
MOV       R0,R6    ; These statements are assembled when
MOV       R1,R7    ; FLAG is not defined by .DEFINE.
.AENDI
```

~

**.AREPEAT, .AENDR**

Description Format:  $\Delta$ .AREPEAT  $\Delta$ <count>  
 <Source statements iteratively assembled>  
 $\Delta$ .AENDR

The label field is not used.

Description: .AREPEAT and .AENDR are the assembler directives that assemble source statements by iteratively expanding them the specified number of times. The condition must be specified as follows.  
 .AREPEAT: The number of iterations.  
 .AENDR: The operand field cannot be used.  
 The source statements between .AREPEAT and .AENDR are iterated the number of times specified with .AREPEAT. Note that the source statements are simply copied the specified number of times, and therefore, the operation is not a loop at program execution.  
 Counts are specified by constants or preprocessor variables.  
 Nothing is expanded if a value of 0 or smaller is specified.

Example:

```

; This example is a division of 64-bit data by 32-bit data.
; R1:R2 (64 bits) ÷ R0 (32 bits) = R2 (32 bits): Unsigned
TST      R0,R0      ; Zero divisor check
BT       zero_div
CMP/HS  R0,R1      ; Overflow check
BT       over_div
DIV0U                    ; Flag initialization
.AREPEAT 32
ROTCL   R2           ; These statements are
DIV1    R0,R1        ; iterated 32 times.
.AENDR
ROTCL   R2           ; R2 = quotient

```

## **.AWHILE, .AENDW**

Description Format:  $\Delta$ .AWHILE  $\Delta$ <term1>  $\Delta$ <relational operator>  $\Delta$ <term2>  
<Source statements iteratively assembled>  
 $\Delta$ .AENDW  
The label field is not used.

Description: .AWHILE and .AENDW are the assembler directives that assemble source statements by iteratively expanding them while the specified condition is satisfied.

The source statements between .AWHILE and .AENDW are iterated while the condition specified with .AWHILE is satisfied. Note that the source statements are simply copied iteratively, and therefore, the operation is not a loop at program execution.

Terms are specified with numeric values or string literals. However, when a numeric value and a string literal are compared, the condition always fails.

Numeric values are specified by constants or preprocessor variables.

String literals are specified by characters or preprocessor variables enclosed with double quotation marks (""). To specify a double quotation mark in a string literal, enter two double quotation marks (" ") in succession.

Conditional iterated expansion terminates when the condition finally fails.

If a condition which never fails is specified, source statements are iteratively expanded for 65,535 times or until the maximum count of statement expansion specified by .ALIMIT is reached. Accordingly, the condition for this directive must be carefully specified.

The following relational operators can be used:

EQ: term1 = term2

NE: term1  $\neq$  term2

GT: term1 > term2

LT: term1 < term2

GE: term1  $\geq$  term2

LE: term1  $\leq$  term2

Numeric values are handled as 32-bit signed integers. For string literals, only EQ and NE conditions can be used.

## Example:

```
TblSiz: .ASSIGNA 50 ; This example is a multiply and accumulate
; operation.
MOV A_Tbl1,R1 ; TblSiz: Data table size
MOV A_Tbl2,R2 ; R1: Start address of data table 1
CLRMAC ; R2: Start address of data table 2
; MAC register initialization
.AWHILE \&TblSiz GT 0 ; While TblSiz is larger than 0,
MAC.W @R0+,@R1+ ; this statement is iteratively assembled.
TblSiz: .ASSIGNA \&TblSiz-1 ; 1 is subtracted from TblSiz.
.AENDW
STS MACL,R0 ; The result is obtained in R0.
```

## .EXITM

Description Format:  $\Delta$ .EXITM

The label field is not used.

Description:

.EXITM terminates an iterated expansion (.AREPEAT to .AENDR) or a conditional iterated expansion (.AWHILE to .AENDW).

Each expansion is terminated when this directive appears.

This directive is also used to exit from macro expansions. The location of this directive must be specified carefully when macro instructions and iterated expansion are combined.

Example:

```

    ~
COUNT .ASSIGNA 0                ; 0 is set to COUNT.
      .AWHILE 1 EQ 1            ; An infinite loop (condition is always satisfied) is
                                ; specified.
      ADD     R0,R1
      ADD     R2,R3
COUNT .ASSIGNA \&COUNT+1      ; 1 is added to COUNT.
      .AIF    \&COUNT EQ 2    ; Condition: COUNT = 2
      .EXITM                    ; When the condition is satisfied
      .AENDI                    ; .AWHILE expansion is terminated.
      .AENDW
    ~
    
```

When COUNT is updated and satisfies the condition specified with the .AIF, .EXITM is assembled. When .EXITM is assembled, .AWHILE expansion is terminated.

The expansion results are as follows:

```

      ADD     R0,R1 ..... When COUNT is 0
      ADD     R2,R3
      ADD     R0,R1 ..... When COUNT is 1
      ADD     R2,R3
    
```

After this, COUNT becomes 2 and expansion is terminated.

**.AERROR**

Description Format:  $\Delta$ .AERROR

The label field is not used.

Description: When .AERROR is assembled, error 667 occurs and the assembler is terminated with an error.

.AERROR can be used to check values such as preprocessor variables.

Example:

```

~
.AIF      \&FLG EQ 1
MOV      R1,R10
MOV      R2,R11
.AELSE
.AERROR           ; When \&FLG is not 1, an error occurs.
.AENDI
~

```



## .ALIMIT

Description Format:  $\Delta$ .ALIMIT  $\Delta$ <count>  
 The label field is not used.

Description: .ALIMIT determines the maximum count for the conditional iterated expansion (.AWHILE to .AENDW).

<count> must be specified in the following format:

- Constant (integer constant, character constant)
- Defined preprocessor variable
- Expression in which a constant or a defined preprocessor variable is used as the term

During conditional iterated (.AWHILE to .AENDW) expansion, if the statement expansion count exceeds the maximum value specified by .ALIMIT, warning 854 occurs and the expansion is terminated.

If .ALIMIT is not specified, the maximum count is 65,535. The maximum count of iteration expansion can be changed by respecifying this directive. The respecification is valid for the source statements after this directive.

Example:

```
.ALIMIT    20
~

FLG: .ASSIGNA    0
     .AWHILE    \&FLG EQ 0      ; Expansion is terminated after performed
     NOP        ; 20 times, and a warning message is output.
     .AENDW

~
```

## 11.7 Macro Function

### 11.7.1 Overview of the Macro Function

The macro function allows commonly used sequences of instructions to be named and defined as one macro instruction. This is called a macro definition. Macro instructions are defined as follows:

```
~  
.MACRO <macro name>  
  <macro body>  
.ENDM  
~
```

A macro name is the name assigned to a macro instruction, and a macro body is the statements to be expanded as the macro instruction.

Using a defined macro instruction by specifying the name is called a macro call. Macro call is as follows:

```
~  
<defined macro name>  
~
```

An example of macro definition and macro call is shown below.

Example:

```
~  
.MACRO SUM ; Processing to obtain the sum of R0, R1, R2,  
MOV R0,R10 ; and R3 is defined as macro instruction SUM.  
ADD R1,R10  
ADD R2,R10  
ADD R3,R10  
.ENDM  
~  
SUM ; This statement calls macro instruction SUM.  
; Macro body MOV R0,R10  
; ADD R1,R10  
; ADD R2,R10  
; ADD R3,R10  
; is expanded from the macro instruction.
```

Parts of the macro body can be modified when expanded by the following procedure:

(1) Macro definition

Define arguments after the macro name in .MACRO.

Use the arguments in the macro body. Arguments must be identified in the macro body by placing a backslash (\) in front of them.

(2) Macro call

Specify macro parameters in the macro call.

When the macro instruction is expanded, the arguments are replaced with their corresponding macro parameters.

Example:

```

~
.MACRO  SUM ARG1                ; Argument ARG1 is defined.
MOV R0, \ARG1                   ; ARG1 is referenced in the macro body.
ADD R1, \ARG1
ADD R2, \ARG1
ADD R3, \ARG1
.ENDM

~

SUM R10                          ; This statement calls macro instruction SUM
                                ; specifying macro parameter R10.
                                ; The argument in the macro body is
                                ; replaced with the macro parameter, and
                                ;
                                ;      MOV R0,R10
                                ;      ADD R1,R10
                                ;      ADD R2,R10
                                ;      ADD R3,R10 is expanded.

```

## 11.7.2 Macro Function Directives

This assembler provides the following macro function directives.

| <b>Directive</b> | <b>Description</b>                                                       |
|------------------|--------------------------------------------------------------------------|
| .MACRO           | Defines a macro instruction.                                             |
| .ENDM            |                                                                          |
| .EXITM           | Terminates macro instruction expansion. Refer to section 11.6.2, .EXITM. |

**.MACRO, .ENDM**

Description Format:  $\Delta$ .MACRO $\Delta$ <macro name>[ $\Delta$ <argument>[,...]]  
 $\Delta$ .ENDM

<argument>: <argument>[=<default argument>]

The label field is not used.

Description: .MACRO and .ENDM define a macro instruction (a sequence of source statements that are collectively named and handled together).

Naming as a macro instruction the source statements (macro body) between .MACRO and .ENDM is called a macro definition.

The operand must be specified as follows:

.MACRO: Macro instruction, argument, or default (can be omitted)

.ENDM: Operand field cannot be used.

**(1) Macro name**

Macro names are the names assigned to macro instructions.

Arguments are specified so that parts of the macro body can be replaced by specific parameters at expansion. Arguments are replaced with the string literals (macro parameters) specified at macro expansion (macro call).

In the macro body, arguments are specified for replacement. The syntax of argument is macro body is as follows:

```
\<argument name>[ ' ]
```

To clearly distinguish the argument name from the rest of the source statement, an apostrophe (') can be added.

**(2) Argument**

Defaults for arguments can be specified in macro definitions. The default specifies the string literal to replace the argument when the corresponding macro parameter is omitted in a macro call.

The syntax of the argument is the same as that of symbol. The maximum length of the argument is 32 characters, and uppercase and lowercase letters are distinguished.

**(3) Default argument**

The default must be enclosed with double quotation marks (") or angle brackets (<>) if any of the following characters are included in the default.

- Space
- Tab
- Comma (,)
- Semicolon (;)
- Double quotation marks (")
- Angle brackets (<>)

The assembler inserts defaults at macro expansion by removing the double quotation marks or angle brackets that enclose the string literals.

#### (4) Restrictions

Macros cannot be defined in the following locations:

- Macro bodies (between `.MACRO` and `.ENDM`)
- Between `.AREPEAT` and `.AENDR`
- Between `.AWHILE` and `.AENDW`

`.END` cannot be used within a macro body.

No symbol can be inserted in the label field of `.ENDM`. `.ENDM` is ignored if a symbol is written in the label field, but no error occurs in this case.

Example:

```
~  
.MACRO SUM ; Processing to obtain the sum of R0, R1, R2,  
MOV R0,R10 ; and R3 is defined as macro instruction SUM.  
ADD R1,R10  
ADD R2,R10  
ADD R3,R10  
.ENDM  
~  
SUM ; This statement calls macro instruction SUM  
; Macro body MOV R0,R10  
; ADD R1,R10  
; ADD R2,R10  
; ADD R3,R10 is expanded.
```



### 11.7.3 Macro Body

The source statements between `.MACRO` and `.ENDM` are called a macro body. The macro body is expanded and assembled by a macro call.

#### (1) Argument reference

Arguments are used to specify the parts to be replaced with macro parameters at macro expansion.

The syntax of argument reference in a macro body is as follows:

```
\<argument name>[' ]
```

To clearly distinguish the argument name from the rest of the source statement, add an apostrophe (`'`).

Example:

```
.MACRO  PLUS1  P, P1          ; P and P1 are arguments.
ADD     #1, \P1             ; Argument P1 is referenced.
.SDATA  "\P'1"             ; Argument P is referenced.
.ENDM
PLUS1   R, R1              ; PLUS1 is expanded.
~
```

Expanded results are as follows:

```
ADD     #1, R1             ; Argument P1 is referenced.
.SDATA  "R1"              ; Argument P is referenced.
```

## (2) Preprocessor variable reference

Preprocessor variables can be referenced in macro bodies.

The syntax for preprocessor variable reference is as follows:

```
\&<preprocessor variable name>[ ' ]
```

To clearly distinguish the preprocessor variable name from the rest of the source statement, add an apostrophe (').

Example:

```

.MACRO  PLUS1
ADD     #1,R\&V1           ; Preprocessor variable V1 is referenced.
.SDATA  "\&V'1"           ; Preprocessor variable V is referenced.
.ENDM

V:      .ASSIGNC "R"        ; Preprocessor variable V is defined.
V1:     .ASSIGNA 1          ; Preprocessor variable V1 is defined.
PLUS1   ; PLUS1 is expanded.

```

Expanded results are as follows:

```

ADD     #1,R1              ; Preprocessor variable V1 is referenced.
.SDATA  "R1"              ; Preprocessor variable V is referenced.

```

## (3) Macro generation number

The macro generation number facility is used to avoid the problem that symbols used within a macro body will be multiply defined if the macro is expanded multiple times. To avoid this problem, specify the macro generation number marker as part of any symbol used in a macro. This will result in symbols that are unique to each macro call.

The macro generation number marker is expanded as a 5-digit decimal number (between 00000 and 99999) unique to the macro expansion.

The syntax for specifying the macro generation number marker is as follows:

```
\@
```


Two or more macro generation number markers can be written in a macro body, and they will be expanded to the same number in one macro call.

Because macro generation number markers are expanded to numbers, they must not be written at the beginning of symbol names.

Example:

```

        .MACRO   RES_STR STR, Rn
        MOV.L   #str\@, \Rn
        BRA    end_str\@
        NOP
str\@   .SDATA  "\STR"
        .ALIGN  2
end_str\@
        .ENDM
        RES_STR "ONE", R0
        RES_STR "TWO", R1
    
```

 Different symbols are generated each time  
 RES\_STR is expanded.

Expanded results are as follows:

```

        MOV.L   #str00000,R0
        BRA    end_str00000
        NOP
str00000 .SDATA  "ONE"
        .ALIGN  2
end_str00000
        MOV.L   #str00001,R1
        BRA    end_str00001
        NOP
str00001 .SDATA  "TWO"
        .ALIGN  2
end_str00001
    
```

#### (4) Macro replacement processing exclusion

When a backslash (\) appears in a macro body, it specifies macro replacement processing. Therefore, a means for excluding this macro processing is required when it is necessary to use the backslash as an ASCII character.

The syntax for macro replacement processing exclusion is as follows:

```
\(<macro replacement processing excluded string literal>)
```

The backslash and the parentheses will be removed in macro processing.

Example:

```
.MACRO BACK_SLASH_SET
\MOV      #"\",R0          ; \ is expanded as an ASCII character.
.ENDM
```

Expanded results are as follows:

```
MOV      #"\",R0          ; \ is expanded as an ASCII character.
```

#### (5) Comments in macros

Comments in macro bodies can be coded as normal comments or as macro internal comments. When comments in the macro body are not required in the macro expansion code (to avoid repeating the same comment in the listing file), those comments can be coded as macro internal comments to suppress their expansion.

The syntax for macro internal comments is as follows:

```
\;<comment>
```

Example:

```
.MACRO PUSH Rn
MOV.L     \Rn,@-R15        \;  \Rn is a register.
.ENDM
PUSH     R0
```

Expanded results are as follows (the comment is not expanded):

```
MOV.L     R0,@-R15
```

## (6) String literal manipulation functions

String literal manipulation functions can be used in a macro body. The following string literal manipulation functions are provided.

- .LEN           String literal length.
- .INSTR        String literal search.
- .SUBSTR       String literal extraction.

### 11.7.4 Macro Call

Expanding a defined macro instruction is called a macro call. The syntax for macro calls is as follows:

#### Description Format

```
[<symbol>[:]] Δ<macro name>[ Δ<macro parameter> [, ...]]  
<macro parameter>: [=<argument name>]=<string literal>
```

The macro name must be defined (.MACRO) before a macro call. String literals must be specified as macro parameters to replace arguments at macro expansion. The arguments must be declared in the macro definition with .MACRO.

#### Description

##### 1. Macro parameter specification

Macro parameters can be specified by either positional specification or keyword specification.

##### 2. Positional specification

The macro parameters are specified in the same order as that of the arguments declared in the macro definition with .MACRO.

##### 3. Keyword specification

Each macro parameter is specified following its corresponding argument, separated by an equal sign (=).

##### 4. Macro parameter syntax

Macro parameters must be enclosed with double quotation marks (") or angle brackets (<>) if any of the following characters are included in the macro parameters:

- Space
- Tab
- Comma (,)
- Semicolon (;)

— Double quotation marks (")

— Angle brackets (< >)

Macro parameters are inserted by removing the double quotation marks or angle brackets that enclose string literals at macro expansion.

Example:

```

.MACRO SUM FROM=0, TO=9          ; Macro instruction SUM and arguments
                                ; FROM and TO are defined.

MOV    R\FROM, R10
COUNT .ASSIGNA    \FROM+1
      .AWHILE \&COUNT LE \TO
      MOV    R\&COUNT, R10
COUNT .ASSIGNA    \&COUNT+1
      .AENDW
      .ENDM

SUM    0, 5
SUM    TO=5

```

Macro body is coded using arguments.

Both will be expanded into the same statements.

Expanded results are as follows (the arguments in the macro body are replaced with macro parameters):

```

MOV    R0, R10
MOV    R1, R10
MOV    R2, R10
MOV    R3, R10
MOV    R4, R10
MOV    R5, R10

```

### 11.7.5 String Literal Manipulation Functions

This assembler provides the following string literal manipulation functions.

| <b>Function</b> | <b>Description</b>                     |
|-----------------|----------------------------------------|
| .LEN            | Counts the length of a string literal. |
| .INSTR          | Searches for a string literal.         |
| .SUBSTR         | Extracts a string literal.             |

## .LEN

Description Format: `.LEN[Δ]("<string literal>")`

Description: `.LEN` counts the number of characters in a string literal and replaces itself with the number of characters in decimal with no radix.

String literals are specified by enclosing the desired characters with double quotation marks ("). To specify a double quotation mark in a string literal, enter two double quotation marks in succession.

Macro arguments and preprocessor variables can be specified in the string literal as shown below.

```
.LEN ("\<argument>")
```

```
.LEN ("\&<preprocessor variable>")
```

This function can only be used within a macro body (between `.MACRO` and `.ENDM`).

Example:

```

~
.MACRO RESERVE_LENGTH P1
.ALIGN 4
.SRES .LEN ("\P1")
.ENDM
~
RESERVE_LENGTH ABCDEF
RESERVE_LENGTH ABC

```

Expanded results are as follows:

```

.ALIGN 4
.SRES 6 ; "ABCDEF" has six characters.
.ALIGN 4
.SRES 3 ; "ABC" has three characters.

```



## .INSTR

Description Format: `.INSTR[Δ]("<string literal 1>","<string literal 2>" [,<start position>])`

Description: `.INSTR` searches string literal 1 for string literal 2, and replaces itself with the numerical value of the position of the found string (with 0 indicating the start of the string) in decimal with no radix. `.INSTR` is replaced with -1 if string literal 2 does not appear in string literal 1.

String literals are specified by enclosing the desired characters with double quotation marks ("). To specify a double quotation mark in a string literal, enter two double quotation marks in succession.

The start position parameter specifies the search start position as a numerical value, with 0 indicating the start of string literal 1. Zero is used as default when this parameter is omitted.

Macro arguments and preprocessor variables can be specified in the string literals and as the start position as shown below.

```
.INSTR("\<argument>", ...)  

.INSTR("\&<preprocessor variable>", ...)
```

This function can only be used within a macro body (between `.MACRO` and `.ENDM`).

Example:

```
~  

.MACRO FIND_STR P1  

.DATA.W .INSTR("ABCDEFGH", "\P1", 0)  

.ENDM  

~  

FIND_STR CDE  

FIND_STR H
```

Expanded results are as follows:

```
.DATA.W 2 ; The start position of "CDE" is 2 (0 indicating the  

beginning of the string) in "ABCDEFGH"  

.DATA.W -1 ; "ABCDEFGH" includes no "H".
```

**.SUBSTR**

Description Format: `.SUBSTR[Δ]("<string literal>",<start position>,<extraction length>)`

Description: `.SUBSTR` extracts from the specified string literal a substring starting at the specified start position of the specified length. `.SUBSTR` is replaced with the extracted string literal enclosed with double quotation marks ("").

String literals are specified by enclosing the desired characters in double quotation marks (""). To specify a double quotation mark in a string literal, enter two double quotation marks in succession.

The value of the extraction start position must be 0 or greater. The value of the extraction length must be 1 or greater.

If illegal or inappropriate values are specified for the start position or extraction length parameters, this function is replaced with a space (" ").

Macro arguments and preprocessor variables can be specified in the string literal, and as the start position and extraction length parameters as shown below.

```
.SUBSTR("\<argument>", ...)
```

```
.SUBSTR("\&<preprocessor variable>", ...)
```

This function can only be used within a macro body (between `.MACRO` and `.ENDM`).

Example:

```

~
.MACRO RESERVE_STR P1=0,P2
.SDATA .SUBSTR("ABCDEFGH",\P1,\P2)
.ENDM

```

```
RESERVE_STR 2,2
```

```
RESERVE_STR ,3
```

; Macro parameter P1 is omitted.

Expanded results are as follows:

```

.SDATA "CD"
.SDATA "ABC"

```

## 11.8 Automatic Literal Pool Generation Function

### 11.8.1 Overview of Automatic Literal Pool Generation

To transfer 2-byte or 4-byte constant data (referred to below as a "literal") to a register, a literal pool (a collection of literals) must be reserved and referred to in PC relative addressing mode. For literal pool location, the following must be considered:

- Is data stored within the range that can be accessed by data transfer instructions?
- Is 2-byte data aligned to a 2-byte boundary and is 4-byte data aligned to a 4-byte boundary?
- Can data be shared by several data move instructions?
- Where in the program should the literal pool be located?

The assembler automatically generates from a single instruction `.DATA` and a PC relative `MOV` or `MOVA` instruction, which moves constant data to a register.

For example, this function enables program (a) below to be coded as (b):

(a)

```
MOV.L DATA1,R0
MOV.L DATA2,R1
```

~

```
.ALIGN 4
DATA1 .DATA.L H'12345678
DATA2 .DATA.L 500000
```

(b)

```
MOV.L #H'12345678,R0
MOV.L #500000,R1
```

~

## 11.8.2 Extended Instructions Related to Automatic Literal Pool Generation

The assembler automatically generates a literal pool corresponding to an extended instruction (MOV.W #imm, Rn; MOV.L #imm, Rn; or MOVA #imm, R0) and calculates the PC relative displacement value.

An extended instruction source statement is expanded to an executable instruction and literal data as shown in table 11.34.

**Table 11.34 Extended Instructions and Expanded Results**

| Extended Instruction | Expanded Result                               |
|----------------------|-----------------------------------------------|
| MOV.W #imm, Rn       | MOV.W @(disp, PC), Rn and 2-byte literal data |
| MOV.L #imm, Rn       | MOV.L @(disp, PC), Rn and 4-byte literal data |
| MOVA #imm, R0        | MOVA @(disp, PC), R0 and 4-byte literal data  |

## 11.8.3 Size Mode for Automatic Literal Pool Generation

Automatic literal pool generation has two modes: size specification mode and size selection mode. In size specification mode, a data transfer instruction (extended instruction) whose operation size is specified is used to generate a literal pool. In size selection mode, when a transfer instruction without size specification is written, the assembler automatically checks the imm operand value and selects a suitable-size transfer instruction.

Table 11.35 shows data transfer instructions and size mode.

**Table 11.35 Data Transfer Instructions and Size Mode**

| Data Transfer Instruction | Size Specification Mode | Size Selection Mode    |
|---------------------------|-------------------------|------------------------|
| MOV #imm, Rn              | Executable instruction  | Selected by assembler  |
| MOV.B #imm, Rn            | Executable instruction  | Executable instruction |
| MOV.W #imm, Rn            | Extended instruction    | Extended instruction   |
| MOV.L #imm, Rn            | Extended instruction    | Extended instruction   |

### (1) Size Specification Mode

In this mode, a data transfer instruction without size specification (MOV #imm,Rn) is handled as a normal executable instruction. This mode is used when **auto\_literal** is not specified as the option.

## (2) Size Selection Mode

In this mode, when a data transfer instruction without size specification (MOV #imm,Rn) is written, the assembler checks the imm operand value and automatically generates a literal pool if necessary. The imm value is checked for the signed value range.

This mode is used when **auto\_literal** is specified as the option.

Table 11.36 shows the instructions selected depending on imm value range.

**Table 11.36 Instructions Selected in Size Selection Mode**

| imm Specification                                | imm Value Range*                              | Selected Instruction                                                                   |
|--------------------------------------------------|-----------------------------------------------|----------------------------------------------------------------------------------------|
| Constant value                                   | H'FFFFFF80 to H'0000007F<br>(-128 to 127)     | MOV.B #imm, Rn                                                                         |
| Constants symbols defined before reference       | H'FFFF8000 to H'FFFFFF7F<br>(-32,768 to -129) | MOV.W #imm, Rn<br>Expansion result:<br>[MOV.W @(disp, PC), Rn and 2-byte literal data] |
| Absolute address symbol defined before reference | H'00000080 to H'00007FFF<br>(128 to 32,767)   | MOV.L #imm, Rn<br>Expansion result:<br>[MOV.L @(disp, PC), Rn and 4-byte literal data] |
| Relative address symbol                          | Does not depend on imm value                  | MOV.L #imm, Rn<br>Expansion result:<br>[MOV.L @(disp, PC), Rn and 4-byte literal data] |
| Externally referenced symbol                     |                                               |                                                                                        |
| Constants symbols defined after reference        |                                               |                                                                                        |
| Absolute address symbol defined after reference  |                                               |                                                                                        |

Note: The values in parentheses ( ) are decimal.

### 11.8.4 Literal Pool Output

The literal pool is output to one of the following locations:

- After an unconditional branch and its delay slot instruction
- Where .POOL has been specified by the programmer

Note that the output location can be selected by the **literal** option. The assembler outputs the literal corresponding to an extended instruction to the nearest output location following the extended instruction. The assembler gathers the literals to be output as a literal pool.

**Note**

When a label is specified in a delay slot instruction, no literal pool will be output to the location following the delay slot.

**(1) Literal Pool Output after Unconditional Branch**

An example of literal pool output is shown below.

**Source program**

```

        .SECTION CD1, CODE, LOCATE=H'0000F000
CD1_START:
        MOV.L  #H'FFFF0000, R0
        MOV.W  #H'FF00, R1
        MOV.L  #CD1_START, R2
        MOV    #H'FF, R3
        RTS
        MOV    R0, R10
        .END

```

**Automatic literal pool generation result (source list)**

|    |                   |   |                                       |
|----|-------------------|---|---------------------------------------|
| 1  | 0000F000          | 1 | .SECTION CD1, CODE, LOCATE=H'0000F000 |
| 2  | 0000F000          | 2 | CD1_START                             |
| 3  | 0000F000 D003     | 3 | MOV.L #H'FFFF0000, R0                 |
| 4  | 0000F002 9103     | 4 | MOV.W #H'FF00, R1                     |
| 5  | 0000F004 D203     | 5 | MOV.L #CD1_START, R2                  |
| 6  | 0000F006 E3FF     | 6 | MOV #H'FF, R3                         |
| 7  | 0000F008 000B     | 7 | RTS                                   |
| 8  | 0000F00A 6A03     | 8 | MOV R0, R10                           |
| 9  |                   |   | **** BEGIN-POOL ****                  |
| 10 | 0000F00C FF00     |   | DATA FOR SOURCE-LINE 4                |
| 11 | 0000F00E 0000     |   | ALIGNMENT CODE                        |
| 12 | 0000F010 FFFF0000 |   | DATA FOR SOURCE-LINE 3                |
| 13 | 0000F014 0000F000 |   | DATA FOR SOURCE-LINE 5                |
| 14 |                   |   | **** END-POOL ****                    |
| 15 |                   | 9 | .END                                  |

## (2) Literal Pool Output to the .POOL Location

If literal pool output location after unconditional branches is not available within the valid displacement range (because the program has a small number of unconditional branches), the assembler outputs error 402. In this case, .POOL must be specified within the valid displacement range.

The valid displacement range is as follows:

- Word-size operation: 0 to 511 bytes
- Longword-size operation: 0 to 1023 bytes

When a literal pool is output to a .POOL location, a branch instruction is also inserted to jump over the literal pool.

An example of literal pool output is shown below.

### Source program

```

        .SECTION CD1, CODE, LOCATE=H'0000F000
CD1_START
        MOV.L   #H'FFFF0000, R0
        MOV.W   #H'FF00, R1
        MOV.L   #CD1_START, R2
        MOV     #H'FF, R3
        .POOL
        END
    
```



### Automatic literal pool generation result (source list)

|    |                   |   |                                       |
|----|-------------------|---|---------------------------------------|
| 1  | 0000F000          | 1 | .SECTION CD1, CODE, LOCATE=H'0000F000 |
| 2  | 0000F000          | 2 | CD1_START:                            |
| 3  | 0000F000 D003     | 3 | MOV.L #H'FFFF0000, R0                 |
| 4  | 0000F002 9103     | 4 | MOV.W #H'FF00, R1                     |
| 5  | 0000F004 D203     | 5 | MOV.L #CD1_START, R2                  |
| 6  | 0000F006 E3FF     | 6 | MOV #H'FF, R3                         |
| 7  | 0000F008          | 7 | .POOL                                 |
| 8  |                   |   | **** BEGIN-POOL ****                  |
| 9  | 0000F008 A006     |   | BRA TO END-POOL                       |
| 10 | 0000F00A 0009     |   | NOP                                   |
| 11 | 0000F00C FF00     |   | DATA FOR SOURCE-LINE 4                |
| 12 | 0000F00E 0000     |   | ALIGNMENT CODE                        |
| 13 | 0000F010 FFFF0000 |   | DATA FOR SOURCE-LINE 3                |
| 14 | 0000F014 0000F000 |   | DATA FOR SOURCE-LINE 5                |
| 15 |                   |   | **** END-POOL ****                    |
| 16 |                   | 8 | .END                                  |

### 11.8.5 Literal Sharing

When the literals for several extended instructions are gathered into a literal pool, the assembler makes the extended instructions share identical immediate value.

The following operand forms can be identified and shared:

- (1) Symbol
- (2) Constant
- (3) Symbol  $\pm$  Constant

In addition to the above, expressions that are determined to have the same value at assembly processing may be shared.

However, extended instructions having different operation sizes do not share literal data even when they have the same immediate value.

An example of literal data sharing among extended instructions is shown on below.



Source program

```

        .SECTION CD1, CODE, LOCATE=H'0000F000
CD1_START:
        MOV.L   #H'FFFF0000, R0
        MOV.W   #H'FF00, R1
        MOV.L   #H'FFFF0000, R2
        MOV     #H'FF, R3
        RTS
        MOV     R0, R10
        .END
    
```



Automatic literal pool generation result (source list)

|    |                   |   |                                       |
|----|-------------------|---|---------------------------------------|
| 1  | 0000F000          | 1 | .SECTION CD1, CODE, LOCATE=H'0000F000 |
| 2  | 0000F000          | 2 | CD1_START:                            |
| 3  | 0000F000 D003     | 3 | MOV.L #H'FFFF0000, R0                 |
| 4  | 0000F002 9103     | 4 | MOV.W #H'FF00, R1                     |
| 5  | 0000F004 D202     | 5 | MOV.L #H'FFFF0000, R2                 |
| 6  | 0000F006 E3FF     | 6 | MOV #H'FF, R3                         |
| 7  | 0000F008 000B     | 7 | RTS                                   |
| 8  | 0000F00A 6A03     | 8 | MOV R0, R10                           |
| 9  |                   |   | **** BEGIN-POOL ****                  |
| 10 | 0000F00C FF00     |   | DATA FOR SOURCE-LINE 4                |
| 11 | 0000F00E 0000     |   | ALIGNMENT CODE                        |
| 12 | 0000F010 FFFF0000 |   | DATA FOR SOURCE-LINE 3, 5             |
| 13 |                   |   | **** END-POOL ****                    |
| 14 |                   | 9 | .END                                  |

### 11.8.6 Literal Pool Output Suppression

When a program has too many unconditional branches, the following problems may occur:

- Many small literal pools are output
- Literals are not shared

In these cases, suppress literal pool output as shown below.

```

~
<delayed branch instruction>
<delay slot instruction>
.NOPOOL
~

```

#### Source program

```

CASE1:
MOV.L   #H'FFFF0000,R0  ----- Extended instruction 1
RTS
NOP
.NOPOOL                ----- No literal pool is output here
CASE2:
MOV.L   #H'FFFF0000,R0  ----- Extended instruction 2
RTS
NOP
----- Literal pool is output here

```

#### Automatic literal pool generation result (source list)

```

20 0000F000          20 CASE1:
21 0000F000 D002    21     MOV.L   #H'FFFF0000,R0
22 0000F002 000B    22     RTS
23 0000F004 0009    23     NOP
24                    24     .NOPOOL
25 0000F006          25 CASE2:
26 0000F006 D001    26     MOV.L   #H'FFFF0000,R0
27 0000F008 000B    27     RTS
28 0000F00A 0009    28     NOP
29                    **** BEGIN-POOL ****
30 0000F00C FFFF0000 DATA FOR SOURCE-LINE 21,26
31                    **** END-POOL  ****

```

## 11.8.7 Notes on Automatic Literal Pool Generation

- (1) If an error occurs for an extended instruction
  - a. Extended instructions must not be specified in delay slots (error 151).
  - b. Extended instructions must not be specified in relative sections having a boundary alignment value of less than 2 (error 152).
  - c. `MOV.L #imm, Rn` or `MOVA #imm, R0` must not be specified in relative sections having a boundary alignment value of less than 4 (error 152).
- (2) If an error occurs when `.POOL` is written  
`.POOL` must not be written after unconditional delayed branches (error 522).
- (3) If an error occurs when `.NOPOOL` is written  
`.NOPOOL` is valid only when written after delay slot instructions. If written at other locations, `.NOPOOL` causes error 521.
- (4) If the displacement of an executable instruction exceeds the valid range when an extended instruction is expanded  
The assembler generates a literal pool and outputs error 402 for the instruction having a displacement outside the valid range.  
Solution: Move the literal pool output location (for example, by `.NOPOOL`), or change the location or addressing mode of the instruction causing the error.
- (5) If the literal pool output location cannot be found  
If the assembler cannot find a literal pool output location satisfying the following conditions in respect to the extended instruction,
  - Same file
  - Same section
  - The nearest output location following the extended instructionthe assembler outputs, at the end of the section which includes the extended instruction, the literal pool and a `BRA` instruction with a `NOP` instruction in the delay slot to jump around the literal pool, and outputs warning 876.
- (6) If the displacement from the extended instruction exceeds the valid range  
If the displacement of the literal pool from the extended instruction exceeds the valid range, error 402 is generated.  
Solution: Output the literal pool within the valid range (for example, using `.POOL`.)

(7) Differences between size specification mode and size selection mode

Version 2.0 of the assembler can only use the size specification mode, but the size selection mode is added to the assembler version 3.1 or higher. If the source program created before for version 2.0 is assembled in the size selection mode by version 3.1 or higher, the imm values of data transfer instructions without size suffix will differ in the range of H'00000080 to H'000000FF (128 to 255) from these assembled by version 2.0.

An example of source listing output in the size specification mode and size selection mode is shown on below.

Example:

### Source program

```

.SECTION CD1, CODE, LOCATE=H'0000F000
MOV.L   #H'FF, R0
MOV.W   #H'FF, R1
MOV.B   #H'FF, R2
MOV     #H'FF, R3
RTS
MOV     R0, R10
.END

```



### Automatic literal pool output in size specification mode (source listing)

|    |                   |   |                                       |
|----|-------------------|---|---------------------------------------|
| 1  | 0000F000          | 1 | .SECTION CD1, CODE, LOCATE=H'0000F000 |
| 2  | 0000F000 D003     | 2 | MOV.L   #H'FF, R0                     |
| 3  | 0000F002 9103     | 3 | MOV.W   #H'FF, R1                     |
| 4  | 0000F004 E2FF     | 4 | MOV.B   #H'FF, R2                     |
| 5  | 0000F006 E3FF     | 5 | MOV     #H'FF, R3                     |
| 6  | 0000F008 000B     | 6 | RTS                                   |
| 7  | 0000F00A 6A03     | 7 | MOV     R0, R10                       |
| 8  |                   |   | ***** BEGIN-POOL *****                |
| 9  | 0000F00C 00FF     |   | DATA FOR SOURCE-LINE 3                |
| 10 | 0000F00E 0000     |   | ALIGNMENT CODE                        |
| 11 | 0000F010 000000FF |   | DATA FOR SOURCE-LINE 2                |
| 12 |                   |   | ***** END-POOL *****                  |
| 13 |                   | 8 | .END                                  |

The contents of R3 is H'FFFFFFF.

### Automatic literal pool output in size selection mode (source listing)

|    |                   |   |                                       |
|----|-------------------|---|---------------------------------------|
| 1  | 0000F000          | 1 | .SECTION CD1, CODE, LOCATE=H'0000F000 |
| 2  | 0000F000 D003     | 2 | MOV.L   #H'FF, R0                     |
| 3  | 0000F002 9103     | 3 | MOV.W   #H'FF, R1                     |
| 4  | 0000F004 E2FF     | 4 | MOV.B   #H'FF, R2                     |
| 5  | 0000F006 9301     | 5 | MOV     #H'FF, R3                     |
| 6  | 0000F008 000B     | 6 | RTS                                   |
| 7  | 0000F00A 6A03     | 7 | MOV     R0, R10                       |
| 8  |                   |   | ***** BEGIN-POOL *****                |
| 9  | 0000F00C 00FF     |   | DATA FOR SOURCE-LINE 3, 5             |
| 10 | 0000F00E 0000     |   | ALIGNMENT CODE                        |
| 11 | 0000F010 000000FF |   | DATA FOR SOURCE-LINE 2                |
| 12 |                   |   | ***** END-POOL *****                  |
| 13 |                   | 8 | .END                                  |

The contents of R3 is H'000000FF.

## 11.9 Automatic Repeat Loop Generation Function

### 11.9.1 Overview of Automatic Repeat Loop Generation Function

In the SH-DSP, SH3-DSP, or SH4AL-DSP, the start and end addresses of the repeat loop are set in the RS and RE registers by the LDRS and LDRE instructions. The address settings differ depending on the number of instructions in the repeat loop. When setting the address, consider the relationship between the address and the number of instructions in the repeat loop shown in table 11.37.

**Table 11.37 Repeat Loop Instructions and Address Setting**

| Register Name | One Instruction | Two Instructions | Three Instructions | Four or more Instructions |
|---------------|-----------------|------------------|--------------------|---------------------------|
| RS            | s_addr0+8       | s_addr0+6        | s_addr0+4          | s_addr                    |
| RE            | s_addr0+4       | s_addr0+4        | s_addr0+4          | e_addr3+4                 |

s\_addr0: Address of the instruction one instruction before the repeat loop start address

s\_addr: Repeat loop start address

e\_addr3: Address of the instruction three instructions before the repeat loop end address

The automatic repeat loop generation automatically generates the PC relative instructions LDRS and LDRE, and the SETRC instruction from a single extended instruction. The LDRS and LDRE instructions transfer the repeat loop start and end to the RS and RE registers addresses based on the number of instructions in the repeat loop, and the SETRC instruction specifies the repetition count.

For example, program A can be written as program B when using the automatic repeat loop generation.

#### Program A:

```

LDRS s_addr0+6
LDRE s_addr0+4
SETRC #10

s_addr0: NOP
PADD A0,M0,A0 ; Repeat loop start address
PCMP X1,M0 ; Repeat loop end address

```

## Program B:

```

                REPEAT s_addr,e_addr,#10
                NOP
s_addr:        PADD A0,M0,A0 ; Repeat loop start address
e_addr:        PCMP X1,M0    ; Repeat loop end address
    
```

### 11.9.2 Extended Instructions of Automatic Repeat Loop Generation Function

The assembler automatically generates necessary instructions from extended instructions (REPEAT s\_label,e\_label,#imm, REPEAT s\_label,e\_label,Rn, and REPEAT s\_label,e\_label) and calculates the PC relative displacement.

Table 11.38 lists the source statement of each extended instruction and its expanded results of two or three executable instructions.

**Table 11.38 Extended Instructions and Expanded Results**

| Extended Instruction        | Expanded Results                                |
|-----------------------------|-------------------------------------------------|
| REPEAT s_label,e_label,#imm | LDRS @(disp,PC), LDRE@(disp,PC), and SETRC #imm |
| REPEAT s_label,e_label,Rn   | LDRS @(disp,PC), LDRE@(disp,PC), and SETRC Rn   |
| REPEAT s_label,e_label      | LDRS @(disp,PC) and LDRE@(disp,PC)              |

### 11.9.3 REPEAT Description

#### Description Format

[<symbol>[:]] ΔREPEAT Δ<start address>,<end address>[,<repeat count>]

#### Statement Elements

1. Start and end addresses  
Enter the labels of the start and end addresses of the repeat loop.
2. Repeat count  
Enter the repeat count as an immediate value or as a general register name.

#### Description

1. REPEAT automatically generates the executable instructions LDRS and LDRE to repeat the instructions in the range from the start address to the end address inclusive.
2. When the repeat count is specified, REPEAT generates a SETRC instruction. When the repeat count is omitted, SETRC is not generated.

### 11.9.4 Coding Examples

To Repeat Four or More Instructions (Basic Example):

```

REPEAT RptStart,RptEnd,#5
PCLR Y0
PCLR A0
RptStart: MOVX @R4+,X1 MOVB @R6+,Y1
          PADD A0,Y0,Y0 PMULS X1,Y1,A0
          DCT PCLR A0
          AND R0,R4
RptEnd:  AND R0,R6

```

This program repeats execution of five instructions from RptStart to RptEnd five times.

The above program has the same meaning as the following:

```

LDRS RptStart
LDRE RptEnd3+4
SETRC #5
PCLR Y0
PCLR A0
RptStart: MOVX @R4+,X1 MOVB @R6+,Y1
RptEnd3:  PADD A0,Y0,Y0 PMULS X1,Y1,A0;           The label is not actually generated.
          DCT PCLR A0
          AND R0,R4
RptEnd:  AND R0,R6

```



To Repeat One Instruction: Specify the same labels as the start and end addresses.

```

        REPEAT Rpt,Rpt,R0
        MOVX @R4+,X1 MOVY @R6+,Y1
Rpt:    PADD A0,Y0,Y0 PMULS X1,Y1,A0 MOVX @R4+,X1 MOVY @R6+,Y1
    
```

The above program has the same meaning as the following:

```

        LDRS RptStart0+8
        LDRE RptStart0+4
        SETRC R0
RptStart0: MOVX @R4+,X1 MOVY @R6+,Y1 ; The label is not actually generated.
Rpt:    PADD A0,Y0,Y0 PMULS X1,Y1,A0 MOVX @R4+,X1 MOVY @R6+,Y1
    
```

To Repeat Two Instructions:

```

        REPEAT RptStart,RptEnd,#10
        PCLR Y0
RptStart: MOVX @R4+,X1 MOVY @R6+,Y1
RptEnd:    PADD A0,Y0,Y0 PMULS X1,Y1,A0
    
```

The above program has the same meaning as the following:

```

        LDRS RptStart0+6
        LDRE RptStart0+4
        SETRC #10
RptStart0: PCLR Y0 ; The label is not actually generated.
RptStart:  MOVX @R4+,X1 MOVY @R6+,Y1
RptEnd:    PADD A0,Y0,Y0 PMULS X1,Y1,A0
    
```

To Repeat Three Instructions:

```

        REPEAT RptStart,RptEnd,R0
        PCLR Y0
RptStart: MOVX @R4+,X1 MOVY @R6+,Y1
        PMULS X1,Y1,A0
RptEnd:  PADD A0,Y0,Y0

```

The above program has the same meaning as the following:

```

        LDRE RptStart0+4
        LDRS RptStart0+4
        SETRC R0
RptStart0: PCLR Y0 ;The label is not actually generated.
RptStart:  MOVX @R4+,X1 MOVY @R6+,Y1
        PMULS X1,Y1,A0
RptEnd:    PADD A0,Y0,Y0

```

**When Repeat Count is Omitted:** When the repeat count is omitted, the assembler does not generate SETRC. To separate the LDRS and LDRE from the SETRC, omit the repeat count.

```

        REPEAT RptStart,RptEnd
        ; The LDRS and LDRE are expanded here.
        MOV #10,R0
OuterLoop:
        SETRC #16
        PCLR Y0
        PCLR A0
RptStart: MOVX @R4+,X1 MOVY @R6+,Y1
        PADD A0,Y0,Y0 PMULS X1,Y1,A0
        DCT PCLR A0
        AND R0,R4
RptEnd:  AND R0,R6
        DT R0
        BF OuterLoop

```

### 11.9.5 Notes on the REPEAT Extended Instruction

**Start and End Addresses:** Only labels in the same section or local labels in the same local block can be specified as the start and end addresses.

The start address must be at a higher address than the REPEAT extended instruction. The end address must be at a higher address than the start address.

#### Instructions Inside Loops:

- If one of the following assembler directives that reserve data or data area or `.ORG` is used inside a loop, the assembler outputs a warning message and counts the directive as one of the instructions to be repeated. If `.ALIGN` is used inside a loop to adjust the boundary alignment, the assembler outputs a warning message and counts `.ALIGN` as one of the instructions to be repeated.

The following are the directives which cause this action:

`.DATA`, `.DATAB`, `.SDATA`, `.SDATAB`, `.SDATAC`, `.SDATAZ`, `.FDATA`, `.FDATAB`,  
`.XDATA`, `.RES`, `.SRES`, `.SRESC`, `.SRESZ`, `.FRES`, `.ALIGN`, and `.ORG`

- The assembler prevents automatic generation of literal pools within a loop. Therefore, even when an unconditional branch is used in a loop, no literal pool is generated. If `.POOL` is used in a loop, the assembler outputs a warning message and ignores `.POOL`.

**Instruction Immediately before Loop:** If three or fewer instructions are to be repeated, the instruction immediately before the loop must be an executable instruction or a DSP instruction. Therefore, when three or fewer instructions are to be repeated and if one of the following is located immediately before the start address of the loop, the assembler outputs an error.

- Assembler directives that reserve a data item or a data area or `.ORG`  
`.DATA`, `.DATAB`, `.SDATA`, `.SDATAB`, `.SDATAC`, `.SDATAZ`, `.FDATA`, `.FDATAB`,  
`.XDATA`, `.RES`, `.SRES`, `.SRESC`, `.SRESZ`, `.FRES`, or `.ORG`
- Literal pool generated by the automatic literal pool generation  
If an unconditional branch instruction and a delay slot instruction are located immediately before a loop, or if `.POOL` is located immediately before a loop, a literal pool may be automatically generated. To prevent literal pool generation before a loop, use `.NOPOOL` immediately after the delay slot instruction.
- One-byte alignment generated by `.ALIGN`

When `.ALIGN` is used at an odd address immediately before a loop, one-byte alignment may be generated (for example, `.ALIGN 4` is specified when the location counter value is 3). In this case, the contents of the byte before a loop is not an executable instruction, and an error message is output. If two or more-byte alignment is generated before a loop, their contents consist of a NOP instruction and the program can be correctly executed.

**Others:**

- One or more executable or DSP instructions must be located between a REPEAT extended instruction and the start address. Otherwise, the assembler outputs an error message.
- A REPEAT extended instruction must not be located between another REPEAT extended instruction and its end address. If REPEAT extended instructions are nested, the assembler outputs an error message.
- A branch instruction, TRAPA instruction (excluding `cpu=sh4aldsp`), or a load instruction toward SR, RS, or RE must not be located between a REPEAT extended instruction and its end address. If one of these instructions is used, the assembler outputs an error message.

## 11.10 Extended Automatic Repeat Loop Generation Function

### 11.10.1 Overview of Extended Automatic Repeat Loop Generation Function

In the SH4AL-DSP, the start and end addresses of the repeat loop are set in the RS and RE registers by the LDRS and LDRE instructions.

The extended automatic repeat loop generation automatically generates the PC relative instructions LDRS and LDRE, and the LDRC instruction from a single extended instruction. The LDRS and LDRE instructions transfer the repeat start and end addresses to the RS and RE registers, and the LDRC instruction specifies the repetition count.

For example, program A can be written as program B when using the extended automatic repeat loop generation.

#### Program A:

```
        LDRS s_addr
        LDRE e_addr
        LDRC #10
        NOP
s_addr: PADD A0,M0,A0 ; Repeat loop start address
e_addr: PCMP X1,M0    ; Repeat loop end address
```

#### Program B:

```
        EREPEAT s_addr,e_addr,#10
        NOP
s_addr: PADD A0,M0,A0 ; Repeat loop start address
e_addr: PCMP X1,M0    ; Repeat loop end address
```

### 11.10.2 Extended Instructions of Extended Automatic Repeat Loop Generation Function

The assembler automatically generates necessary instructions from extended instructions (EREPEAT s\_label,e\_label,#imm, EREPEAT s\_label,e\_label,Rn, and EREPEAT s\_label,e\_label).

Table 11.39 lists the source statement of each extended instruction and its expanded results of two or three executable instructions.

**Table 11.39 Extended Instructions and Expanded Results**

| Extended Instruction         | Expanded Results                               |
|------------------------------|------------------------------------------------|
| EREPEAT s_label,e_label,#imm | LDRS @(disp,PC), LDRE@(disp,PC), and LDRC #imm |
| EREPEAT s_label,e_label,Rn   | LDRS @(disp,PC), LDRE@(disp,PC), and LDRC Rn   |
| EREPEAT s_label,e_label      | LDRS @(disp,PC) and LDRE@(disp,PC)             |

### 11.10.3 EREPEAT Description

#### Description Format

```
[<symbol>[:]] ΔEREPEAT Δ<start address>,<end address>[,<repeat count>]
```

#### Statement Elements

1. Start and end addresses  
Enter the labels of the start and end addresses of the repeat loop.
2. Repeat count  
Enter the repeat count as an immediate value or as a general register name.

#### Description

1. EREPEAT automatically generates the executable instructions LDRS and LDRE to repeat the instructions in the range from the start address to the end address inclusive.
2. When the repeat count is specified, EREPEAT generates a LDRC instruction. When the repeat count is omitted, LDRC is not generated.

### 11.10.4 Coding Examples

Basic Example:

```

        EREPEAT RptStart,RptEnd,#5
        PCLR Y0
        PCLR A0
RptStart: MOVX @R4+,X1 MOVY @R6+,Y1
        PADD A0,Y0,Y0 PMULS X1,Y1,A0
        DCT PCLR A0
        AND R0,R4
RptEnd:  AND R0,R6
    
```

This program repeats execution of five instructions from RptStart to RptEnd five times.

The above program has the same meaning as the following:

```

        LDRS RptStart
        LDRE RptEnd3+4
        LDRC #5
        PCLR Y0
        PCLR A0
RptStart: MOVX @R4+,X1 MOVY @R6+,Y1
        PADD A0,Y0,Y0 PMULS X1,Y1,A0
        DCT PCLR A0
        AND R0,R4
RptEnd:  AND R0,R6
    
```

**When Repeat Count is Omitted:** When the repeat count is omitted, the assembler does not generate LDRC. To separate the LDRS and LDRE from the LDRC, omit the repeat count.

```
EREPEAT RptStart,RptEnd
; The LDRE and LDRE are expanded here.
MOV #10,R0
```

```
OuterLoop:
```

```
LDRC #16
PCLR Y0
PCLR A0
```

```
RptStart: MOVX @R4+,X1 MOVY @R6+,Y1
PADD A0,Y0,Y0 PMULS X1,Y1,A0
```

```
DCT PCLR A0
AND R0,R4
```

```
RptEnd: AND R0,R6
```

```
DT R0
BF OuterLoop
```



### 11.10.5 Notes on the EREPEAT Extended Instruction

**Start and End Addresses:** Only labels in the same section or local labels in the same local block can be specified as the start and end addresses.

The start address must be at a higher address than the EREPEAT extended instruction. The end address must be at a higher address than the start address.

#### Instructions Inside Loops:

- If one of the following assembler directives that reserve data or data area or .ORG is used inside a loop, the assembler outputs a warning message and counts the directive as one of the instructions to be repeated. If .ALIGN is used inside a loop to adjust the boundary alignment, the assembler outputs a warning message and counts .ALIGN as one of the instructions to be repeated.

The following are the directives which cause this action:

.DATA, .DATAB, .SDATA, .SDATAB, .SDATAC, .SDATAZ, .FDATA, .FDATAB,  
.XDATA, .RES, .SRES, .SRESC, .SRESZ, .FRES, .ALIGN, and .ORG

- The assembler prevents automatic generation of literal pools within a loop. Therefore, even when an unconditional branch is used in a loop, no literal pool is generated. If .POOL is used in a loop, the assembler outputs a warning message and ignores .POOL.

**Instruction Immediately before Loop:** The instruction immediately before the loop must be an executable instruction or a DSP instruction. Therefore, if one of the following is located immediately before the start address of the loop, the assembler outputs an error.

- Assembler directives that reserve a data item or a data area or .ORG  
.DATA, .DATAB, .SDATA, .SDATAB, .SDATAC, .SDATAZ, .FDATA, .FDATAB,  
.XDATA, .RES, .SRES, .SRESC, .SRESZ, .FRES, or .ORG
- Literal pool generated by the automatic literal pool generation  
If an unconditional branch instruction and a delay slot instruction are located immediately before a loop, or if .POOL is located immediately before a loop, a literal pool may be automatically generated. To prevent literal pool generation before a loop, use .NOPOOL immediately after the delay slot instruction.
- One-byte alignment generated by .ALIGN

When `.ALIGN` is used at an odd address immediately before a loop, one-byte alignment may be generated (for example, `.ALIGN 4` is specified when the location counter value is 3). In this case, the contents of the byte before a loop is not an executable instruction, and an error message is output. If two or more-byte alignment is generated before a loop, their contents consist of a NOP instruction and the program can be correctly executed.

**Others:**

- An EREPEAT extended instruction must not be used as another EREPEAT end instruction. If EREPEAT extended instructions are nested, the assembler outputs an error message.
- A delayed branch instruction, or a load instruction toward SR, RS, or RE must not be used as an EREPEAT end instruction. If one of these instructions is used, the assembler outputs an error message.

## Section 12 Compiler Error Messages

### 12.1 Error Format and Error Levels

In this section, error messages output in the following format and the details of errors are explained.

Error number            (Error level) Error message

Error details

There are five different error levels, corresponding to different degrees of seriousness.

| Error Level | Error Type  | Description                                                              |
|-------------|-------------|--------------------------------------------------------------------------|
| (I)         | Information | Processing is continued and the object program is output.                |
| (W)         | Warning     | Processing is continued and the object program is output.                |
| (E)         | Error       | Processing is continued but the object program is not output.            |
| (F)         | Fatal       | Processing is interrupted and an error message is output simultaneously. |
| (-)         | Internal    | Processing is interrupted and an error message is output simultaneously. |

### 12.2 Error Messages

#### **C0001 (I) Character combination "String literal" in comment**

A comment has "string literal".

#### **C0002 (I) No declarator**

A declaration without a declarator exists.

#### **C0003 (I) Unreachable statement**

A statement that will not be executed exists.

#### **C0004 (I) Constant as condition**

A constant expression is specified as the condition for an **if** or **switch** statement.

**C0005 (I) Precision lost**

Precision may be lost when assigning with type conversion a right hand side value to the left hand side value.

**C0006 (I) Conversion in argument**

A function parameter expression is converted into a parameter type specified in the prototype declaration.

**C0008 (I) Conversion in return**

A return statement expression is converted into a value type that should be returned from a function.

**C0010 (I) Elimination of needless expression**

A needless expression exists.

**C0011 (I) Used before set symbol: "variable name" in "function name"**

A local variable is used before setting its value.

**C0012 (I) Unused variable "variable name"**

An unused variable exists.

**C0015 (I) No return value**

A return statement is not returning a value in a function that should return a type other than the **void** type.

**C0016 (I) Conversion in case constant expression**

A constant expression of a **case** label is converted into the promoted type of the controlling expression.

**C0017 (I) Missing return statement**

There is a control path that a return statement does not exist in a function that should return a type other than the **void** type.

**C0100 (I) Function "function name" not optimized**

A function which is too large cannot be optimized.

**C0101 (I) Optimizing range divided in function "function name"**

The optimizing range of "function name" is divided into many sections.

**C0102 (I) Register is not allocated to "variable name" in "function name"**

Any register cannot be allocated to the variable of the register storage class.

**C0200 (I) No prototype function**

There is no prototype declaration.

**C1000 (W) Illegal pointer assignment**

A pointer is assigned to a pointer with a different data type.

**C1001 (W) Illegal comparison in "operator"**

The operands of the binary operator `==` or `!=` are a pointer and an integer other than 0, respectively.

**C1002 (W) Illegal pointer for "operator"**

The operands of the binary operator `==`, `!=`, `>`, `<`, `>=`, or `<=` are pointers assigned to different types.

**C1003 (W) Illegal pointer initialization**

The type specified for a pointer differs from the type in specification of the initial value for the pointer.

**C1005 (W) Undefined escape sequence**

An undefined escape sequence (a backslash and the character following the backslash) is used in a character constant or string literal.

**C1007 (W) Long character constant**

A character constant consists of two or more characters.

**C1008 (W) Identifier too long**

An identifier consists of more than 8189 characters. The 8190th and subsequent characters are invalid.

**C1010 (W) Character constant too long**

A character constant consists of more than four characters.

**C1012 (W) Floating point constant overflow**

The value of a floating-point constant exceeds the limit. Assumes the internally represented value corresponding to  $+\infty$  or  $-\infty$  depending on the sign of the result.

**C1013 (W) Integer constant overflow**

The integer value exceeds the limit of an unsigned long long integer constant. Assumes a value ignoring the overflowed upper bits.

**C1014 (W) Escape sequence overflow**

The value of an escape sequence indicating a bit pattern in a character constant or string literal exceeds 255. The low order byte is valid.

**C1015 (W) Floating point constant underflow**

The absolute value of a floating-point constant is less than the lower limit. Assumes 0.0 as the value of the constant.

**C1016 (W) Argument mismatch**

The data type assigned to a pointer specified as a formal parameter in a prototype declaration differs from the data type assigned to a pointer used as the corresponding actual parameter in a function call. Uses the internal representation of the pointer used for the function call actual parameter.

**C1017 (W) Return type mismatch**

The function return type and the type of a return statement expression are pointers but the data types assigned to these pointers are different. Uses the internal representation of the pointer specified in the return statement expression.

**C1019 (W) Illegal constant expression**

The operands of the relational operator `<`, `>`, `<=`, or `>=` in a constant expression are pointers to different data types. Assumes 0 as the result value.

**C1020 (W) Illegal constant expression of "-"**

The operands of the binary operator `-` in a constant expression are pointers to different data types. Assumes 0 as the result value.

**C1021 (W) Register saving pragma conflicts in interrupt function "function name"**

Invalid `#pragma` that controls saving or recovery of register contents corresponding to an interrupt function indicated by "function name". The `#pragma` specification is ignored.

**C1022 (W) First operand of "operator" is not lvalue**

The first operand "operator" cannot be the lvalue.

**C1023 (W) Can not convert Japanese code "code" to output type**

Some Japanese codes cannot be converted into the specified output codes.

**C1024 (W) Out of float**

The number of significant digits in a floating-point constant exceeds 17. The 18th and subsequent digits are invalid.

**C1026 (W) Address of packed member**

The address of a structure member with **pack=1** specification is referred to.

**C1027 (W) Invalid #pragma gbr\_base/gbr\_base1**

Both **gbr=auto** and either **#pragma gbr\_base** or **#pragma gbr\_base1** have been specified. The **#pragma** specification is ignored.

**C1028 (W) #pragma "identifier" has no effect**

The specified **#pragma** identifier is invalid.

**C1029 (W) Function with ifunc calls "function name" without ifunc**

A function with **ifunc** calls a function without **ifunc** specified.

**C1030 (W) Bit order mismatch**

The structure and the structure member have different **bit\_order**.

**C1031 (W) Multiple #pragma for one function**

**#pragma** is specified for a single function more than once.

**C1200 (W) Division by floating point zero**

Division by the floating-point number 0.0 is carried out in a constant expression. Assumes the internal representation value corresponding to  $+\infty$  or  $-\infty$  depending on the sign of the operands.

**C1201 (W) Ineffective floating point operation**

Invalid floating-point operations such as  $\infty - \infty$  or 0.0/0.0 are carried out in a constant expression. Assumes the internal representation value corresponding to a not-a-number indicating the result of an ineffective operation.

**C1300 (W) Command parameter specified twice**

The same compiler option is specified more than once. Uses the last specified compiler option.

**C1301 (W) "option" option ignored**

"option" is ignored at compilation.

**C1302 (W) "double=float" option ignored**

Both **double=float** and **cpu=sh2afpu, sh4, or sh4a** have been specified. The compiler ignores **double=float** and assumes that **fpu=single** has been specified.

**C1304 (W) "CPU type 1" is interpreted as "CPU type 2"**

**cpu=<CPU type 1>** is invalid. The compiler will interpret this as **cpu=<CPU type 2>**.

**C1308 (W) Duplicate number specified in option "option": "number"**

The same number is specified twice in "option".

**C1309 (W) Section name "Section name" specified**

The name may be the same as that of created by the compiler.

**C1310 (W) "repeat" option ignored**

The compiler ignores the **repeat** option.

**C1311 (W) "softpipe" option ignored**

The compiler ignores the **softpipe** option.

**C1312 (W) "fdiv" option ignored**

The compiler ignores the **fdiv** option.

**C1313 (W) "bss\_order=declaration" option ignored**

The compiler ignores the **bss\_order=declaration** option.

**C1314 (W) File\_inline "file name" ignored by #pragma global\_register mismatch**

**#pragma global\_register** is specified incorrectly. The **file\_inline** option is ignored.

**C1315 (W) File\_inline "file name" ignored by same file as source file**

The file to be compiled is same as the **file\_inline** option's. The **file\_inline option** is ignored.

**C1400 (W) Function "function name" in #pragma inline is not expanded**

A function specified using the **#pragma inline** could not be expanded. Ignores the **#pragma inline** specification.

**C1402 (W) #pragma "identifier" ignored**

The **#pragma "identifier"** specification is ignored.

**C1405 (W) Illegal #pragma syntax**

The specified **#pragma** keyword is not allowed in this compiler syntax.

**C1410 (W) A struct/union/class has different pack specifications**

A single structure, union, or class has members with different pack specifications.

**C1501 (W) Division by zero**

Division by zero is generated.



**C1600 (W) Debugging information describing location of "name" is lost**

The compiler did not output symbol information on variable "name" because the total amount of symbol information to be output by the compiler had exceeded the limit. So variable "name" does not appear in the [Watch] window.

One of the reasons for this error may be a locally defined structure that has many members. If this is the case, the error may be avoided in either of the following ways.

- Use the pointer to variable "name".
- Define variable "name" as static.

**C1700 (W) Memory qualifier ignored**

Ignores the specification of the memory qualifier.

**C1701 (W) Conversion from pointer without memory qualifier to pointer with memory qualifier**

A pointer without the memory qualifier was converted to a pointer with the memory qualifier. The memory qualifier becomes invalid.

**C1702 (W) Conversion from pointer with circular qualifier to pointer without circular qualifier**

A pointer with the `__circ` qualifier was converted to a pointer without the `__circ` qualifier. The `__circ` qualifier becomes invalid.

**C1703 (W) Fixed point constant overflow**

The value of a fixed-point constant exceeds the limit.

**C1704 (W) Out of Fixed point**

The number of significant digits in a fixed-point constant exceeds 17.

**C1705 (W) Modulo addressing may be illegal in function "function name"**

Modulo addressing may be illegal in a function indicated by "function name".

**C1800 (W) Variable "variable name" type mismatch in files**

The types of the variable are different in files. Do not use the `file_inline` option.

**C2000 (E) Illegal preprocessor keyword**

An illegal keyword is used in a preprocessor directive.

**C2001 (E) Illegal preprocessor syntax**

There is an error in a preprocessor directive or in a macro call specification.

**C2002 (E) Missing ", "**

A comma (,) is not used to delimit two arguments in a **#define** directive.

**C2003 (E) Missing ")"**

A right parenthesis ()) does not follow a name in a defined expression that determines whether the name is defined by a **#define** directive.

**C2004 (E) Missing ">"**

A right angle bracket (>) does not follow a file name in an **#include** directive.

**C2005 (E) Cannot open include file "file name"**

The file specified by an **#include** directive cannot be opened.

**C2006 (E) Multiple #define's**

The same macro name is redefined by **#define** directives.

**C2008 (E) Processor directive #elif mismatches**

There is no **#if**, **#ifdef**, **#ifndef**, or **#elif** directive corresponding to an **#elif** directive.

**C2009 (E) Processor directive #else mismatches**

There is no **#if**, **#ifdef**, or **#ifndef** directive corresponding to an **#else** directive.

**C2010 (E) Macro parameters mismatch**

The number of macro call parameters and the number of macro definition parameters are different.

**C2011 (E) Line too long**

After macro expansion, a source program line exceeds the compiler limit.

**C2012 (E) Keyword as a macro name**

A preprocessor keyword is used as a macro name in a **#define** or **#undef** directive.

**C2013 (E) Processor directive #endif mismatches**

There is no **#if**, **#ifdef**, or **#ifndef** directive corresponding to an **#endif** directive.

**C2014 (E) Missing #endif**

There is no **#endif** directive corresponding to an **#if**, **#ifdef**, or **#ifndef** directive, and the end of file is detected.

**C2016 (E) Preprocessor constant expression too complex**

The total number of operators and operands in a constant expression specified by an **#if** or **#elif** directive exceeds the limit.

**C2017 (E) Missing "**

A closing double quotation mark (") does not follow a file name in an **#include** directive.

**C2018 (E) Illegal #line**

The line count specified by a **#line** directive exceeds the limit.

**C2019 (E) File name too long**

The length of a file name exceeds the limit.

**C2020 (E) System identifier "name" redefined**

The name of the defined symbol is the same as that of an intrinsic function.

**C2021 (E) Invalid number specified in option "option": "number"**

An invalid value is specified in "option". Check the range of the value.

**C2022 (E) Error level message cannot be changed: "change\_message"**

The level of an error-level message cannot be changed.

**C2027 (E) Cannot read specified file: "file name"**

The specified file cannot be read correctly. Check the file specification.

**C2100 (E) Multiple storage classes**

Two or more storage class specifiers are used in a declaration.

**C2101 (E) Address of register**

A unary-operator **&** is used for a variable that has a register storage class.

**C2102 (E) Illegal type combination**

A combination of type specifiers is illegal.

**C2103 (E) Bad self reference structure**

A structure or union member has the same data type as its parent.

**C2104 (E) Illegal bit field width**

A constant expression indicating the width of a bit field is not an integer or it is negative.

**C2105 (E) Incomplete tag used in declaration**

An incomplete tag name declared with a struct or union, or an undeclared tag name is used in a **typedef** declaration or in the declaration of a data type not assigned to a pointer or to a function return value.

**C2106 (E) Extern variable initialized**

A compound statement specifies an initial value for an **extern** storage class variable.

**C2107 (E) Array of function**

An array with a function type is specified.

**C2108 (E) Function returning array**

A function type with an array return value type is specified.

**C2109 (E) Illegal function declaration**

A storage class other than **extern** is specified in the declaration of a function type variable used in a compound statement.

**C2110 (E) Illegal storage class**

The storage class in an external definition is specified as **auto** or **register**.

**C2111 (E) Function as a member**

A member of a structure or union is declared as a function type.

**C2112 (E) Illegal bit field**

The type specifier for a bit field is illegal. **char**, **unsigned char**, **short**, **unsigned short**, **int**, **unsigned int**, **long**, **unsigned long**, **long long**, **unsigned long long**, **bool**, **enum**, or a combination of **const** or **volatile** with one of the above types is allowed as a type specifier for a bit field.

**C2113 (E) Bit field too wide**

The width of a bit field is greater than the size (8, 16, 32, or 64 bits) indicated by its type specifier.

**C2114 (E) Multiple variable declarations**

A variable name is declared more than once in the same scope.

**C2115 (E) Multiple tag declarations**

A structure, union, or enum tag name is declared more than once in the same scope.

**C2117 (E) Empty source program**

There are no external definitions in the source program.

**C2118 (E) Prototype mismatch "function name"**

A function type differs from the one specified in the declaration.

**C2119 (E) Not a parameter name "parameter name"**

An identifier not in the function parameter list is declared as a parameter.

**C2120 (E) Illegal parameter storage class**

A storage class other than **register** is specified in a function parameter declaration.

**C2121 (E) Illegal tag name**

The combination of a structure, union, or enum with a tag name differs from the declared combination.

**C2122 (E) Bit field width 0**

The width of a bit field specifying a member name is 0.

**C2123 (E) Undefined tag name**

An undefined tag name is specified in an enum declaration.

**C2124 (E) Illegal enum value**

A non-integral constant expression is specified as a value for an enum member.

**C2125 (E) Function returning function**

A function type with a function type return value is specified.

**C2126 (E) Illegal array size**

The value specifying the number of array elements is not an integer or out of range of 1 to 2147483647.

**C2127 (E) Missing array size**

The number of elements in an array is not specified.

**C2128 (E) Illegal pointer declaration for "\*"**

A type specifier other than **const** or **volatile** is specified following an asterisk (\*), which indicates a pointer declaration.

**C2129 (E) Illegal initializer type**

The initial value specified for a variable is not a type that can be assigned to a variable.

**C2130 (E) Initializer should be constant**

A value other than a constant expression is specified as either the initial value of a structure, union, or array variable or as the initial value of a static variable.

**C2131 (E) No type nor storage class**

Storage class or type specifiers is not given in an external data definition.

**C2132 (E) No parameter name**

A parameter is declared even though the function parameter list is empty.

**C2133 (E) Multiple parameter declarations**

Either a parameter name is declared in a macro or function definition parameter list more than once or a parameter is declared inside and outside the function declarator.

**C2134 (E) Initializer for parameter**

An initial value is specified in the declaration of a parameter.

**C2135 (E) Multiple initialization**

A variable is initialized more than once.

**C2136 (E) Type mismatch**

An **extern** or **static** storage class variable or function is declared more than once with different data types.

**C2137 (E) Null declaration for parameter**

An identifier is not specified in the function parameter declaration.

**C2138 (E) Too many initializers**

The number of initial values specified for a structure, union, or array is greater than the number of structure members or array elements. This error also occurs if two or more initial values are specified when the first member of a union is scalar.

**C2139 (E) No parameter type**

A type is not specified in a function parameter declaration.

**C2140 (E) Illegal bit field**

A bit field is used in a union.

**C2141 (E) Struct has no member name**

An anonymous bit field is used as the first member of a structure.

### **C2142 (E) Illegal void type**

**void** is used illegally. **void** can only be used in the following three cases:

- (1) To specify a type assigned to a pointer
- (2) To specify a function return type
- (3) To explicitly specify that a function whose prototype is declared does not have a parameter

### **C2143 (E) Illegal static function**

There is a function declaration with a **static** storage class function that has no definition in the source program.

### **C2144 (E) Type mismatch**

Variables or functions with the same name which have an **extern** storage class are assigned to different data types.

### **C2145 (E) Const/volatile specified for incomplete type**

An incomplete type is specified as a **const** or **volatile** type.

### **C2200 (E) Index not integer**

An array index expression type is not integer.

### **C2201 (E) Cannot convert parameter "n"**

The n-th parameter of a function call cannot be converted to the type of parameter specified in the prototype declaration.

### **C2202 (E) Number of parameters mismatch**

The number of parameters for a function call is not equal to the number of parameters specified in the prototype declaration.

### **C2203 (E) Illegal member reference for "."**

The expression to the left-hand side of the (.) operator is not a structure or union.

### **C2204 (E) Illegal member reference for "->"**

The expression to the left-hand side of the -> operator is not a pointer to a structure or union.

### **C2205 (E) Undefined member name**

An undeclared member name is used to reference a structure or union.

**C2206 (E) Modifiable lvalue required for "operator"**

The operand for a prefix or suffix operator ++ or -- has a left value that cannot be assigned (a left value whose type is not array or const).

**C2207 (E) Scalar required for "!"**

The unary operator ! is used on an expression that is not scalar.

**C2208 (E) Pointer required for "\*"**

The unary operator \* is used on an expression that is not a pointer or on an expression of a pointer for **void**.

**C2209 (E) Arithmetic type required for "operator"**

The unary operator + or – is used on a non-arithmetic expression.

**C2210 (E) Integer required for "~"**

The unary operator ~ is used on a non-integral expression.

**C2211 (E) Illegal sizeof**

A **sizeof** operator is used for a bit field member, function, **void**, or array with an undefined size.

**C2212 (E) Illegal cast**

Either array, struct, or union is specified in a cast operator, or the operand of a cast operator is **void**, struct, or union and cannot be converted.

**C2213 (E) Arithmetic type required for "operator"**

The binary operator \*, /, \*=, or /= is used in an expression that is not an arithmetic expression.

**C2214 (E) Integer required for "operator"**

The binary operator <<, >>, &, |, ^, %, <<=, >>=, &=, |=, ^=, or %= is used in an expression that is not an integer expression.

**C2215 (E) Illegal type for "+"**

The combination of operand types used with the binary operator + is not allowed. Only the following type combinations are allowed for the binary operator +:

- (1) Two arithmetic operands
- (2) Pointer and integer

**C2216 (E) Illegal type for parameter**

Type **void** is specified for a function call parameter type.



### **C2217 (E) Illegal type for "-"**

The combination of operand types used with the binary operator `-` is not allowed. Only the following three combinations are allowed for the binary operator:

- (1) Two arithmetic operands
- (2) Two pointers assigned to the same data type
- (3) The first operand is a pointer and the second operand is an integer

### **C2218 (E) Scalar required**

The first operand of the conditional operator `?:` is not a scalar.

### **C2219 (E) Type not compatible in "?:"**

The types of the second and third operands of the conditional operator `?:` do not match with each other. Only the following six combinations are allowed for the second and third operands when using the `?:` operator:

- (1) Two arithmetic operands
- (2) Two **void** operands
- (3) Two pointers assigned to the same data type
- (4) A pointer and an integer constant whose value is zero, or another pointer assigned to **void** that was converted from an integer constant whose value is zero
- (5) A pointer and another pointer assigned to **void**
- (6) Two structure or union variables with the same data type

### **C2220 (E) Modifiable lvalue required for "operator"**

An expression whose left value cannot be assigned (a left value whose type is not array or **const**) is used as an operand of an assignment operator `=`, `*=`, `/=`, `%=`, `+=`, `-=`, `<<=`, `>>=`, `&=`, `^=`, or `|=`.

### **C2221 (E) Illegal type for "operator"**

The operand of the suffix operator `++` or `--` is a pointer assigned to function type, **void** type, or to a data type other than scalar type.

**C2222 (E) Type not compatible for "="**

The operand types for the assignment operator = do not match. Only the following five combinations are allowed for the operands of the assignment operator =:

- (1) Two arithmetic operands
- (2) Two pointers assigned to the same data type
- (3) The left operand is a pointer and the right operand is an integer constant whose value is zero, or another pointer assigned to **void** that was converted from an integer constant whose value is zero
- (4) A pointer and another pointer assigned to **void**
- (5) Two structure or union variables with the same data type

**C2223 (E) Incomplete tag used in expression**

An incomplete tag name is used for a structure or union in an expression.

**C2224 (E) Illegal type for assign**

The operand types of the assignment operator += or -= are illegal.

**C2225 (E) Undeclared name "name"**

An undeclared name is used in an expression.

**C2226 (E) Scalar required for "operator"**

The binary operator && or || is used in a non-scalar expression.

**C2227 (E) Illegal type for equality**

The combination of operand types for the equality operator == or != is not allowed. Only the following three combinations of operand types are allowed for the equality operator == or !=:

- (1) Two arithmetic operands
- (2) Two pointers assigned to the same data type
- (3) A pointer and an integer constant whose value is zero or another pointer assigned to **void**

**C2228 (E) Illegal type for comparison**

The combination of operand types for the relational operator >, <, >=, or <= is not allowed. Only the following two combinations of operand types are allowed for a relational operator:

- (1) Two arithmetic operands
- (2) Two pointers assigned to the same data type

**C2230 (E) Illegal function call**

An expression which is not a function type or a pointer assigned to a function type is used for a function call.

**C2231 (E) Address of bit field**

The unary operator & is used in a bit field.

**C2232 (E) Illegal type for "operator"**

The operand of the prefix operator ++ or -- is a pointer assigned to a function type, **void** type, or to a data type other than scalar type.

**C2233 (E) Illegal array reference**

An expression used as an array is an array or a pointer assigned to a data type other than a function or **void**.

**C2234 (E) Illegal typedef name reference**

A **typedef** name is used as a variable in an expression.

**C2235 (E) Illegal cast**

An attempt is made to cast a pointer with a floating-point or fixed-point type.

**C2236 (E) Illegal cast in constant**

In a constant expression, an attempt is made to cast a pointer with a **char** or **short** type.

**C2237 (E) Illegal constant expression**

In a constant expression, a pointer constant is cast with an integer and the result is manipulated.

**C2238 (E) Lvalue or function type required for "&"**

The unary operator & is not used in the lvalue or an expression other than function type.

**C2239 (E) Illegal section name**

The section name includes a character that is not available for use.

**C2240 (E) Illegal section naming**

There is an error in section naming. The same section name is specified for different use of the section.

**C2300 (E) Case not in switch**

A **case** label is specified outside a **switch** statement.

**C2301 (E) Default not in switch**

A **default** label is specified outside a **switch** statement.

**C2302 (E) Multiple labels**

A label name is defined more than once in a function.

**C2303 (E) Illegal continue**

A **continue** statement is specified outside a **while**, **for**, or **do** statement.

**C2304 (E) Illegal break**

A **break** statement is specified outside a **while**, **for**, **do**, or **switch** statement.

**C2305 (E) Void function returns value**

A **return** statement specifies a return value for a function with a **void** return type.

**C2306 (E) Case label not constant**

A **case** label expression is not an integer constant expression.

**C2307 (E) Multiple case labels**

Two or more **case** labels with the same value are specified for one **switch** statement.

**C2308 (E) Multiple default labels**

Two or more **default** labels are specified for one **switch** statement.

**C2309 (E) No label for goto**

There is no label corresponding to the destination specified by a **goto** statement.

**C2310 (E) Scalar required**

The control expression (that determines statement execution) for a **while**, **for**, or **do** statement is not a scalar.

**C2311 (E) Integer required**

The control expression (that determines statement execution) for a **switch** statement is not an integer.

**C2312 (E) Missing (**

The control expression (that determines statement execution) does not have a left parenthesis (**(**) for an **if**, **while**, **for**, **do**, or **switch** statement.

**C2313 (E) Missing ;**

A **do** statement is ended without a semicolon (;).

**C2314 (E) Scalar required**

A control expression (that determines statement execution) for an **if** statement is not a scalar.

**C2316 (E) Illegal type for return value**

An expression in a **return** statement cannot be converted to the type of value expected to be returned by the function.

**C2400 (E) Illegal character "character"**

An illegal character is detected.

**C2401 (E) Incomplete character constant**

An end of line indicator is detected in the middle of a character constant.

**C2402 (E) Incomplete string**

An end of line indicator is detected in the middle of a string literal.

**C2403 (E) EOF in comment**

An end of file indicator is detected in the middle of a comment.

**C2404 (E) Illegal character code "character code"**

An illegal character code is detected.

**C2405 (E) Null character constant**

There are no characters in a character constant (i.e., no characters are specified between two quotation marks).

**C2407 (E) Incomplete logical line**

A backslash (\) or a backslash followed by an end of line indicator (\ (RET) ) is specified as the last character in a non-empty source file.

**C2408 (E) Comment nest too deep**

The nesting level of the comment exceeds the limit of 255.

**C2500 (E) Illegal token "phrase"**

An illegal token sequence is used.

**C2501 (E) Division by zero**

An integer or a fixed point is divided by zero in a constant expression.

**C2600 (E) "string literal"**

An error message specified by the **#error** string literal is output to the list file if the **nolistfile** option is not specified.

**C2650 (E) Invalid pointer reference**

The specified address does not match the boundary alignment value.

**C2700 (E) Function "function name" in #pragma interrupt already declared**

A function specified in an interrupt function declaration **#pragma interrupt** has been declared as a normal function.

**C2701 (E) Multiple interrupt for one function**

An interrupt function declaration **#pragma interrupt** has been declared more than once for the same function.

**C2702 (E) Multiple #pragma interrupt options**

The same type of interrupt is declared more than once.

**C2703 (E) Illegal #pragma interrupt declaration**

An interrupt function declaration **#pragma interrupt** is specified incorrectly.

**C2704 (E) Illegal reference to interrupt function**

The interrupt function is incorrectly referenced.

**C2705 (E) Illegal parameter in interrupt function**

Parameter types to be used for an interrupt function do not match.

**C2706 (E) Missing parameter declaration in interrupt function**

There is no declaration for a variable to be used for an optional specification of an interrupt function.

**C2707 (E) Parameter out of range in interrupt function**

The parameter value `tn` of an interrupt function exceeds the limit of 256.

**C2709 (E) Illegal section name declaration**

The **#pragma section** specification is illegal.

**C2710 (E) Section name too long**

The specified section name exceeds the limit of 31 characters.

**C2711 (E) Section name table overflow**

The number of sections specified in one file exceeds the limit of 64.

**C2712 (E) GBR based displacement overflow**

The variable declared in `#pragma gbr_base` or `#pragma gbr_base1` overflows.

**C2713 (E) Illegal #pragma interrupt function type**

The function type specified `#pragma interrupt` is illegal.

**C2799 (E) GBR used in-line function**

A GBR-related intrinsic function cannot be used when `gbr=auto` is specified.

**C2800 (E) Illegal parameter number in in-line function**

The number of parameters to be used for an intrinsic function do not match.

**C2801 (E) Illegal parameter type in in-line function**

There are different parameter types in an intrinsic function.

**C2802 (E) Parameter out of range in in-line function**

A parameter exceeds the range that can be specified in an intrinsic function.

**C2803 (E) Invalid offset value in in-line function**

An argument for an intrinsic function is incorrectly specified.

**C2804 (E) Illegal in-line function**

An intrinsic function that cannot be used by the specified `cpu` option exists.

**C2805 (E) Function "function name" in #pragma inline/inline\_asm already declared**

The function indicated by "function name" exists before the `#pragma` specification.

**C2806 (E) Multiple #pragma for one function**

Two or more `#pragma` directives are incorrectly specified for one function.

**C2807 (E) Illegal #pragma inline/inline\_asm declaration**

`#pragma inline` or `#pragma inline_asm` is specified illegally.

**C2808 (E) Illegal option for #pragma inline\_asm**

The `code=machinecode` option is specified in addition to the `#pragma inline_asm` specification.

**C2809 (E) Illegal #pragma inline/inline\_asm function type**

An identifier type that specifies `#pragma inline` or `#pragma inline_asm` is illegal.

**C2810 (E) Global variable "variable name" in #pragma gbr\_base/gbr\_base1 already declared**

A variable definition indicated by "variable name" exists before the `#pragma` specification.

**C2811 (E) Multiple #pragma for one global variable**

Two or more `#pragma` directives are incorrectly specified for one variable.

**C2812 (E) Illegal #pragma gbr\_base/gbr\_base1 declaration**

The `#pragma gbr_base` or `#pragma gbr_base1` specification is illegal.

**C2813 (E) Illegal #pragma gbr\_base/gbr\_base1 global variable type**

An identifier type that specifies `#pragma gbr_base` or `#pragma gbr_base1` is illegal.

**C2814 (E) Function "function name" in #pragma noregsave/noregalloc/regsave already declared**

The function indicated by "function name" exists before the `#pragma` specification.

**C2815 (E) Illegal #pragma noregsave/noregalloc/regsave declaration**

The `#pragma noregsave`, `#pragma noregalloc`, or `#pragma regsave` specification is illegal.

**C2816 (E) Illegal #pragma noregsave/noregalloc/regsave function type**

An identifier type that specifies `#pragma noregsave`, `#pragma noregalloc`, or `#pragma regsave` is illegal.

**C2817 (E) Symbol "identifier" in #pragma abs16/abs20/abs28/abs32 already declared**

A name indicated by "identifier" exists before the `#pragma` specification.

**C2818 (E) Multiple #pragma for one symbol**

More than one `#pragma` is incorrectly specified for one identifier.

**C2819 (E) Illegal #pragma abs16/abs20/abs28/abs32 declaration**

The `#pragma abs16/abs20/abs28/abs32` specification is illegal.



**C2820 (E) Illegal #pragma abs16/abs20/abs28/abs32 symbol type**

An identifier type that specifies **#pragma abs16/abs20/abs28/abs32** is illegal.

**C2821 (E) Global variable "variable name" in #pragma global\_register already declared**

The variable that specifies **#pragma global\_register** has already been defined.

**C2822 (E) Illegal register "register" in #pragma global\_register**

The register that specifies **#pragma global\_register** is illegal.

**C2823 (E) Illegal #pragma global\_register declaration**

The specification of **#pragma global\_register** is illegal.

**C2824 (E) Illegal #pragma global\_register type**

A variable that cannot specify **#pragma global\_register** exists.

**C2828 (E) Illegal #pragma entry declaration**

There is an error in the **#pragma entry** declaration syntax.

**C2829 (E) Function "function name" in #pragma entry already declared**

A symbol with the same name as the function exists before the **#pragma entry** declaration or **#pragma** has already been specified.

**C2830 (E) Illegal #pragma entry function type**

The specified symbol is not a function.

**C2831 (E) Multiple #pragma entry declaration**

There are two or more **#pragma entry** declarations.

**C2832 (E) Illegal #pragma stacksize declaration**

There is an error in the **#pragma stacksize** declaration syntax.

**C2833 (E) Multiple #pragma stacksize declaration**

There are multiple **#pragma stacksize** declarations.

**C2840 (E) Illegal #pragma ifunc declaration**

There is an error in the **#pragma ifunc** declaration syntax.

**C2841 (E) Illegal #pragma ifunc function type**

An illegal identifier is specified in the **#pragma ifunc** declaration.

**C2842 (E) Function "function name" in #pragma ifunc already declared**

The name indicated by "function name" is declared before the **#pragma** specification.

**C2843 (E) Illegal floating type used in function**

The **float** or **double** type is used in the function. The **float** or **double** type must not be used when the function is declared by **#pragma ifunc**.

**C2844 (E) Illegal #pragma pack/unpack declaration**

There is an error in the **#pragma pack/unpack** declaration syntax.

**C2845 (E) Illegal #pragma bit\_order declaration**

There is an error in the **#pragma bit\_order** declaration syntax.

**C2846 (E) Packed structure used in in-line function**

The structure specified with **pack** is used for the intrinsic function.

**C2847 (E) Illegal #pragma tbr declaration**

There is an error in the **#pragma tbr** specification.

**C2848 (E) Function "function name" in #pragma tbr already declared**

The function indicated by "function name" exists before the **#pragma tbr** specification.

**C2849 (E) Illegal offset in #pragma tbr**

An illegal offset is specified.

**C2850 (E) Illegal #pragma tbr function type**

The specified symbol is not a function.

**C2851 (F) Too many function in tbr**

The number of functions specified in **#pragma tbr** exceeds the limit.

**C2852 (E) Variable "variable name" in #pragma address already declared**

The variable specified in **#pragma address** has already been defined.

**C2853 (E) Illegal #pragma address symbol type**

A compound type member or a symbol which is not a variable name is specified in **#pragma address**.

**C2854 (E) Illegal address in #pragma address**

The specified address has one of the following errors.

- (1) The specified address is not a multiple of 4 when the corresponding variable or structure has boundary alignment value 4.
- (2) The specified address is not a multiple of 2 when the corresponding variable or structure has boundary alignment value 2.
- (3) The same address is specified for different variables.
- (4) The address ranges for different variables overlap each other.
- (5) **#pragma abs16/abs20/abs28** is specified but the absolute address is not included in that range.
- (6) **abs16/abs20/abs28** option is specified but the absolute address is not included in that range.

**C2855 (E) All registers are used in #pragma global\_register**

All registers are occupied by **#pragma global\_register**.

**C2856 (E) Illegal usage of in-line function "function name"**

The intrinsic function "function name" is used incorrectly.

**C2857 (E) Function "function name" in #pragma already declared**

The function is defined before the **#pragma** declaration is not specifiable.

**C2858 (E) Illegal #pragma "identifier" function type**

The symbol specified for **#pragma "identifier"** is not a function.

**C2859 (E) Illegal #pragma "identifier" declaration**

The **#pragma "identifier"** declaration has a syntax error.

**C2900 (E) Incompatible memory qualifiers**

There had been an attempt to convert to a pointer type with incompatible memory qualifiers.

**C2901 (E) Illegal type qualifier**

There is an error in the specification of the type qualifier.

**C2902 (E) Illegal arithmetic conversion**

There is an error in the arithmetic conversion.

**C2903 (E) Illegal \_\_circ specification**

There is an error in the **\_\_circ** specification.

**C3000 (F) Statement nest too deep**

The nesting level of an **if**, **while**, **for**, **do**, or **switch** statement exceeds the limit.

**C3001 (F) Block nest too deep**

The nesting level of a compound statement exceeds the limit.

**C3006 (F) Too many parameters**

The number of parameters in a function declaration or a function call exceeds the limit.

**C3007 (F) Too many macro parameters**

The number of parameters in a macro definition or a macro call exceeds the limit.

**C3008 (F) Line too long**

After a macro expansion, the length of a line exceeds the limit.

**C3009 (F) String literal too long**

The length of a string literal exceeds 32766 characters. The length of a string literal is the number of bytes when linking string literals specified continuously. The length of the string literal is not the length in the source program but the number of bytes included in the string literal data. Escape sequence is counted as one character.

**C3013 (F) Too many switches**

The number of **switch** statements exceeds the limit.

**C3014 (F) For nest too deep**

The nesting level of a **for** statement exceeds the limit.

**C3015 (F) Symbol table overflow**

The number of symbols to be generated by the compiler exceeds the limit.

**C3016 (F) Internal label overflow**

The number of internal labels to be generated by the compiler exceeds the limit.

**C3017 (F) Too many case labels**

The number of **case** labels in one **switch** statement exceeds the limit.

**C3018 (F) Too many goto labels**

The number of **goto** labels defined in one function exceeds the limit.

**C3019 (F) Cannot open source file "file name"**

A source file cannot be opened.

**C3020 (F) Source file input error "file name"**

A source or include file cannot be read.

**C3021 (F) Memory overflow**

The compiler cannot allocate sufficient memory to compile the program.

**C3022 (F) Switch nest too deep**

The nesting level of a **switch** statement exceeds the limit.

**C3023 (F) Type nest too deep**

The number of types (pointer, array, and function) that qualify the basic type exceeds 16.

**C3024 (F) Array dimension too deep**

An array has more than six dimensions.

**C3025 (F) Source file not found**

A source file name is not specified in the command line.

**C3026 (F) Expression too complex**

An expression is too complex.

**C3027 (F) Source file too complex**

The nesting level of statements in the program is too deep or an expression is too complex.

**C3030 (F) Too many compound statements**

The number of compound statements in one function exceeds 2048.

**C3031 (F) Data size overflow**

The size of an array or a structure exceeds the limit of 2147483647 bytes.

**C3100 (F) Misaligned pointer access**

There has been an attempt to reference or specify using a pointer that has an invalid alignment.

**C3201 (F) Object size overflow**

The object file size exceeds the limit of 4 Gbytes.

**C3203 (F) Assembly source line too long**

The assembly source line is too long to output.

**C3204 (F) Illegal stack access**

The size of a stack to be used in a function (including a local variable area, register save area, and parameter push area to call other functions) or a parameter area to call the function exceeds 2 Gbytes.

**C3205 (F) Cannot apply repeat operation for a loop**

An extended repeat loop cannot be generated against a loop.

Modify the loop size small, or cancel the **repeat** option.

**C3300 (F) Cannot open internal file**

An error occurred due to one of the following three causes:

- (1) An intermediate file internally generated by the compiler cannot be opened.
- (2) A file that has the same file name as the intermediate file already exists.
- (3) A file which the compiler uses internally cannot be opened.

**C3301 (F) Cannot close internal file**

An intermediate file internally generated by the compiler cannot be closed. Make sure the compiler is correctly installed.

**C3302 (F) Cannot input internal file**

An intermediate file internally generated by the compiler cannot be read. Make sure the compiler is correctly installed.

**C3303 (F) Cannot output internal file**

An intermediate file internally generated by the compiler cannot be written to. Increase the disk space.

**C3304 (F) Cannot delete internal file**

An intermediate file internally generated by the compiler cannot be deleted. Check that the intermediate file generated by the compiler is not being accessed.

**C3305 (F) Invalid command parameter "option name"**

An invalid compiler option is specified.

### **C3306 (F) Interrupt in compilation**

An interrupt generated by a (CNTL) + C command (from a standard input terminal) is detected during compilation.

### **C3307 (F) Compiler version mismatch**

File versions in the compiler do not match the other file versions. Refer to the Install Guide for the installation procedure, and reinstall the compiler.

### **C3308 (F) Cannot create file "file name"**

The compiler cannot create necessary files.

### **C3320 (F) Command parameter buffer overflow**

The command line specification exceeds 4096 characters.

### **C3321 (F) Illegal environment variable**

An error occurred due to one of the following five causes:

- (1) The environment variable **SHC\_LIB** was not specified.
- (2) Other than "SH1", "SH2", "SH2E", "SH2DSP", "SHDSP", "SH2A", "SH2AFPU", "SH3", "SH3DSP", "SH4", "SH4A", or "SH4ALDSP" is set for the environment variable **SHCPU**.
- (3) The environment variable **SHC\_TMP** was not set.
- (4) The folder name specified for the environment variable **SHC\_TMP** does not exist.
- (5) Double-quotation marks (" ") are used in the path name of the environment variable **SHC\_TMP**.

### **C3322 (F) Current directory cannot be read to get its name**

Information on the current directory cannot be read.

### **C4000-C4999 (—) Internal error**

An internal error occurred during compilation. Report the error occurrence to your local Renesas sales office.

### **C5003 (F) #include file "file name" includes itself**

### **C5004 (F) Out of memory**

### **C5005 (F) Could not open source file "name"**

### **C5006 (E) Comment unclosed at end of file**

- C5007 (E) (I) Unrecognized token**
- C5008 (E) (I) Missing closing quote**
- C5009 (I) Nested comment is not allowed**
- C5010 (E) "#" not expected here**
- C5011 (E) Unrecognized preprocessing directive**
- C5012 (E) Parsing restarts here after previous syntax error**
- C5013 (F) (E) Expected a file name**
- C5014 (E) Extra text after expected end of preprocessing directive**
- C5016 (F) "name" is not a valid source file name**
- C5017 (E) Expected a "]"**
- C5018 (E) Expected a ")"**
- C5019 (E) Extra text after expected end of number**
- C5020 (E) Identifier "name" is undefined**
- C5021 (W) Type qualifiers are meaningless in this declaration**
- C5022 (E) Invalid hexadecimal number**
- C5024 (E) Invalid octal digit**
- C5025 (E) Quoted string should contain at least one character**



- C5026 (E) Too many characters in character constant**
- C5027 (W) Character value is out of range**
- C5028 (E) Expression must have a constant value**
- C5029 (E) Expected an expression**
- C5030 (E) Floating constant is out of range**
- C5031 (E) Expression must have integral type**
- C5032 (E) Expression must have arithmetic type**
- C5033 (E) Expected a line number**
- C5034 (E) Invalid line number**
- C5035 (F) #error directive: "line number"**
- C5036 (E) The #if for this directive is missing**
- C5037 (E) The #endif for this directive is missing**
- C5038 (W) Directive is not allowed -- an #else has already appeared**
- C5039 (W) Division by zero**
- C5040 (E) Expected an identifier**
- C5041 (E) Expression must have arithmetic or pointer type**
- C5042 (E) Operand types are incompatible ("type 1" and "type 2")**

- C5044 (E) Expression must have pointer type**
- C5045 (W) #undef may not be used on this predefined name**
- C5046 (W) This predefined name may not be redefined**
- C5047 (W) Incompatible redefinition of macro "name" (declared at line "line number")**
- C5049 (E) Duplicate macro parameter name**
- C5050 (E) "##" may not be first in a macro definition**
- C5051 (E) "##" may not be last in a macro definition**
- C5052 (E) Expected a macro parameter name**
- C5053 (E) Expected a ":"**
- C5054 (W) Too few arguments in macro invocation**
- C5055 (W) Too many arguments in macro invocation**
- C5056 (E) Operand of sizeof may not be a function**
- C5057 (E) This operator is not allowed in a constant expression**
- C5058 (E) This operator is not allowed in a preprocessing expression**
- C5059 (E) Function call is not allowed in a constant expression**
- C5060 (E) This operator is not allowed in an integral constant expression**
- C5061 (W) Integer operation result is out of range**

- C5062 (W) Shift count is negative**
- C5063 (W) Shift count is too large**
- C5064 (W) Declaration does not declare anything**
- C5065 (E) Expected a ";"**
- C5066 (E) Enumeration value is out of "int" range**
- C5067 (E) Expected a "}"**
- C5068 (W) Integer conversion resulted in a change of sign**
- C5069 (W) Integer conversion resulted in truncation**
- C5070 (E) Incomplete type is not allowed**
- C5071 (E) Operand of sizeof may not be a bit field**
- C5075 (E) Operand of "\*" must be a pointer**
- C5077 (E) This declaration has no storage class or type specifier**
- C5079 (E) Expected a type specifier**
- C5080 (E) A storage class may not be specified here**
- C5081 (E) More than one storage class may not be specified**
- C5083 (W) Type qualifier specified more than once**
- C5084 (E) Invalid combination of type specifiers**

- C5085 (E) Invalid storage class for a parameter**
- C5086 (E) Invalid storage class for a function**
- C5087 (E) A type specifier may not be used here**
- C5088 (E) Array of functions is not allowed**
- C5089 (E) Array of void is not allowed**
- C5090 (E) Function returning function is not allowed**
- C5091 (E) Function returning array is not allowed**
- C5093 (E) Function type may not come from a typedef**
- C5094 (E) The size of an array must be greater than zero**
- C5095 (E) Array is too large**
- C5097 (E) A function may not return a value of this type**
- C5098 (E) An array may not have elements of this type**
- C5100 (E) Duplicate parameter name**
- C5101 (E) "name" has already been declared in the current scope**
- C5103 (E) Class is too large**
- C5105 (E) Invalid size for bit field**
- C5106 (E) Invalid type for a bit field**

- C5107 (E) Zero-length bit field must be unnamed**
- C5108 (W) Signed bit field of length 1**
- C5109 (E) Expression must have (pointer-to-) function type**
- C5110 (E) Expected either a definition or a tag name**
- C5111 (I) Statement is unreachable**
- C5112 (E) Expected "while"**
- C5114 (E) Entity-kind "name" was referenced but not defined**
- C5115 (E) A continue statement may only be used within a loop**
- C5116 (E) A break statement may only be used within a loop or switch**
- C5117 (W) Non-void entity-kind "name" should return a value**
- C5118 (E) A void function may not return a value**
- C5119 (E) Cast to type "type" is not allowed**
- C5120 (E) Return value type does not match the function type**
- C5121 (E) A case label may only be used within a switch**
- C5122 (E) A default label may only be used within a switch**
- C5123 (E) Case label value has already appeared in this switch**
- C5124 (E) Default label has already appeared in this switch**

- C5125 (E) Expected a "("**
- C5126 (E) Expression must be an lvalue**
- C5127 (E) Expected a statement**
- C5128 (I) Loop is not reachable from preceding code**
- C5129 (E) A block-scope function may only have extern storage class**
- C5130 (E) Expected a "{"**
- C5131 (E) Expression must have pointer-to-class type**
- C5132 (E) Expression must have pointer-to-struct-or-union type**
- C5133 (E) Expected a member name**
- C5134 (E) Expected a field name**
- C5135 (E) Entity-kind "name" has no member "member name"**
- C5136 (E) Entity-kind "name" has no field "field name"**
- C5137 (E) Expression must be a modifiable lvalue**
- C5139 (E) Taking the address of a bit field is not allowed**
- C5140 (E) Too many arguments in function call**
- C5142 (E) Expression must have pointer-to-object type**
- C5143 (F) Program too large or complicated to compile**

- C5144 (E) A value of type "type 1" cannot be used to initialize an entity of type "type 2"**
- C5145 (E) Entity-kind "name" may not be initialized**
- C5146 (E) Too many initializer values**
- C5147 (E) Declaration is incompatible with "name" (declared at line "line number")**
- C5148 (E) Entity-kind "name" has already been initialized**
- C5149 (E) A global-scope declaration may not have this storage class**
- C5150 (E) A type name may not be redeclared as a parameter**
- C5151 (E) A typedef name may not be redeclared as a parameter**
- C5153 (E) Expression must have class type**
- C5154 (E) Expression must have struct or union type**
- C5157 (E) Expression must be an integral constant expression**
- C5158 (E) Expression must be an lvalue or a function designator**
- C5159 (E) Declaration is incompatible with previous "name" (declared at line "line number")**
- C5160 (E) Name conflicts with previously used external name "name"**
- C5161 (I) Unrecognized #pragma**
- C5163 (F) Could not open temporary file "name"**
- C5164 (F) Name of directory for temporary files is too long ("name")**

- C5165 (E) Too few arguments in function call**
- C5166 (E) Invalid floating constant**
- C5167 (E) Argument of type "type 1" is incompatible with parameter of type "type 2"**
- C5168 (E) A function type is not allowed here**
- C5169 (E) Expected a declaration**
- C5170 (W) Pointer points outside of underlying object**
- C5171 (E) Invalid type conversion**
- C5172 (I) External/internal linkage conflict with previous declaration**
- C5173 (E) Floating-point value does not fit in required integral type**
- C5174 (I) Expression has no effect**
- C5175 (W) Subscript out of range**
- C5177 (W) (I) Entity-kind "name" was declared but never referenced**
- C5179 (W) Right operand of "%" is zero**
- C5182 (F) Could not open source file "name" (no directories in search list)**
- C5183 (E) Type of cast must be integral**
- C5184 (E) Type of cast must be arithmetic or pointer**
- C5185 (I) Dynamic initialization in unreachable code**



- C5186 (W) Pointless comparison of unsigned integer with zero**
- C5187 (I) Use of "=" where "==" may have been intended**
- C5189 (F) Error while writing "file name" file**
- C5191 (W) Type qualifier is meaningless on cast type**
- C5192 (W) Unrecognized character escape sequence**
- C5193 (I) Zero used for undefined preprocessing identifier**
- C5219 (F) Error while deleting file "file name"**
- C5221 (W) Floating-point value does not fit in required floating-point type**
- C5224 (W) The format string requires additional arguments**
- C5225 (W) The format string ends before this argument**
- C5226 (W) Invalid format string conversion**
- C5228 (W) Trailing comma is nonstandard**
- C5229 (W) Bit field cannot contain all values of the enumerated type**
- C5235 (E) Variable "name" was declared with a never-completed type**
- C5236 (W) (I) Controlling expression is constant**
- C5237 (I) Selector expression is constant**
- C5238 (E) Invalid specifier on a parameter**

- C5239 (E) Invalid specifier outside a class declaration**
- C5240 (E) Duplicate specifier in declaration**
- C5241 (E) A union is not allowed to have a base class**
- C5242 (E) Multiple access control specifiers are not allowed**
- C5243 (E) Class or struct definition is missing**
- C5244 (E) Qualified name is not a member of class "type" or its base classes**
- C5245 (E) A nonstatic member reference must be relative to a specific object**
- C5246 (E) A nonstatic data member may not be defined outside its class**
- C5247 (E) Entity-kind "name" has already been defined**
- C5248 (E) Pointer to reference is not allowed**
- C5249 (E) Reference to reference is not allowed**
- C5250 (E) Reference to void is not allowed**
- C5251 (E) Array of reference is not allowed**
- C5252 (E) Reference entity-kind "name" requires an initializer**
- C5253 (E) Expected a ","**
- C5254 (E) Type name is not allowed**
- C5255 (E) Type definition is not allowed**

- C5256 (E) Invalid redeclaration of type name "name" (declared at line "line number")**
- C5257 (E) Const entity-kind "name" requires an initializer**
- C5258 (E) "this" may only be used inside a nonstatic member function**
- C5259 (E) Constant value is not known**
- C5261 (I) Access control not specified ("name" by default)**
- C5262 (E) Not a class or struct name**
- C5263 (E) Duplicate base class name**
- C5264 (E) Invalid base class**
- C5265 (E) Entity-kind "name" is inaccessible**
- C5266 (E) "name" is ambiguous**
- C5269 (E) Implicit conversion to inaccessible base class "type" is not allowed**
- C5274 (E) Improperly terminated macro invocation**
- C5276 (E) Name followed by "::" must be a class or namespace name**
- C5277 (E) Invalid friend declaration**
- C5278 (E) A constructor or destructor may not return a value**
- C5279 (E) Invalid destructor declaration**
- C5280 (E) (W) Declaration of a member with the same name as its class**

- C5281 (E) Global-scope qualifier (leading "::") is not allowed**
- C5282 (E) The global scope has no "name"**
- C5283 (E) Qualified name is not allowed**
- C5284 (W) NULL reference is not allowed**
- C5285 (E) Initialization with "{...}" is not allowed for object of type "type"**
- C5286 (E) Base class "type" is ambiguous**
- C5287 (E) Derived class "type" contains more than one instance of class "type"**
- C5288 (E) Cannot convert pointer to base class "type 1" to pointer to derived class "type 2" -- base class is virtual**
- C5289 (E) No instance of constructor "name" matches the argument list**
- C5290 (E) Copy constructor for class "type" is ambiguous**
- C5291 (E) No default constructor exists for class "type"**
- C5292 (E) "name" is not a nonstatic data member or base class of class "type"**
- C5293 (E) Indirect nonvirtual base class is not allowed**
- C5294 (E) Invalid union member -- class "type" has a disallowed member function**
- C5297 (E) Expected an operator**
- C5298 (E) Inherited member is not allowed**
- C5299 (E) Cannot determine which instance of entity-kind "name" is intended**

- C5300 (E) A pointer to a bound function may only be used to call the function**
- C5302 (E) Entity-kind "name" has already been defined**
- C5304 (E) No instance of entity-kind "name" matches the argument list**
- C5305 (E) Type definition is not allowed in function return type declaration**
- C5306 (E) Default argument not at end of parameter list**
- C5307 (E) Redefinition of default argument**
- C5308 (E) More than one instance of entity-kind "name" matches the argument list:**
- C5309 (E) More than one instance of constructor "name" matches the argument list:**
- C5310 (E) Default argument of type "type 1" is incompatible with parameter of type "type 2"**
- C5311 (E) Cannot overload functions distinguished by return type alone**
- C5312 (E) No suitable user-defined conversion from "type 1" to "type 2" exists**
- C5313 (E) Type qualifier is not allowed on this function**
- C5314 (E) Only nonstatic member functions may be virtual**
- C5315 (E) The object has type qualifiers that are not compatible with the member function**
- C5316 (E) Program too large to compile (too many virtual functions)**
- C5317 (E) Return type is not identical to nor covariant with return type "type" of overridden virtual function entity-kind "name"**

- C5318 (E) Override of virtual entity-kind "name" is ambiguous**
- C5319 (E) Pure specifier ("= 0") allowed only on virtual functions**
- C5320 (E) Badly-formed pure specifier (only "= 0" is allowed)**
- C5321 (E) Data member initializer is not allowed**
- C5322 (E) Object of abstract class type "type" is not allowed:**
- C5323 (E) Function returning abstract class "type" is not allowed:**
- C5324 (I) Duplicate friend declaration**
- C5325 (E) Inline specifier allowed on function declarations only**
- C5326 (E) "inline" is not allowed**
- C5327 (E) Invalid storage class for an inline function**
- C5328 (E) Invalid storage class for a class member**
- C5329 (E) Local class member entity-kind "name" requires a definition**
- C5330 (E) Entity-kind "name" is inaccessible**
- C5332 (E) Class "type" has no copy constructor to copy a const object**
- C5333 (E) Defining an implicitly declared member function is not allowed**
- C5334 (E) Class "type" has no suitable copy constructor**
- C5335 (E) Linkage specification is not allowed**

- C5336 (E) Unknown external linkage specification**
  
- C5337 (E) Linkage specification is incompatible with previous "name" (declared at line "line number")**
  
- C5338 (E) More than one instance of overloaded function "name" has "C" linkage**
  
- C5339 (E) Class "type" has more than one default constructor**
  
- C5340 (E) Value copied to temporary, reference to temporary used**
  
- C5341 (E) "operator" must be a member function**
  
- C5342 (E) Operator may not be a static member function**
  
- C5343 (E) No arguments allowed on user-defined conversion**
  
- C5344 (E) Too many parameters for this operator function**
  
- C5345 (E) Too few parameters for this operator function**
  
- C5346 (E) Nonmember operator requires a parameter with class type**
  
- C5347 (E) Default argument is not allowed**
  
- C5348 (E) More than one user-defined conversion from "type 1" to "type 2" applies:**
  
- C5349 (E) No operator "operator" matches these operands**
  
- C5350 (E) More than one operator "operator" matches these operands:**
  
- C5351 (E) First parameter of allocation function must be of type "size\_t"**
  
- C5352 (E) Allocation function requires "void \*" return type**

- C5353 (E) Deallocation function requires "void" return type**
- C5354 (E) First parameter of deallocation function must be of type "void \*"**
- C5356 (E) Type must be an object type**
- C5357 (E) Base class "type" has already been initialized**
- C5359 (E) Entity-kind "name" has already been initialized**
- C5360 (E) Name of member or base class is missing**
- C5363 (E) Invalid anonymous union -- nonpublic member is not allowed**
- C5364 (E) Invalid anonymous union -- member function is not allowed**
- C5365 (E) Anonymous union at global or namespace scope must be declared static**
- C5366 (E) Entity-kind "name" provides no initializer for:**
- C5367 (E) Implicitly generated constructor for class "type" cannot initialize:**
- C5368 (W) Entity-kind "name" defines no constructor to initialize the following:**
- C5369 (E) Entity-kind "name" has an uninitialized const or reference member**
- C5370 (W) Entity-kind "name" has an uninitialized const field**
- C5371 (E) Class "type" has no assignment operator to copy a const object**
- C5372 (E) Class "type" has no suitable assignment operator**
- C5373 (E) Ambiguous assignment operator for class "type"**



- C5375 (E) Declaration requires a typedef name**
- C5377 (E) "virtual" is not allowed**
- C5378 (E) "static" is not allowed**
- C5380 (E) Expression must have pointer-to-member type**
- C5381 (I) Extra ";" ignored**
- C5382 (W) Nonstandard member constant declaration (standard form is a static const integral member)**
- C5384 (E) No instance of overloaded "name" matches the argument list**
- C5386 (E) No instance of entity-kind "name" matches the required type**
- C5388 (E) "operator->" for class "type 1" returns invalid type "type 2"**
- C5389 (E) A cast to abstract class "type" is not allowed:**
- C5391 (E) A new-initializer may not be specified for an array**
- C5392 (E) Member function "name" may not be redeclared outside its class**
- C5393 (E) Pointer to incomplete class type is not allowed**
- C5394 (E) Reference to local variable of enclosing function is not allowed**
- C5397 (E) Implicitly generated assignment operator cannot copy:**
- C5399 (I) Entity-kind "name" has an operator newxxxx () but no default operator deletexxxx ()**

- C5400 (I) Entity-kind "name" has a default operator deletexxxx () but no operator newxxxx ()**
- C5401 (E) Destructor for base class "type" is not virtual**
- C5403 (E) Entity-kind "name" has already been declared**
- C5404 (E) Function "main" may not be declared inline**
- C5405 (E) Member function with the same name as its class must be a constructor**
- C5407 (E) A destructor may not have parameters**
- C5408 (E) Copy constructor for class "type 1" may not have a parameter of type "type2 "**
- C5409 (E) Entity-kind "name" returns incomplete type "type"**
- C5410 (E) Protected entity-kind "name" is not accessible through a "type" pointer or object**
- C5411 (E) A parameter is not allowed**
- C5412 (E) An "asm" declaration is not allowed here**
- C5413 (E) No suitable conversion function from "type 1" to "type 2" exists**
- C5414 (W) Delete of pointer to incomplete class**
- C5415 (E) No suitable constructor exists to convert from "type 1" to "type 2"**
- C5416 (E) More than one constructor applies to convert from "type 1" to "type 2":**
- C5417 (E) More than one conversion function from "type 1" to "type 2" applies:**

- C5418 (E) More than one conversion function from "type" to a built-in type applies:**
  
- C5424 (E) A constructor or destructor may not have its address taken**
  
- C5427 (E) Qualified name is not allowed in member declaration**
  
- C5429 (E) The size of an array in "new" must be non-negative**
  
- C5430 (W) Returning reference to local temporary**
  
- C5432 (E) "enum" declaration is not allowed**
  
- C5433 (E) Qualifiers dropped in binding reference of type "type 1" to initializer of type "type 2"**
  
- C5434 (E) A reference of type "type 1" (not const-qualified) cannot be initialized with a value of type "type 2"**
  
- C5435 (E) A pointer to function may not be deleted**
  
- C5436 (E) Conversion function must be a nonstatic member function**
  
- C5437 (E) Template declaration is not allowed here**
  
- C5438 (E) Expected a "<"**
  
- C5439 (E) Expected a ">"**
  
- C5440 (E) Template parameter declaration is missing**
  
- C5441 (E) Argument list for entity-kind "name" is missing**
  
- C5442 (E) Too few arguments for entity-kind "name"**
  
- C5443 (E) Too many arguments for entity-kind "name"**

- C5445 (E) Entity-kind "name 1" is not used in declaring the parameter types of entity-kind "name 2"**
- C5449 More than one instance of entity-kind "name" matches the required type**
- C5452 (E) Return type may not be specified on a conversion function**
- C5456 (E) Excessive recursion at instantiation of entity-kind "name"**
- C5457 (E) "name" is not a function or static data member**
- C5458 (E) Argument of type "type 1" is incompatible with template parameter of type "type 2"**
- C5459 (E) Initialization requiring a temporary or conversion is not allowed**
- C5461 (E) Initial value of reference to non-const must be an lvalue**
- C5463 (E) "template" is not allowed**
- C5464 (E) "type" is not a class template**
- C5466 (E) "main" is not a valid name for a function template**
- C5467 (E) Invalid reference to entity-kind "name" (union/nonunion mismatch)**
- C5468 (E) A template argument may not reference a local type**
- C5469 (E) Tag kind of "name 1" is incompatible with declaration of entity-kind "name 2" (declared at line "line number")**
- C5470 (E) The global scope has no tag named "name"**
- C5471 (E) Entity-kind "name 1" has no tag member named "name 2"**

- C5473 (E) Entity-kind "name" may be used only in pointer-to-member declaration**
- C5475 (E) A template argument may not reference a non-external entity**
- C5476 (E) Name followed by "::~" must be a class name or a type name**
- C5477 (E) Destructor name does not match name of class "type"**
- C5478 (E) Type used as destructor name does not match type "type"**
- C5479 (I) Entity-kind "name" redeclared "inline" after being called**
- C5481 (E) Invalid storage class for a template declaration**
- C5484 (E) Invalid explicit instantiation declaration**
- C5485 (E) Entity-kind "name" is not an entity that can be instantiated**
- C5486 (E) Compiler generated entity-kind "name" cannot be explicitly instantiated**
- C5487 (E) Inline entity-kind "name" cannot be explicitly instantiated**
- C5488 (E) Pure virtual entity-kind "name" cannot be explicitly instantiated**
- C5489 (E) Entity-kind "name" cannot be instantiated -- no template definition was supplied**
- C5490 (E) Entity-kind "name" cannot be instantiated -- it has been explicitly specialized**
- C5493 (E) No instance of entity-kind "name" matches the specified type**
- C5496 (E) Template parameter "name" may not be redeclared in this scope**
- C5497 (W) Declaration of "name" hides template parameter**

- C5498 (E) Template argument list must match the parameter list**
- C5499 (E) Conversion function to convert from "type 1" to "type 2" is not allowed**
- C5500 (E) Extra parameter of postfix "operatorxxxx" must be of type "int"**
- C5501 (E) An operator name must be declared as a function**
- C5502 (E) Operator name is not allowed**
- C5503 (E) Entity-kind "name" cannot be specialized in the current scope**
- C5505 (E) Too few template parameters -- does not match previous declaration**
- C5506 (E) Too many template parameters -- does not match previous declaration**
- C5507 (E) Function template for operator delete (void \*) is not allowed**
- C5508 (E) Class template and template parameter may not have the same name**
- C5510 (E) A template argument may not reference an unnamed type**
- C5511 (E) Enumerated type is not allowed**
- C5512 (W) Type qualifier on a reference type is not allowed**
- C5513 (E) A value of type "type 1" cannot be assigned to an entity of type "type 2"**
- C5514 (W) Pointless comparison of unsigned integer with a negative constant**
- C5515 (E) Cannot convert to incomplete class "type"**
- C5516 (E) Const object requires an initializer**

- C5517 (E) Object has an uninitialized const or reference member**
- C5519 (E) Entity-kind "name" may not have a template argument list**
- C5520 (E) Initialization with "{...}" expected for aggregate object**
- C5521 (E) Pointer-to-member selection class types are incompatible ("type 1" and "type 2")**
- C5522 (W) Pointless friend declaration**
- C5526 (E) A parameter may not have void type**
- C5529 (E) This operator is not allowed in a template argument expression**
- C5530 (E) Try block requires at least one handler**
- C5531 (E) Handler requires an exception declaration**
- C5532 (E) Handler is masked by default handler**
- C5533 (E) Handler is potentially masked by previous handler for type "type"**
- C5534 (I) Use of a local type to specify an exception**
- C5535 (I) Redundant type in exception specification**
- C5536 (E) Exception specification is incompatible with that of previous entity-kind "name" (declared at line "line number"):**
- C5540 (E) Support for exception handling is disabled**
- C5541 (W) Omission of exception specification is incompatible with previous entity-kind "name" (declared at line "line number")**

- C5542 (F) Could not create instantiation request file "name"**
  
- C5543 (E) Non-arithmetic operation not allowed in nontype template argument**
  
- C5544 (E) Use of a local type to declare a nonlocal variable**
  
- C5545 (E) Use of a local type to declare a function**
  
- C5546 (E) Transfer of control bypasses initialization of:**
  
- C5548 (E) Transfer of control into an exception handler**
  
- C5549 (W) Entity-kind "name" is used before its value is set**
  
- C5550 (W) Entity-kind "name" was set but never used**
  
- C5551 (E) Entity-kind "name" cannot be defined in the current scope**
  
- C5552 (W) Exception specification is not allowed**
  
- C5553 (W) External/internal linkage conflict for entity-kind "name" (declared at line "line number")**
  
- C5554 (W) Entity-kind "name" will not be called for implicit or explicit conversions**
  
- C5555 (E) Tag kind of "name" is incompatible with template parameter of type "type"**
  
- C5556 (E) Function template for operator new (size\_t) is not allowed**
  
- C5558 (E) Pointer to member of type "type" is not allowed**
  
- C5559 (E) Ellipsis is not allowed in operator function parameter list**
  
- C5563 (F) Invalid preprocessor output file**



- C5598 (E) A template parameter may not have void type**
- C5601 (E) A throw expression may not have void type**
- C5603 (E) Parameter of abstract class type "type" is not allowed:**
- C5604 (E) Array of abstract class "type" is not allowed:**
- C5610 (W) Entity-kind "name 1" does not match "name 2" -- virtual function override intended?**
- C5611 (W) Overloaded virtual function "name 1" is only partially overridden in entity-kind "name 2"**
- C5612 (E) Specific definition of inline template function must precede its first use**
- C5614 (F) Invalid error number: "specified number"**
- C5624 (E) "name" is not a type name**
- C5641 (F) "name" is not a valid directory**
- C5642 (F) Cannot build temporary file name**
- C5656 (E) Transfer of control into a try block**
- C5657 (W) Inline specification is incompatible with previous "name" (declared at line "line number")**
- C5658 (E) Closing brace of template definition not found**
- C5660 (E) Invalid packing alignment value**
- C5662 (W) Call of pure virtual function**

- C5663 (E) Invalid source file identifier string**
- C5664 (E) A class template cannot be defined in a friend declaration**
- C5673 (E) A reference of type "type 1" cannot be initialized with a value of type "type 2"**
- C5674 (E) Initial value of reference to const volatile must be an lvalue**
- C5678 (I) Call of entity-kind "name" (declared at line "line number") cannot be inlined**
- C5679 (I) Entity-kind "name" cannot be inlined**
- C5693 (E) <typeinfo> must be included before typeid is used**
- C5694 (E) "name" cannot cast away const or other type qualifiers**
- C5695 (E) The type in a dynamic\_cast must be a pointer or reference to a complete class type, or void \***
- C5696 (E) The operand of a pointer dynamic\_cast must be a pointer to a complete class type**
- C5697 (E) The operand of a reference dynamic\_cast must be an lvalue of a complete class type**
- C5698 (E) The operand of a runtime dynamic\_cast must have a polymorphic class type**
- C5701 (E) An array type is not allowed here**
- C5702 (E) Expected an "="**
- C5703 (E) Expected a declarator in condition declaration**
- C5704 (E) "name", declared in condition, may not be redeclared in this scope**

- C5705 (E) Default template arguments are not allowed for function templates**
- C5706 (E) Expected a ",", or ">"**
- C5707 (E) Expected a template parameter list**
- C5708 (W) Incrementing a bool value is deprecated**
- C5709 (E) bool type is not allowed**
- C5710 (E) Offset of base class "name 1" within class "name 2" is too large**
- C5711 (E) Expression must have bool type (or be convertible to bool)**
- C5717 (E) The type in a const\_cast must be a pointer, reference, or pointer to member to an object type**
- C5718 (E) A const\_cast can only adjust type qualifiers; it cannot change the underlying type**
- C5719 (E) mutable is not allowed**
- C5720 (W) Redclaration of entity-kind "name" is not allowed to alter its access**
- C5722 (W) Use of alternative token "<:" appears to be unintended**
- C5723 (W) Use of alternative token "%:" appears to be unintended**
- C5724 (E) namespace definition is not allowed**
- C5725 (E) Name must be a namespace name**
- C5726 (E) Namespace alias definition is not allowed**
- C5727 (E) namespace-qualified name is required**

- C5728 (E) A namespace name is not allowed**
- C5730 (E) Entity-kind "name" is not a class template**
- C5732 (E) Allocation operator may not be declared in a namespace**
- C5733 (E) Deallocation operator may not be declared in a namespace**
- C5734 (E) Entity-kind "name 1" conflicts with using-declaration of entity-kind "name 2"**
- C5735 (E) Using-declaration of entity-kind "name 1" conflicts with entity-kind "name 2" (declared at line "line number")**
- C5737 (W) Using-declaration ignored -- it refers to the current namespace**
- C5738 (E) A class-qualified name is required**
- C5741 (W) Using-declaration of entity-kind "name" ignored**
- C5742 (E) Entity-kind "name 1" has no actual member "name 2"**
- C5750 (E) Entity-kind "name" (declared at line "line number") was used before its template was declared**
- C5751 (E) Static and nonstatic member functions with same parameter types cannot be overloaded**
- C5752 (E) No prior declaration of entity-kind "name"**
- C5753 (E) A template-id is not allowed**
- C5754 (E) A class-qualified name is not allowed**

- C5755 (E) Entity-kind "name" may not be redeclared in the current scope**
- C5756 (E) Qualified name is not allowed in namespace member declaration**
- C5757 (E) Entity-kind "name" is not a type name**
- C5761 (E) Typename may only be used within a template**
- C5766 (W) Exception specification for virtual entity-kind "name 1" is incompatible with that of overridden entity-kind "name 2"**
- C5767 (W) Conversion from pointer to smaller integer**
- C5768 (W) Exception specification for implicitly declared virtual entity-kind "name 1" is incompatible with that of overridden entity-kind "name 2"**
- C5771 (E) "explicit" is not allowed**
- C5772 (E) Declaration conflicts with "name" (reserved class name)**
- C5773 (E) Only "()" is allowed as initializer for array entity-kind "name"**
- C5774 (E) "virtual" is not allowed in a function template declaration**
- C5775 (E) Invalid anonymous union -- class member template is not allowed**
- C5776 (E) Template nesting depth does not match the previous declaration of entity-kind "name"**
- C5777 (E) This declaration cannot have multiple "template <...>" clauses**
- C5779 (E) "name", declared in for-loop initialization, may not be redeclared in this scope**

- C5782 (E) Definition of virtual entity-kind "name" is required here**
- C5784 (E) A storage class is not allowed in a friend declaration**
- C5785 (E) Template parameter list for "name" is not allowed in this declaration**
- C5786 (E) entity-kind "name" is not a valid member class or function template**
- C5787 (E) Not a valid member class or function template declaration**
- C5788 (E) A template declaration containing a template parameter list may not be followed by an explicit specialization declaration**
- C5789 (E) Explicit specialization of entity-kind "name 1" must precede the first use of entity-kind "name 2"**
- C5790 (E) Explicit specialization is not allowed in the current scope**
- C5791 (E) Partial specialization of entity-kind "name" is not allowed**
- C5792 (E) Entity-kind "name" is not an entity that can be explicitly specialized**
- C5793 (E) Explicit specialization of entity-kind "name" must precede its first use**
- C5794 (W) Template parameter "template" may not be used in an elaborated type specifier**
- C5795 (E) Specializing entity-kind "name" requires "template<>" syntax**
- C5800 (E) This declaration may not have extern "C" linkage**
- C5801 (E) "name" is not a class or function template name in the current scope**

- C5802 (W) Specifying a default argument when redeclaring an unreferenced function template is nonstandard**
- C5803 (E) Specifying a default argument when redeclaring an already referenced function template is not allowed**
- C5804 (E) Cannot convert pointer to member of base class "type 1" to pointer to member of derived class "type 2" – base class is virtual**
- C5805 (E) Exception specification is incompatible with that of entity-kind "name" (declared at line "line number"):**
- C5806 (W) Omission of exception specification is incompatible with entity-kind "name" (declared at line "line number")**
- C5807 (E) The parse of this expression has changed between the point at which it appeared in the program and the point at which the expression was evaluated -- "typename" may be required to resolve the ambiguity**
- C5808 (E) Default-initialization of reference is not allowed**
- C5809 (E) Uninitialized entity-kind "name" has a const member**
- C5810 (E) Uninitialized base class "type" has a const member**
- C5811 (E) Const entity-kind "name" requires an initializer -- class "type" has no explicitly declared default constructor**
- C5812 (W) Const object requires an initializer -- class "type" has no explicitly declared default constructor**
- C5815 (I) Type qualifier on return type is meaningless**
- C5817 (E) Static data member declaration is not allowed in this class**

- C5818 (E) Template instantiation resulted in an invalid function declaration**
  
- C5822 (E) Invalid destructor name for type "type"**
  
- C5824 (E) Destructor reference is ambiguous -- both entity-kind "name 1" and entity-kind "name 2" could be used**
  
- C5825 (E) Virtual inline entity-kind "name" was never defined**
  
- C5826 (W) Entity-kind "name" was never referenced**
  
- C5827 (E) Only one member of a union may be specified in a constructor initializer list**
  
- C5831 (I) Support for placement delete is disabled**
  
- C5832 (E) No appropriate operator delete is visible**
  
- C5833 (E) Pointer or reference to incomplete type is not allowed**
  
- C5834 (E) Invalid partial specialization -- entity-kind "name" is already fully specialized**
  
- C5835 (E) Incompatible exception specifications**
  
- C5836 (W) Returning reference to local variable**
  
- C5837 (W) Omission of explicit type is nonstandard ("int" assumed)**
  
- C5838 (E) More than one partial specialization matches the template argument list of entity-kind "name"**
  
- C5840 (E) A template argument list is not allowed in a declaration of a primary template**



- C5841 (E) Partial specializations may not have default template arguments**
  
- C5842 (E) Entity-kind "name 1" is not used in template argument list of entity-kind "name 2"**
  
- C5843 (E) The type of partial specialization template parameter entity-kind "name" depends on another template parameter**
  
- C5844 (E) The template argument list of the partial specialization includes a nontype argument whose type depends on a template parameter**
  
- C5845 (E) This partial specialization would have been used to instantiate entity-kind "name"**
  
- C5846 (E) This partial specialization would have been made the instantiation of entity-kind "name" ambiguous**
  
- C5847 (E) Expression must have integral or enum type**
  
- C5848 (E) Expression must have arithmetic or enum type**
  
- C5849 (E) Expression must have arithmetic, enum, or pointer type**
  
- C5850 (E) Type of cast must be integral or enum**
  
- C5851 (E) Type of cast must be arithmetic, enum, or pointer**
  
- C5852 (E) Expression must be a pointer to a complete object type**
  
- C5853 (E) A partial specialization of a member class template must be declared in the class of which it is a member**
  
- C5854 (E) A partial specialization nontype argument must be the name of a nontype parameter or a constant**

- C5855 (E) Return type is not identical to return type "type" of overridden virtual function entity-kind "name"**
- C5857 (E) A partial specialization of a class template must be declared in the namespace of which it is a member**
- C5858 (E) Entity-kind "name" is a pure virtual function**
- C5859 (E) Pure virtual entity-kind "name" has no overrider**
- C5861 (E) Invalid character in input line**
- C5862 (E) Function returns incomplete type "type"**
- C5864 (E) "name" is not a template**
- C5865 (E) A friend declaration may not declare a partial specialization**
- C5867 (W) Declaration of "size\_t" does not match the expected type "type"**
- C5868 (E) Space required between adjacent ">" delimiters of nested template argument lists (">>" is the right shift operator)**
- C5870 (W) Invalid multibyte character sequence**
- C5871 (E) Template instantiation resulted in unexpected function type of "type 1" (the meaning of a name may have changed since the template declaration -- the type of the template is "type 2")**
- C5873 (E) Non-integral operation not allowed in nontype template argument**
- C5875 (E) Embedded C++ does not support templates**
- C5876 (E) Embedded C++ does not support exception handling**

- C5877 (E) Embedded C++ does not support namespaces**
- C5878 (E) Embedded C++ does not support run-time type information**
- C5879 (E) Embedded C++ does not support the new cast syntax**
- C5880 (E) Embedded C++ does not support using-declarations**
- C5881 (E) Embedded C++ does not support "mutable"**
- C5882 (E) Embedded C++ does not support multiple or virtual inheritance**
- C5885 (E) "type 1" cannot be used to designate constructor for "type 2"**
- C5891 (E) An explicit template argument list is not allowed on this declaration**
- C5894 (E) Entity-kind "name" is not a template**
- C5896 (E) Expected a template argument**
- C5898 (E) Nonmember operator requires a parameter with class or enum type**
- C5900 (E) Using-declaration of entity-kind "name" is not allowed**
- C5901 (E) Qualifier of destructor name "type 1" does not match type "type 2"**
- C5902 (W) Type qualifier ignored**
- C5916 (E) Cannot convert pointer to member of derived class "type 1" to pointer to member of base class "type 2" – base class is virtual**
- C5919 (F) Invalid output file: "name"**

- C5920 (F) Cannot open output file: "name"**
  
- C5926 (F) Cannot open definition list file: "name"**
  
- C5928 (E) Incorrect use of va\_start**
  
- C5929 (E) Incorrect use of va\_arg**
  
- C5930 (E) Incorrect use of va\_end**
  
- C5935 (E) "typedef" may not be specified here**
  
- C5936 (W) Redclaration of entity-kind "name" alters its access**
  
- C5937 (E) A class or namespace qualified name is required**
  
- C5940 (W) Missing return statement at end of non-void entity-kind "name"**
  
- C5941 (W) Duplicate using-declaration of "name" ignored**
  
- C5946 (E) Name following "template" must be a member template**
  
- C5947 (E) Name following "template" must have a template argument list**
  
- C5952 (E) A template parameter may not have class type**
  
- C5953 (E) A default template argument cannot be specified on the declaration of a member of a class template**
  
- C5954 (E) A return statement is not allowed in a handler of a function try block of a constructor**
  
- C5959 (W) Declared size for bit field is larger than the size of the bit field type; truncated to "size" bits**

- C5960 (E) Type used as constructor name does not match type "type"**
- C5961 (W) Use of a type with no linkage to declare a variable with linkage**
- C5962 (W) Use of a type with no linkage to declare a function**
- C5963 (E) Return type may not be specified on a constructor**
- C5964 (E) Return type may not be specified on a destructor**
- C5965 (E) Incorrectly formed universal character name**
- C5966 (E) Universal character name specifies an invalid character**
- C5967 (E) A universal character name cannot designate a character in the basic character set**
- C5968 This universal character is not allowed in an identifier**
- C5978 (E) A template friend declaration cannot be declared in a local class**
- C5979 (E) Ambiguous "?" operation: second operand of type "type 1" can be converted to third operand type "type 2", and vice versa**
- C5980 (E) Call of an object of a class type without appropriate operator ( ) or conversion functions to pointer-to-function type**
- C5982 (E) There is more than one way an object of type "type" can be called for the argument list**
- C5986 (E) Expected a section name string**
- C5988 (E) Invalid pragma declaration**
- C5989 (E) "name" has already been specified by other pragma**

- C5990 (E) Pragma may not be specified after definition**
- C5991 (E) Invalid kind of pragma is specified to this symbol**
- C5994 (W) Operator new and operator delete cannot be given internal linkage**
- C5995 (E) Storage class "mutable" is not allowed for anonymous unions**
- C5997 (E) Abstract class type "type" is not allowed as catch type:**
- C5998 (E) A qualified function type cannot be used to declare a nonmember function or a static member function**
- C5999 (E) A qualified function type cannot be used to declare a parameter**
- C6000 (E) Cannot create a pointer or reference to qualified function type**
- C6001 (W) Extra braces are nonstandard**
- C6002 (E) An empty template parameter list is not allowed in a template template parameter declaration**
- C6005 (E) Expected "class"**
- C6006 (E) The "class" keyword must be used when declaring a template template parameter**
- C6007 (W) "function name 1" is hidden by "function name 2" -- virtual function override intended?**
- C6008 (E) A qualified name is not allowed for a friend declaration that is a function definition**
- C6009 (E) "type 1" is not compatible with "type 2"**

- C6010 (W) A storage class may not be specified here**
  
- C6011 (E) Class member designated by a using-declaration must be visible in a direct base class**
  
- C6016 (E) A template template parameter cannot have the same name as one of its template parameters**
  
- C6017 (E) Recursive instantiation of default argument**
  
- C6018 (E) A parameter of a template template parameter cannot depend on the type of another template parameter**
  
- C6019 (E) "instantiation name" is not an entity that can be defined**
  
- C6023 (E) A qualified friend template declaration must refer to a specific previously declared template**
  
- C6028 (E) "class name" has no member class "member name"**
  
- C6029 (E) The global scope has no class named "class name"**
  
- C6030 (E) Recursive instantiation of template default argument**
  
- C6031 (E) Access declarations and using-declarations cannot appear in unions**
  
- C6032 (E) "name" is not a class member**
  
- C6038 (W) Invalid redeclaration of nested class**
  
- C6045 (E) "template name" cannot be declared in this scope**

## 12.3 Standard Library Error Messages

For some library functions, if an error occurs during the library function execution, an error code is set in the macro **errno** defined in the header file `<errno.h>` contained in the standard library. Error messages are defined in the error codes so that error messages can be output. The following shows an example of an error message output program.

### Example:

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <errno.h>

main()
{
    FILE *fp;

    fp=fopen("file", "w");
    fp=NULL;

    fclose(fp); /* error occurred */

    printf("%s\n", strerror(errno)); /* print error message */
}
```

### Description:

1. Since the file pointer of NULL is passed to the **fclose** function as an actual parameter, an error will occur. In this case, an error code corresponding to **errno** is set.
2. The **strerror** function returns a pointer of the string literal of the corresponding error message when the error code is passed as an actual parameter. An error message is output by specifying the output of the string literal of the **printf** function.



**Table 12.1 List of Standard Library Error Messages**

| <b>Error No.</b> | <b>Error Message/Explanation</b>                                                                                                              | <b>Functions to Set Error Code</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1100<br>(ERANGE) | Data out of range<br>An overflow occurred.                                                                                                    | frexp, ldexp, modf, ceil, floor, fmod, atof, atoi, atol, atoll, atofixed, atolaccum, strtod, strtol, strtoul, strtoll, stroull, strtolfixed, strtolaccum, perror, fprintf, fscanf, printf, scanf, sprintf, sscanf, vfprintf, vprintf, vsprintf, acos, acosf, asin, asinf, atan, atan2, atan2f, atanf, ceilf, cos, cosf, cosh, coshf, exp, expf, floorf, fmodf, ldexpf, log, log10, log10f, logf, modff, pow, powf, sin, sinf, sinh, sinhf, sqrt, sqrtf, tan, tanf, tanh, tanhf, fabs, fabsf, frexpf |
| 1101<br>(EDOM)   | Data out of domain<br>Results for mathematical parameters are not defined.                                                                    | acos, acosf, asin, asinf, atan, atan2, atan2f, atanf, ceil, ceilf, cos, cosf, cosh, coshf, exp, expf, floor, floorf, fmod, fmodf, ldexp, ldexpf, log, log10, log10f, logf, modf, modff, pow, powf, sin, sinf, sinh, sinhf, sqrt, sqrtf, tan, tanf, tanh, tanhf, fabs, fabsf, frexp, frexpf                                                                                                                                                                                                          |
| 1104<br>(ESTRN)  | Too long string<br>The length of string literal exceeds 512 characters.                                                                       | atof, atoi, atol, atoll, atofixed, atolaccum, strtod, strtol, strtoul, strtoll, strtoull, strtolfixed, strtolaccum                                                                                                                                                                                                                                                                                                                                                                                  |
| 1106<br>(PTRERR) | Invalid file pointer<br>The NULL pointer constant is specified as the file pointer value.                                                     | fclose, fflush, freopen, setbuf, setvbuf, fprintf, fscanf, printf, scanf, sprintf, sscanf, vfprintf, vprintf, vsprintf, fgetc, fgets, fputc, fputs, ungetc, fread, fwrite, fseek, ftell, rewind, perror                                                                                                                                                                                                                                                                                             |
| 1200<br>(ECBASE) | Invalid radix<br>An invalid radix was specified.                                                                                              | atoi, atol, atoll, strtol, strtoul, strtoll, strtoull                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 1202<br>(ETLN)   | Number too long<br>The specified number exceeds the number of significant digits.                                                             | atof, atofixed, atolaccum, strtod, strtolfixed, strtolaccum, fscanf, scanf, sscanf                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 1204<br>(EEXP)   | Exponent too large<br>The specified exponent exceeds three digits.                                                                            | strtod, fscanf, scanf, sscanf, atof                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 1206<br>(EEXPN)  | Normalized exponent too large<br>The exponent exceeds three digits when the string literal is normalized to the IEEE standard decimal format. | strtod, fscanf, scanf, sscanf, atof                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

**Table 12.1 List of Standard Library Error Messages (cont)**

| <b>Error No.</b>  | <b>Error Message/Explanation</b>                                                                                                  | <b>Functions to Set Error Code</b>                                                                                                                                                                                  |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1210<br>(EFLATO)  | Overflow out of float<br>A float-type decimal value is out of range (overflow).                                                   | fscanf, scanf, sscanf                                                                                                                                                                                               |
| 1220<br>(EFLATU)  | Underflow out of float<br>A float-type decimal value is out of range (underflow).                                                 | fscanf, scanf, sscanf                                                                                                                                                                                               |
| 1250<br>(EDBLO)   | Overflow out of double<br>A double-type decimal value is out of range (overflow).                                                 | fscanf, scanf, sscanf                                                                                                                                                                                               |
| 1260<br>(EDBLU)   | Underflow out of double<br>A double-type decimal value is out of range (underflow).                                               | fscanf, scanf, sscanf                                                                                                                                                                                               |
| 1270<br>(ELDBLO)  | Overflow out of long double<br>A long double-type decimal value is out of range (overflow).                                       | fscanf, scanf, sscanf                                                                                                                                                                                               |
| 1280<br>(ELDBLU)  | Underflow out of long double<br>A long double-type decimal value is out of range (underflow).                                     | fscanf, scanf, sscanf                                                                                                                                                                                               |
| 1300<br>(NOTOPN)  | File not open<br>The file is not open.                                                                                            | fclose, fflush, setbuf, setvbuf, fprintf, fscanf, printf, scanf, sprintf, sscanf, vfprintf, vprintf, vsprintf, fgetc, fgets, fputc, fputs, gets, puts, ungetc, fread, fwrite, fseek, ftell, rewind, perror, freopen |
| 1302<br>(EBADF)   | Bad file number<br>An output function was issued for an input-only file, or an input function was issued for an output-only file. | fprintf, fscanf, printf, scanf, sprintf, sscanf, vfprintf, vprintf, vsprintf, fgetc, fgets, fputc, fputs, gets, puts, ungetc, perror, fread, fwrite                                                                 |
| 1304<br>(ECSPEC)  | Error in format<br>An erroneous format was specified for an input/output function using format.                                   | fprintf, fscanf, printf, scanf, sprintf, sscanf, vfprintf, vprintf, vsprintf, perror                                                                                                                                |
| 1400<br>(EFIXEDO) | Overflow out of <code>__fixed</code><br>A <code>__fixed</code> -type decimal value is out of range (overflow).                    | fscanf, scanf, sscanf                                                                                                                                                                                               |
| 1410<br>(EFIXEDU) | Underflow out of <code>__fixed</code><br>A <code>__fixed</code> -type decimal value is out of range (underflow).                  | fscanf, scanf, sscanf                                                                                                                                                                                               |

**Table 12.1 List of Standard Library Error Messages (cont)**

| <b>Error No.</b>   | <b>Error Message/Explanation</b>                                                                                           | <b>Functions to Set Error Code</b>                                                                                                                                                                                                                                                                  |
|--------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1420<br>(EACCUMO)  | Overflow out of <code>__accum</code><br>An <code>__accum</code> -type decimal value is out of range (overflow).            | <code>fscanf</code> , <code>scanf</code> , <code>sscanf</code>                                                                                                                                                                                                                                      |
| 1430<br>(EACCUMU)  | Underflow out of <code>__accum</code><br>An <code>__accum</code> -type decimal value is out of range (underflow).          | <code>fscanf</code> , <code>scanf</code> , <code>sscanf</code>                                                                                                                                                                                                                                      |
| 1440<br>(ELFIXEDO) | Overflow out of <code>long __fixed</code><br>A <code>long __fixed</code> -type decimal value is out of range (overflow).   | <code>fscanf</code> , <code>scanf</code> , <code>sscanf</code>                                                                                                                                                                                                                                      |
| 1450<br>(ELFIXEDU) | Underflow out of <code>long __fixed</code><br>A <code>long __fixed</code> -type decimal value is out of range (underflow). | <code>fscanf</code> , <code>scanf</code> , <code>sscanf</code>                                                                                                                                                                                                                                      |
| 1460<br>(ELACCUMO) | Overflow out of <code>long __accum</code><br>A <code>long __accum</code> -type decimal value is out of range (overflow).   | <code>fscanf</code> , <code>scanf</code> , <code>sscanf</code>                                                                                                                                                                                                                                      |
| 1470<br>(ELACCUMU) | Underflow out of <code>long __accum</code><br>A <code>long __accum</code> -type decimal value is out of range (underflow). | <code>fscanf</code> , <code>scanf</code> , <code>sscanf</code>                                                                                                                                                                                                                                      |
| 2100<br>(EMALRESM) | Error in waiting semaphore<br>Failed to define semaphore resources for <code>malloc</code> .                               | <code>calloc</code> , <code>free</code> , <code>malloc</code> , <code>realloc</code> ,<br><code>calloc__X</code> , <code>free__X</code> , <code>malloc__X</code> ,<br><code>realloc__X</code> , <code>calloc__Y</code> , <code>free__Y</code> ,<br><code>malloc__Y</code> , <code>realloc__Y</code> |
| 2101<br>(EMALFRSM) | Error in signaling semaphore<br>Failed to define semaphore resources for <code>strtok</code> .                             | <code>calloc</code> , <code>free</code> , <code>malloc</code> , <code>realloc</code> ,<br><code>calloc__X</code> , <code>free__X</code> , <code>malloc__X</code> ,<br><code>realloc__X</code> , <code>calloc__Y</code> , <code>free__Y</code> ,<br><code>malloc__Y</code> , <code>realloc__Y</code> |
| 2110<br>(ETOKRESM) | Error in waiting semaphore<br>Failed to define semaphore resources for <code>strtok</code> .                               | <code>strtok</code>                                                                                                                                                                                                                                                                                 |
| 2111<br>(ETOKFRSM) | Error in signaling semaphore<br>Failed to release semaphore resources for <code>malloc</code> .                            | <code>strtok</code>                                                                                                                                                                                                                                                                                 |
| 2120<br>(EIOBRESM) | Error in waiting semaphore<br>Failed to release semaphore resources for <code>_job</code> .                                | <code>fopen</code>                                                                                                                                                                                                                                                                                  |
| 2121<br>(EIOBFRSM) | Error in signaling semaphore<br>Failed to release semaphore resources for <code>_job</code> .                              | <code>fopen</code>                                                                                                                                                                                                                                                                                  |



## Section 13 Assembler Error Messages

### 13.1 Error Message Format and Error Levels

This section gives lists of error messages in order of error code. A list of error messages are provided for each level of errors in the format below:

**Error code (Error Level: W, E, or F) Error Message**

Meaning of the error message.

Error levels are classified into the following three types:

- (W): Warning error (Continues compiling processing and outputs the object program.)
- (E): Error (Continues compiling processing but does not output the object program.)
- (F): Fatal error (Aborts compiling processing.)

### 13.2 Error Messages

**10 (E) NO INPUT FILE SPECIFIED**

There is no input source file specified.  
Specify an input source file.

**20 (E) CANNOT OPEN FILE <file name>**

The specified file cannot be opened.  
Check and correct the file name and directory.

**30 (E) INVALID COMMAND PARAMETER**

The command line options are not correct.  
Check and correct the command line options.

**40 (E) CANNOT ALLOCATE MEMORY**

All available memory is used up during processing.  
This error only occurs when the amount of available user memory is extremely small. If there is other processing occurring at the same time as assembly, interrupt that processing and restart the assembler. If the error still occurs, check and correct the memory management employed on the host system.

**50 (E) INVALID FILE NAME <file name>**

The file name including the directory is too long or invalid file name.

Check and correct the file name.

It is possible that the object module output by the assembler after this error has occurred will not be usable with the debugger.

**101 (E) SYNTAX ERROR IN SOURCE STATEMENT**

Syntax error in source statement.

Check and correct the whole source statement.

**102 (E) SYNTAX ERROR IN DIRECTIVE**

Syntax error in assembler directive source statement.

Check and correct the whole source statement.

**104 (E) LOCATION COUNTER OVERFLOW**

The value of location counter exceeded its maximum value.

Reduce the size of the program.

**105 (E) ILLEGAL INSTRUCTION IN STACK SECTION**

An executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data is in the stack section.

Remove, from the stack section, the executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data.

**106 (E) TOO MANY ERRORS**

Error display terminated due to too many errors.

Check and correct the whole source statement.

**108 (E) ILLEGAL CONTINUATION LINE**

Illegal continuation line.

Check and correct continuation line.

**150 (E) INVALID DELAY SLOT INSTRUCTION**

Illegal delay slot instruction placed following delayed branch instruction.

Change the order of the instructions so that the illegal delay slot instruction does not immediately follow a delayed branch instruction.

**151 (E) ILLEGAL EXTENDED INSTRUCTION POSITION**

Extended instruction placed following a delayed branch instruction.

Place an executable instruction following the delayed branch instruction.

**152 (E) ILLEGAL BOUNDARY ALIGNMENT VALUE**

Illegal boundary alignment value specified for a section including extended instructions.  
Specify 2 or a larger multiple of 2 as a boundary alignment value.

**160 (E) REPEAT LOOP NESTING**

Another REPEAT is located between a REPEAT and its end address.  
Correct the REPEAT location.

**161 (E) ILLEGAL START ADDRESS FOR REPEAT LOOP**

No executable or DSP instructions are located between a REPEAT and the start address.  
Use one or more executable or DSP instructions between the REPEAT and the start address.

**162 (E) ILLEGAL DATA BEFORE REPEAT LOOP**

Illegal data is found immediately before the loop specified by a REPEAT instruction.  
If an assembler directive is located before the loop, correct the directive. If a literal pool is located before the loop, use a .NOPOOL directive to prevent the literal pool output.  
When three or fewer instructions are to be repeated, an executable or DSP instruction must be located before the loop.

**163 (E) ILLEGAL INSTRUCTION IN REPEAT LOOP**

An illegal instruction is used in a repeat loop.  
A branch instruction, TRAPA instruction (excluding `cpu=sh4aldsp`), or a load instruction toward SR, RS, or RE must not be used between a REPEAT extended instruction and its end address.

**164 (E) ILLEGAL INSTRUCTION IN REPEAT LOOP**

An illegal instruction is used as a repeat end instruction.  
A branch instruction, or a load instruction toward SR, RS, or RE must not be used as a repeat end instruction.

**200 (E) UNDEFINED SYMBOL REFERENCE**

Undefined symbol reference.  
Define the symbol.

**201 (E) ILLEGAL SYMBOL OR SECTION NAME**

Reserved word specified as symbol or section name.  
Correct the symbol or section name.

**202 (E) ILLEGAL SYMBOL OR SECTION NAME**

Illegal symbol or section name.  
Correct the symbol or section name.

**203 (E) ILLEGAL LOCAL LABEL**

Illegal local label.

Correct the local label.

**300 (E) ILLEGAL MNEMONIC**

Illegal operation.

Correct the operation.

**301 (E) TOO MANY OPERANDS OR ILLEGAL COMMENT**

Too many operands of executable instruction, or illegal comment format.

Correct the operands or comment.

**304 (E) LACKING OPERANDS**

Too few operands.

Correct the operands.

**307 (E) ILLEGAL ADDRESSING MODE**

Illegal addressing mode in operand.

Correct the operand.

**308 (E) SYNTAX ERROR IN OPERAND**

Syntax error in operand.

Correct the operand.

**309 (E) FLOATING POINT REGISTER MISMATCH**

A double-precision floating-point register is specified for a single-precision operation, or a single-precision floating-point register is specified for a double-precision operation.

Correct the operation size or the floating-point register.

**350 (E) SYNTAX ERROR IN SOURCE STATEMENT (<mnemonic>)**

There are syntax error(s) in the DSP instruction statement.

Correct the source statement.

**351 (E) ILLEGAL COMBINATION OF MNEMONICS (<mnemonic>, <mnemonic>)**

Illegal combination of DSP operation instruction is specified.

Correct the combination of DSP operation instructions.

**352 (E) ILLEGAL CONDITION (<mnemonic>)**

Illegal condition for DSP operation instruction is specified.

Delete the condition or change the DSP operation instruction.



**353 (E) ILLEGAL POSITION OF INSTRUCTION (<mnemonic>)**

The DSP operation instruction is specified in an illegal position.

Specify the DSP operation instruction in the correct position.

**354 (E) ILLEGAL ADDRESSING MODE (<mnemonic>)**

The addressing mode of the DSP operation instruction is illegal.

Correct the operand.

**355 (E) ILLEGAL REGISTER NAME (<mnemonic>)**

The register name of the DSP operation instruction is illegal.

Correct the register name.

**357 (E) ILLEGAL COMBINATION OF MNEMONICS (<mnemonic>)**

An illegal data transfer instruction is specified.

Correct the data transfer instruction.

**371 (E) ILLEGAL COMBINATION OF MNEMONICS (<mnemonic>, <mnemonic>)**

The combination of data transfer instructions is illegal.

Correct the combination of data transfer instructions.

**372 (E) ILLEGAL ADDRESSING MODE (<mnemonic>)**

An illegal addressing mode for the data transfer instruction operand is specified.

Correct the operand.

**373 (E) ILLEGAL REGISTER NAME (<mnemonic>)**

An illegal register name for the data transfer instruction is specified.

Correct the register name.

**400 (E) CHARACTER CONSTANT TOO LONG**

Character constant is longer than 4 characters.

Correct the character constant.

**402 (E) ILLEGAL VALUE IN OPERAND**

Operand value out of range for this instruction.

Change the value.

**403 (E) ILLEGAL OPERATION FOR RELATIVE VALUE**

Attempt to perform multiplication, division, or logic operation on relative-address value.

Correct the expression.

**404 (E) ILLEGAL IMMEDIATE DATA**

An illegal value (forward reference symbol, external reference symbol, or relative address symbol) is specified for the immediate value.

Correct the immediate value.

**407 (E) MEMORY OVERFLOW**

Memory overflow during expression calculation.

Simplify the expression.

**408 (E) DIVISION BY ZERO**

Attempt to divide by 0.

Correct the expression.

**409 (E) REGISTER IN EXPRESSION**

Register name in expression.

Correct the expression.

**411 (E) INVALID STARTOF/SIZEOF OPERAND**

STARTOF or SIZEOF specifies illegal section name.

Correct the section name.

**412 (E) ILLEGAL SYMBOL IN EXPRESSION**

Relative-address value specified as shift value.

Correct the expression.

**450 (E) ILLEGAL DISPLACEMENT VALUE**

Illegal displacement value. (Negative value is specified.)

Correct the displacement value.

**452 (E) ILLEGAL DATA AREA ADDRESS**

PC-relative data transfer instruction specifies illegal address for data area.

Access a correct address according to the instruction operation size. (4-byte boundary for MOV.L and MOVA, and 2-byte boundary for MOV.W.)

**453 (E) LITERAL POOL OVERFLOW**

More than 510 extended instructions exist that have not output literals.

Output literal pools using .POOL.

**460 (E) ILLEGAL SYMBOL**

A label which does not reference a forward position, an undefined symbol, or a symbol other than a label is specified as an operand of a REPEAT, or the start address comes after (which means at a higher address than) the end address.

Correct the operand.

**461 (E) SYNTAX ERROR IN OPERAND**

Illegal operand.

Correct the operand.

**462 (E) ILLEGAL VALUE IN OPERAND**

The distance between a REPEAT and the label is out of range.

Correct the location of the REPEAT or the label.

**463 (E) NO INSTRUCTION IN REPEAT LOOP**

No instruction is found in a REPEAT loop, or no instruction is found at the end address.

Write an instruction between the start and end addresses, or specify an address storing an instruction as the end address.

**500 (E) SYMBOL NOT FOUND**

Label not defined in directive that requires label.

Insert a label.

**501 (E) ILLEGAL ADDRESS VALUE IN OPERAND**

Illegal specification of the start address or the value of location counter in section.

Correct the start address or value of location counter.

**502 (E) ILLEGAL SYMBOL IN OPERAND**

Illegal value (forward reference symbol, import symbol, relative-address symbol, or undefined symbol) specified in operand.

Correct the operand.

**503 (E) UNDEFINED EXPORT SYMBOL**

Symbol declared for export symbol not defined in the file.

Define the symbol. Alternatively, remove the export symbol declaration.

**504 (E) INVALID RELATIVE SYMBOL IN OPERAND**

Illegal value (forward reference symbol or import symbol) specified in operand.

Correct the operand.

**505 (E) ILLEGAL OPERAND**

Misspelled operand.

Correct the operand.

**506 (E) ILLEGAL OPERAND**

Illegal element specified in operand.

Correct the operand.

**508 (E) ILLEGAL VALUE IN OPERAND**

Operand value out of range for this directive.

Correct the operand.

**510 (E) ILLEGAL BOUNDARY VALUE**

Illegal boundary alignment value.

Correct the boundary alignment value.

**512 (E) ILLEGAL EXECUTION START ADDRESS**

Illegal execution start address.

Correct the execution start address.

**513 (E) ILLEGAL REGISTER NAME**

Illegal register name.

Correct the register name.

**514 (E) INVALID EXPORT SYMBOL**

Symbol declared for export symbol that cannot be exported.

Remove the declaration for the export symbol.

**516 (E) EXCLUSIVE DIRECTIVES**

Inconsistent directive specification.

Check and correct all related directives.

**517 (E) INVALID VALUE IN OPERAND**

Illegal value (forward reference symbol, an import symbol, or relative-address symbol) specified in operand.

Correct the operand.

**518 (E) INVALID IMPORT SYMBOL**

Symbol declared for import defined in the file.

Remove the declaration for the import symbol.

**519 (E) ILLEGAL SYMBOL IN OPERAND**

A symbol whose value is an address or a location counter value is specified for a constant value operand when the CPU type is SH2A or SH2A-FPU.

Do not specify such a value for an operand when the CPU type is SH2A or SH2A-FPU.

**520 (E) ILLEGAL .CPU DIRECTIVE POSITION**

.CPU is not specified at the beginning of the program, or specified more than once.

Specify .CPU at the beginning of the program once.

**521 (E) ILLEGAL .NOPOOL DIRECTIVE POSITION**

.NOPOOL placed at illegal position.

Place .NOPOOL following a delayed branch instruction.

**522 (E) ILLEGAL .POOL DIRECTIVE POSITION**

.POOL placed following a delayed branch instruction.

Place an executable instruction following the delayed branch instruction.

**523 (E) ILLEGAL OPERAND**

Illegal .LINE operand.

Correct the operand.

**525 (E) ILLEGAL .LINE DIRECTIVE POSITION**

.LINE specified during macro expansion or conditional iterated expansion.

Change the specified position of .LINE.

**526 (E) STRING TOO LONG**

The operand character string has more than 255 characters.

The character strings to specify to the operand of .SDATA, .SDATAB, .SDATAC, and .SDATAZ directives must have 255 or less characters.

**527 (E) CANNOT SUPPORT COMMON SECTION SINCE VERSION 5**

COMMON is specified for the section attribute.

Common section cannot be used.

More than one section can be allocated to the same address by using a colon (:) in the **start** option of the optimizing linkage editor.

**528 (E) SPECIFICATION OF THE ADDRESS OVERLAPS**

Address allocation overlaps in a section.

Check the specified contents of .SECTION and .ORG.

**529 (E) THE ADDRESS BETWEEN SECTIONS OVERLAPS**

Address allocation overlaps between sections.

Check the specified contents of .SECTION and .ORG.

**530 (E) ILLEGAL OPERAND**

Error in the operand of .FILE.

Correct the operand in .FILE.

**531 (E) ILLEGAL .FILE DIRECTIVE POSITION**

Macro expansion or conditional iterated expansion is specified for .FILE.

Correct the location of .FILE.

**532 (E) ILLEGAL OPERAND**

Error in the operand of .STACK.

Correct the stack value to be a multiple of 4.

**533 (E) ILLEGAL .STACK DIRECTIVE POSITION**

.STACK is specified in macro expansion or conditional iterated expansion.

Correct the location of .STACK.

**600 (E) INVALID CHARACTER**

Illegal character.

Correct it.

**601 (E) INVALID DELIMITER**

Illegal delimiter character.

Correct it.

**602 (E) INVALID CHARACTER STRING FORMAT**

Character string error.

Correct it.

**603 (E) SYNTAX ERROR IN SOURCE STATEMENT**

Source statement syntax error.

Check and correct the whole source statement.

**604 (E) ILLEGAL SYMBOL IN OPERAND**

Illegal operand specified in a directive.

No symbol or location counter (\$) can be specified as an operand of this directive.

**610 (E) MULTIPLE MACRO NAMES**

Macro name reused in macro definition (.MACRO directive).  
Correct the macro name.

**611 (E) MACRO NAME NOT FOUND**

Macro name not specified (.MACRO directive).  
Specify a macro name in the name field of the .MACRO directive.

**612 (E) ILLEGAL MACRO NAME**

Macro name error (.MACRO directive).  
Correct the macro name.

**613 (E) ILLEGAL .MACRO DIRECTIVE POSITION**

.MACRO directive appears in macro body (between .MACRO and .ENDM directives),  
between .AREPEAT and .AENDR directives, or between .AWHILE and .AENDW directives.  
Remove the .MACRO directive.

**614 (E) MULTIPLE MACRO PARAMETERS**

Identical formal parameters repeated in formal parameter declaration in macro definition  
(.MACRO directive).  
Correct the formal parameters.

**615 (E) ILLEGAL .END DIRECTIVE POSITION**

.END directive appears in macro body (between .MACRO and .ENDM directives).  
Remove the .END directive.

**616 (E) MACRO DIRECTIVES MISMATCH**

.ENDM directive appears without a preceding .MACRO directive, or an .EXITM directive  
appears outside of a macro body (between .MACRO and .ENDM directives), outside  
of .AREPEAT and .AENDR directives, or outside of .AWHILE and .AENDW directives.  
Remove the .ENDM or .EXITM directive.

**618 (E) MACRO EXPANSION TOO LONG**

Line with over 8,192 characters generated by macro expansion.  
Correct the definition or call so that the line is less than or equal to 8,192 characters.

**619 (E) ILLEGAL MACRO PARAMETER**

Macro parameter name error in macro call, or error in formal parameter in a macro body (between .MACRO and .ENDM directives).

Correct the formal parameter.

When there is an error in a formal parameter in a macro body, the error will be detected and flagged during macro expansion.

**620 (E) UNDEFINED PREPROCESSOR VARIABLE**

Reference to an undefined preprocessor variable.

Define the preprocessor variable.

**621 (E) ILLEGAL .END DIRECTIVE POSITION**

.END directive in macro expansion.

Remove the .END directive.

**622 (E) ')' NOT FOUND**

Matching parenthesis missing in macro processing exclusion.

Add the missing macro processing exclusion parenthesis.

**623 (E) SYNTAX ERROR IN STRING FUNCTION**

Syntax error in character string manipulation function.

Check and correct the character string manipulation function.

**624 (E) MACRO PARAMETERS MISMATCH**

Too many numbers of macro parameters for positional specification in macro call.

Correct the number of macro parameters.

**631 (E) END DIRECTIVE MISMATCH**

Terminating preprocessor directive does not agree with matching directive.

Check and correct the preprocessor directives.

**640 (E) SYNTAX ERROR IN OPERAND**

Syntax error in conditional assembly directive operand.

Check and correct the whole source statement.

**641 (E) INVALID RELATIONAL OPERATOR**

Error in conditional assembly directive relational operator.

Correct the relational operator.



**642 (E) ILLEGAL .END DIRECTIVE POSITION**

.END directive appears between .AREPEAT and .AENDR directives or between .AWHILE and .AENDW directives.

Remove the .END directive.

**643 (E) DIRECTIVE MISMATCH**

.AENDR or .AENDW directive does not form a proper pair with .AREPEAT or .AWHILE directive.

Check and correct the preprocessor directives.

**644 (E) ILLEGAL .AENDW OR .AENDR DIRECTIVE POSITION**

.AENDW or .AENDR directive appears between .AIF and .AENDI directives.

Remove the .AENDW or .AENDR directive.

**645 (E) EXPANSION TOO LONG**

After .AREPEAT or .AWHILE expansion, the number of characters in a line exceeds 8,192 characters.

Correct the .AREPEAT or .AWHILE to generate lines of less than or equal to 8,192 characters.

**650 (E) INVALID INCLUDE FILE**

Error in .INCLUDE file name.

Correct the file name.

**651 (E) CANNOT OPEN INCLUDE FILE**

Could not open the file specified by .INCLUDE directive.

Correct the file name.

**652 (E) INCLUDE NEST TOO DEEP**

File inclusion nesting exceeded 30 levels.

Limit the nesting to 30 or fewer levels.

**653 (E) SYNTAX ERROR IN OPERAND**

Syntax error in .INCLUDE operand.

Correct the operand.

**660 (E) .ENDM NOT FOUND**

Missing .ENDM following .MACRO.

Insert .ENDM.

**662 (E) ILLEGAL .END DIRECTIVE POSITION**

.END appears between .AIF and .AENDI directives.

Remove .END.

**663 (E) ILLEGAL .END DIRECTIVE POSITION**

.END appears in included file.

Remove .END.

**664 (E) ILLEGAL .END DIRECTIVE POSITION**

.END appears between .AIF and .AENDI directives.

Remove .END.

**665 (E) EXPANSION TOO LONG**

The number of line characters exceeds 8,192 in .DEFINE.

Correct the characters as 8,192 or less.

**667 (E) SUCCESSFUL CONDITION .AERROR**

Statement including .AERROR was processed in the .AIF condition.

Check and correct the conditional statement so that .AERROR is not processed.

**668 (E) ILLEGAL VALUE IN OPERAND**

Error in the operand of .AIFDEF.

Specify, as the operand of this directive, a symbol defined by .DEFINE.

**669 (E) STRING TOO LONG**

The operand character string exceeds 255 characters.

The character strings to specify to the operand of .ASSIGNC, .DEFINE, and character manipulating functions (.LEN, .INSTR, and .SUBSTR) must have 255 or less characters.

**670 (E) ILLEGAL SYMBOL IN OPERAND**

A symbol other than a preprocessor variable is specified in a preprocessor directive when the CPU type is SH2A or SH2A-FPU.

Correct the symbol.

**700 (W) ILLEGAL VALUE IN OPERAND (<mnemonic>)**

The operand value of the DSP operation instruction is out of range.

Correct the operand value.

**701 (W) MULTIPLE REGISTER IN DESTINATION (<mnemonic>, <mnemonic>)**

The same register is specified as multiple destination operands of the DSP instruction.  
Specify the register correctly.

**702 (W) ILLEGAL OPERATION SIZE (<mnemonic>)**

The operation size of the DSP operation instruction or the data transfer instruction is illegal.  
Cancel or correct the operation size.

**703 (W) MULTIPLE REGISTER IN DESTINATION (<mnemonic>, <mnemonic>)**

The same register is specified as the destination registers of the DSP operation instruction and data transfer instruction.  
Specify the register correctly.

**704 (W) A PRIVILEGED INSTRUCTION "mnemonic" IS USED**

A privileged instruction is found when the **CHKMD** option is specified.

**705 (W) A LDTLB INSTRUCTION IS USED**

A LDTLB instruction is found when the **CHKTLB** option is specified.

**706 (W) A CACHE INSTRUCTION "mnemonic" IS USED**

A cache-related instruction is found when the **CHKCACHE** option is specified.

**707 (W) A DSP INSTRUCTION "mnemonic" IS USED**

A DSP-related instruction is found when the **CHKDSP** option is specified.

**708 (W) A FPU INSTRUCTION "mnemonic" IS USED**

An FPU-related instruction is found when the **CHKFPU** option is specified.

**800 (W) SYMBOL NAME TOO LONG**

A preprocessor variable name exceeds 32 characters.  
Correct the preprocessor variable.  
The assembler ignores the 33rd and later characters.

**801 (W) MULTIPLE SYMBOLS**

Symbol already defined.  
Remove the symbol redefinition.  
The assembler ignores the second and later definitions.

**807 (W) ILLEGAL OPERATION SIZE**

Illegal operation size.

Correct the operation size.

The assembler ignores the incorrect operation size specification.

**808 (W) ILLEGAL CONSTANT SIZE**

Illegal notation of integer constant.

Correct the notation.

The assembler may misinterpret the integer constant, i.e., interpret it as a value not intended by the programmer.

**810 (W) TOO MANY OPERANDS**

Too many operands or illegal comment format.

Correct the operand or the comment.

The assembler ignores the extra operands.

**811 (W) ILLEGAL SYMBOL DEFINITION**

A label specified in assembler directive that cannot have a label is written.

Remove the label.

The assembler ignores the label.

**813 (W) SECTION ATTRIBUTE MISMATCH**

A different section type is specified on section restart, or a section start address is respecified at the restart of absolute-address section.

Do not respecify a different section type or a start address on section restart.

The specification of starting section remains valid.

**814 (W) ILLEGAL OBJECT CODE SIZE**

Illegal allocation size.

Only :12 can be specified for the allocation size.

**815 (W) MULTIPLE MODULE NAMES**

Respecification of object module name.

Specify the object module name once in a program.

The assembler ignores the second and later object module name specifications.

### 816 (W) ILLEGAL DATA AREA ADDRESS

Illegal allocation of data or data area.

Locate the word data or data area on an even address. Locate the long-word or single-precision data or data area on an address of a multiple of 4. Locate the double-precision data or data area on an address of a multiple of 8.

The assembler corrects the location of the data or data area according to its specified size.

### 817 (W) ILLEGAL BOUNDARY VALUE

A boundary alignment value less than 4 specified for a code section or stack section.

The specification is valid, but if an executable instruction, DSP instruction, or extended instruction is located at an odd address, warning 882 occurs.

Special care must be taken when specifying 1 for code section or stack section boundary alignment value.

### 818 (W) COMMANDLINE OPTION MISMATCH FOR FLOATING DIRECTIVE

When the CPU type is SH2E, **round=nearest** or **denormalize=on** is specified, or when the CPU type is SH2A-FPU, **denormalize=on** is specified.

Change the specification in the **round** or **denormalize** option.

The assembler creates the object code according to the specification in the **round** or **denormalize** option.

### 825 (W) ILLEGAL INSTRUCTION IN DUMMY SECTION

An executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data is in dummy section.

Remove, from the dummy section, the executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data.

The assembler ignores the executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data in dummy section.

### 826 (W) ILLEGAL PRECISION

The floating-point constant does not have the same precision specified with the operation size.

Correct the operation size or the precision type of the floating-point constant.

The assembler assumes the precision specified with the operation size.

### 832 (W) MULTIPLE 'P' DEFINITIONS

Symbol P already defined before a default section is used.

Do not define P as a symbol if a default section is used.

The assembler regards P as the name of the default section, and ignores other definitions of the symbol P.

**835 (W) ILLEGAL VALUE IN OPERAND**

Operand value out of range for the executable instruction.

Correct the value.

The assembler generates object code with a value corrected to be within range.

**836 (W) ILLEGAL CONSTANT SIZE**

Illegal notation of integer constant.

Correct the notation.

The assembler may misinterpret the integer constant, i.e., interpret it as a value not intended by the programmer.

**837 (W) SOURCE STATEMENT TOO LONG**

After .AREPEAT or .AWHILE expansion, the number of characters in a line exceeds 8192 characters.

Rewrite the source statement to be within 8,192 bytes by, for example, rewriting the comment.

Alternatively, rewrite the statement as a multi-line statement.

**838 (W) ILLEGAL CHARACTER CODE**

The shift JIS code, EUC code, or LATIN1 code is specified outside character strings and comments, or the **sjis**, **euc**, or **latin1** option is not specified.

Specify the shift JIS code, EUC code, LATIN1 code in character strings or comments. Or specify the **sjis**, **euc**, or **latin1** option.

**839 (W) ILLEGAL FIGURE IN OPERAND**

Fixed-point data having six or more digits is specified in word size, or that having 11 or more digits is specified in long-word size.

Reduce the digits to the limit.

**840 (W) OPERAND OVERFLOW**

Floating-point data overflowed.

Modify the value.

The assembler assumes  $+\infty$  when the value is positive and  $-\infty$  when negative.

**841 (W) OPERAND UNDERFLOW**

Floating-point data underflowed.

Modify the value.

The assembler assumes  $+0$  when the value is positive and  $-0$  when negative.

**842 (W) OPERAND DENORMALIZED**

Denormalized numbers are specified for floating-point data.  
Check and correct the floating-point data.  
The assembler creates the object code according to the specification (sets denormalized numbers).

**843 (W) INEFFECTIVE FLOATING POINT OPERATION**

An invalid operation such as  $\infty - \infty$  or  $0.0 / 0.0$  is specified in a constant expression.  
An internal representation corresponding to a not-a-number, which represents an invalid operation result, is assumed.

**844 (W) DIVISION BY FLOATING POINT ZERO**

Division by zero is specified in a constant expression.  
An internal representation corresponding to  $+\infty$  or  $-\infty$  is assumed depending on the sign.

**845 (W) ILLEGAL IMMEDIATE VALUE**

Illegal immediate value; the lower eight bits are not 0.  
The assembler corrects the lower eight bits of the immediate value to be 0.

**850 (W) ILLEGAL SYMBOL DEFINITION**

Symbol specified in label field.  
Remove the symbol.

**851 (W) MACRO SERIAL NUMBER OVERFLOW**

Macro serial number exceeded 99,999.  
Reduce the number of macro calls.

**852 (W) UNNECESSARY CHARACTER**

Characters appear after the operands.  
Correct the operand(s).

**854 (W) .AWHILE ABORTED BY .ALIMIT**

Expansion count has reached the maximum value specified by .ALIMIT, and expansion has been terminated.  
Check and correct the condition for iterated expansion.

**856 (W) MULTIPLE SYMBOLS**

A stack value is defined for the same symbol again.  
Remove the stack value redefinition.  
The assembler ignores the second and later definitions.

**870 (W) ILLEGAL DISPLACEMENT VALUE**

Illegal displacement value.

Either the displacement value is not an even number when the operation size is word, or the displacement value is not a multiple of 4 when the operation size is long word.

Take account of the fact that the assembler corrects the displacement value.

The assembler generates object code with the displacement corrected according to the operation size.

For a word size operation the assembler discards the low order bit of the displacement to create an even number, and for a long-word-size operation the assembler discards the two low order bits of the displacement to create a multiple of 4.

**874 (W) CANNOT CHECK DATA AREA BOUNDARY**

Cannot check data area boundary for PC-relative data transfer instructions.

Note carefully the data area boundary at linkage process.

The assembler outputs this message when a data transfer instruction is included in a relative-address section, or when an import symbol is used to indicate a data area.

**875 (W) CANNOT CHECK DISPLACEMENT SIZE**

Cannot check displacement size for PC-relative data transfer instructions.

Note carefully the distance between data transfer instructions and data area at linkage.

The assembler outputs this message when a data transfer instruction is included in a relative-address section, or when an import symbol is used to indicate a data area.

**876 (W) ASSEMBLER OUTPUTS BRA INSTRUCTION**

The assembler automatically outputs a BRA instruction.

Specify a literal pool output position using .POOL, or check that the program to which a BRA instruction is added can run normally.

When a literal pool output location is not available, the assembler automatically outputs literal pool and a BRA instruction to jump over the literal pool.

**880 (W) .END NOT FOUND**

No .END in the program.

Insert an .END.

**881 (W) ILLEGAL DIRECTIVE IN REPEAT LOOP**

An illegal assembler directive was found in a .REPEAT loop.

Delete the directive.

If a directive that reserves a data item or a data area, .ALIGN, or .ORG is used in a .REPEAT loop, the assembler counts the directive as one of the instructions to be repeated.



**882 (W) ILLEGAL ADDRESS**

The executable instruction and extended instruction are written in an odd address.  
Write the executable instruction and extended instruction are written in an even address.

**883 (W) MULTIPLE FILE NAMES**

.FILE is specified more than once.  
The second and later specifications are ignored.

**884 (W) "CPU type 1" is interpreted as "CPU type 2"**

cpu=<CPU type 1> is invalid.  
It is interpreted as cpu=<CPU type 2> for assembling.

**885 (W) CANNOT SUPPORT "CPU type"**

The CPU type specified by .CPU is not supported.  
It is interpreted as the CPU type specified by the **cpu** option.

**901 (F) SOURCE FILE INPUT ERROR**

Source file input error.  
Check the hard disk for adequate free space. Create the required free space, e.g. by deleting unnecessary files.

**902 (F) MEMORY OVERFLOW**

Insufficient memory. (Unable to process the temporary information.)  
Subdivide the program.

**903 (F) LISTING FILE OUTPUT ERROR**

Output error on the listing file.  
Check the hard disk for adequate free space. Create the required free space, e.g. by deleting unnecessary files.

**904 (F) OBJECT FILE OUTPUT ERROR**

Output error on the object file.  
Check the hard disk for adequate free space. Create the required free space, e.g. by deleting unnecessary files.

**905 (F) MEMORY OVERFLOW**

Insufficient memory. (Unable to process the line information.)

Subdivide the program.

**906 (F) MEMORY OVERFLOW**

Insufficient memory. (Unable to process the symbol information.)

Subdivide the program.

**907 (F) MEMORY OVERFLOW**

Insufficient memory. (Unable to process the section information.)

Subdivide the program.

**908 (F) SECTION OVERFLOW**

Too much number of sections.

When debugging information is output, up to 62,265 sections can be enabled.

When debugging information is not output, up to 65,274 sections can be enabled.

Subdivide the program.

**933 (F) ILLEGAL ENVIRONMENT VARIABLE**

The specified target CPU is incorrect.

Correct the target CPU.

**935 (F) SUBCOMMAND FILE INPUT ERROR**

Subcommand file input error.

Check the hard disk for adequate free space. Create the required free space, e.g. by deleting unnecessary files.

**950 (F) MEMORY OVERFLOW**

Insufficient memory.

Subdivide the source program.

**951 (F) LITERAL POOL OVERFLOW**

The number of literal pools exceeds 100,000.

Subdivide the source program.

**952 (F) LITERAL POOL OVERFLOW**

Literal pool capacity overflow.

Insert unconditional branch before overflow.

**953 (F) MEMORY OVERFLOW**

Insufficient memory.

Subdivide the source program.

**954 (F) LOCAL BLOCK NUMBER OVERFLOW**

The number of local blocks that are valid in the local label exceeds 100,000.

Subdivide the source program.

**956 (F) EXPAND FILE INPUT/OUTPUT ERROR**

File output error for preprocessor expansion.

Check the hard disk for adequate free space. Create the required free space, e.g. by deleting unnecessary files.

**957 (F) MEMORY OVERFLOW**

Insufficient memory.

Subdivide the source program.

**958 (F) MEMORY OVERFLOW**

Insufficient memory.

Subdivide the source program.

**964 (F) MEMORY OVERFLOW**

Insufficient memory (Unable to process the symbol information).

Subdivide the source program.

**970 (F) MEMORY OVERFLOW**

Insufficient memory.

Section size is too large. A large offset may have been given to the location counter using `.ORG`, or a large data area may have been reserved by using directives such as `.DATAB`.

Subdivide the section or reduce the data area.



## Section 14 Error Messages for the Optimizing Linkage Editor

### 14.1 Error Format and Error Levels

This section gives a list of error messages and explains details of errors in the following format.

**Error number**      **(Error level) Error message**  
                          Error details

There are five different error levels, corresponding to different degrees of seriousness.

| <b>Error Number</b>        | <b>Error Level</b> | <b>Error Type</b> | <b>Description</b>                                                     |
|----------------------------|--------------------|-------------------|------------------------------------------------------------------------|
| L0000–L0999<br>P0000–P0999 | (I)                | Information       | Processing is continued.                                               |
| L1000–L1999<br>P1000–P1999 | (W)                | Warning           | Processing is continued.                                               |
| L2000–L2999<br>P2000–P2999 | (E)                | Error             | Option analysis processing is continued;<br>processing is interrupted. |
| L3000–L3999<br>P3000–P3999 | (F)                | Fatal             | Processing is interrupted.                                             |
| L4000–<br>P4000–           | (–)                | Internal          | Processing is interrupted.                                             |

Error numbers beginning with an **L** are optimizing linkage editor output messages.

Error numbers beginning with a **P** are prelinker output messages. Output of errors with numbers beginning with a **P** cannot be controlled using the **nomessage** or **change\_message** options.

### 14.2 Return Values for Errors

When terminating execution, the optimizing linkage editor returns a numeric value to the OS indicating the processing result as shown below.

| Return Value | Description                                                                                                                       |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------|
| 0            | Processing was completed successfully, or processing was terminated after an information message or a warning message was output. |
| 1            | An error, a fatal error, or an internal error occurred and processing was forcibly terminated.                                    |

### 14.3 List of Messages

#### L0001 (I) Section "section" created by optimization "optimization"

The section named **section** was created as a result of the optimization.

#### L0002 (I) Symbol "symbol" created by optimization "optimization"

The symbol named **symbol** was created as a result of the optimization.

#### L0003 (I) "file"-"symbol" moved to "section" by optimization

As a result of **variable\_access** optimization, the symbol named **symbol** in **file** was moved.

#### L0004 (I) "file"-"symbol" deleted by optimization

As a result of **symbol\_delete** optimization, the symbol named **symbol** in **file** was deleted.

#### L0005 (I) The offset value from the symbol location has been changed by optimization : "file"-"section"-"symbol ± offset"

As a result of the size being changed by optimization within the range of **symbol ± offset**, the **offset** value was changed. Check that this does not cause a problem. To disable changing of the **offset** value, cancel the specification of the **goptimize** option on assembly of **file**.

#### L0100 (I) No inter-module optimization information in "file"

No inter-module optimization information was found in **file**. Inter-module optimization is not performed on **file**. To perform inter-module optimization, specify the **goptimize** option on compiling and assembly. Note however that the **goptimize** option is not available in **asmsh**.

#### L0101 (I) No stack information in "file"

No stack information was found in **file**. **file** may be an assembler output file or a **SYSROF->ELF** converted file. The contents of the file will not be in the stack information file output by the optimizing linkage editor.

- L0102 (I) Stack size "size" specified to the undefined symbol "symbol" in "file"**  
Stack size **size** is specified for the undefined symbol named **symbol** in **file**.
- L0103 (I) Multiple stack sizes specified to the symbol "symbol"**  
Multiple stack sizes are specified for the symbol named **symbol**.
- L0300 (I) Mode type "mode type 1" in "file" differ from "mode type 2"**  
A file with a different mode type was input.
- L0400 (I) Unused symbol "file"-"symbol"**  
The symbol named **symbol** in **file** is not used.
- L0500 (I) Generated CRC code at "address"**  
Generated CRC code at **address**.
- L0510 (I) Section "section" was moved other area specified in option "cpu=<attribute>" section** without dividing is allocated according to **cpu=<attribute>**.
- L0511 (I) Sections "section name", "new section name" are Non-contiguous section** was divided and the newly created section is **new section name**.
- L1000 (W) Option "option" ignored**  
The option named **option** is invalid, and is ignored.
- L1001 (W) Option "option 1" is ineffective without option "option 2"**  
**option 1** needs specifying **option 2**. **option 1** is ignored.
- L1002 (W) Option "option 1" cannot be combined with option "option 2"**  
**option 1** and **option 2** cannot be specified simultaneously. **option 1** is ignored.
- L1003 (W) Divided output file cannot be combined with option "option"**  
**option** and the option to divide the output file cannot be specified simultaneously. **option** is ignored. The first input file name is used as the output file name.
- L1004 (W) Fatal level message cannot be changed to other level : "number"**  
The level of a fatal error type message cannot be changed. The specification of **number** is ignored. Only errors at the information/warning/error level can be changed with the **change\_message** option.
- L1005 (W) Subcommand file terminated with end option instead of exit option**  
There is no processing specification following the **end** option. Processing is done with the **exit** option assumed.

- L1006 (W) Options following exit option ignored**  
All options following the **exit** option is ignored.
- L1007 (W) Duplicate option : "option"**  
Duplicate specifications of **option** were found. Only the last specification is effective.
- L1008 (W) Option "option" is effective only in cpu type "CPU type"**  
**option** is effective only in **CPU type**. **option** is ignored.
- L1010 (W) Duplicate file specified in option "option" : "file"**  
**option** was used to specify the same file twice. The second specification is ignored.
- L1011 (W) Duplicate module specified in option "option" : "module"**  
**option** was used to specify the same module twice. The second specification is ignored.
- L1012 (W) Duplicate symbol/section specified in option "option" : "name"**  
**option** was used to specify the same symbol name or section name twice. The second specification is ignored.
- L1013 (W) Duplicate number specified in option "option" : "number"**  
**option** was used to specify the same error number. Only the last specification is effective.
- L1100 (W) Cannot find "name" specified in option "option"**  
The symbol name or section name specified in **option** cannot be found. The **name** specification is ignored.
- L1101 (W) "name" in rename option conflicts between symbol and section**  
**name** specified by the **rename** option exists as both a section name and as a symbol name. Rename is performed for the symbol name only in this case.
- L1102 (W) Symbol "symbol" redefined in option "option"**  
The symbol specified by **option** has already been defined. Processing is continued without any change.
- L1103 (W) Invalid address value specified in option "option" : "address"**  
**address** specified by **option** is invalid. The **address** specification is ignored.
- L1104 (W) Invalid section specified in option "option" : "section"**  
An invalid section was specified in **option**. Confirm the following:  
(1) The **-output** option does not accept a section that has no initial value.  
(2) The **-jump\_entries\_for\_pic** option accepts only a program section.



**L1110 (W) Entry symbol "symbol" in entry option conflicts**

A symbol other than **symbol** specified by the **entry** option is specified as the entry symbol on compiling or assembling. The option specification is given priority.

**L1120 (W) Section address is not assigned to "section"**

**section** has no addresses specified for it. **section** will be located at the rearmost address. Specify the address of the section using the optimizing linkage editor option **-start**.

**L1121 (W) Address cannot be assigned to absolute section "section" in start option**

**section** is an absolute address section. An address assigned to an absolute address section is ignored.

**L1122 (W) Section address in start option is incompatible with alignment : "section"**

The address of **section** specified by the **start** option conflicts with memory boundary alignment requirements. The section address is modified to conform to boundary alignment.

**L1130 (W) Section attribute mismatch in rom option : "section 1, section 2"**

The attributes and boundary alignment of **section 1** and **section 2** specified by the **rom** option are different. The larger value is effective as the boundary alignment of **section 2**.

**L1140 (W) Load address overflowed out of record-type in option "option"**

A **record** type smaller than the address value was specified. The range exceeding the specified **record** type has been output as different **record** type.

**L1141 (W) Cannot fill unused area from "address" with the specified value**

Specified data cannot be output to addresses higher than **address** because the unused area size is not a multiple of the value specified by the **space** option.

**L1150 (W) Sections in "option" option have no symbol**

The section specified in **option** does not have an externally defined symbol.

**L1160 (W) Undefined external symbol "symbol"**

An undefined external symbol **symbol** was referenced.

**L1170 (W) Specified SBR addresses conflict**

Different **SBR** addresses have been specified. Processing is done with **SBR=USER** assumed.

**L1171 (W) Least significant byte in SBR="constant" ignored**

The least significant 8 bits in address **constant** specified by the **SBR** option are ignored.

- L1180 (W) Directive command "directive" is duplicated in "file"**  
**directive** was specified in multiple source files.  
**directive** cannot be written more than once across files.
- L1181 (W) Fail to write "type of output code"**  
Failed to write **type of output code** to the output file.  
The output file may not contain the address to which **type of output code** should be output.  
**Type of output code:**  
When failed to write ID code -> **ID Code**  
→**L1181 Fail to write "ID Code"**  
When failed to write PROTECT/OFSREG code -> **Protect Code** or **OFSREG Code**  
→**L1181 Fail to write "Protect Code" or "OFSREG Code"**  
When failed to write CRC code -> **CRC Code**  
→**L1181 Fail to write "CRC Code"**
- L1182 (W) Cannot generate vector table section "section"**  
The input file contains vector table **section**. The linkage editor does not create the **section** automatically.
- L1183 (W) Interrupt number "vector number" of "section" is defined in input file**  
The vector number specified by the VECTN option is defined in the input file.  
Processing is continued with priority given on the definition in the input file.
- L1190 (W) Section "section" was moved other area specified in option "cpu=<memory attribute>"**  
The object size was modified through optimization of access to external variables.  
Accordingly, the **section** in the area specified by the next **cpu** specification was moved.
- L1191 (W) Area of "FIX" is within the range of the area specified by "cpu=<memory type>" : "<start>-<end>"**  
In the **cpu** option, the address range of <start>-<end> specified for **FIX** overlapped with that specified for another memory type. The setting for **FIX** is valid.
- L1192 (W) Bss Section "section name" is not initialized**  
**section name**, which is a data section without an initial value, cannot be initialized by the initial setup program. Check the address range specified with **-cpu** and the sizes of pointer variables.

- L1193 (W) Section "section name" specified in option "option" is ignored**  
**option** specified for the section newly created due to **-cpu=stride** is invalid. Do not specify **option** for the newly created section.
- L1194 (W) Section "option" in relocation "file"-"section"-"offset" is changed.**  
The relocation **section file offset** now refers to a location in the new section created with the division of **section**. To prevent division, declare the **contiguous\_section** option for **section**.
- L1200 (W) Backed up file "file 1" into "file 2"**  
Input file **file 1** was overwritten. A backup copy of the data in the previous version of **file 1** was saved in **file 2**.
- L1300 (W) No debug information in input files**  
There is no debugging information in the input files. The **debug**, **sdebug**, or **compress** option has been ignored. Check whether the relevant option was specified at compilation or assembly.
- L1301 (W) No inter-module optimization information in input files**  
No inter-module optimization information is present in the input files. The **optimize** option has been ignored. Check whether the **goptimize** option was specified at compilation or assembly.
- L1302 (W) No stack information in input files**  
No stack information is present in the input files. The **stack** option is ignored. If all input files are assembler output files or **SYSROF->ELF** converted files, the **stack** option is ignored.
- L1303 (W) No rts information in input files**  
No information in input files to generate **.rts** file. The processing will end without creating an **.rts** file.
- L1304 (W) No utl information in input files**  
The information necessary to generate a **utl** file was not input.
- L1305 (W) Entry address in "file" conflicts : "address"**  
Multiple files with different entry addresses are input.
- L1310 (W) "section" in "file" is not supported in this tool**  
An unsupported section was present in **file**. **section** has been ignored.

- L1311 (W) Invalid debug information format in "file"**  
Debugging information in **file** is not **dwarf2**. The debugging information has been deleted.
- L1320 (W) Duplicate symbol "symbol" in "file"**  
The symbol named **symbol** is duplicated. The symbol in the first file input is given priority.
- L1321 (W) Entry symbol "symbol" in "file" conflicts**  
Multiple object files containing more than one entry symbol definition were input. Only the entry symbol in the first file input is effective.
- L1322 (W) Section alignment mismatch : "section"**  
Sections with the same name but different boundary alignments were input. Only the largest boundary alignment specification is effective.
- L1323 (W) Section attribute mismatch : "section"**  
Sections with the same name but different attributes were input. If they are an absolute section and relative section, the section is treated as an absolute section. If the read/write attributes mismatch, both are allowed.
- L1324 (W) Symbol size mismatch : "symbol" in "file"**  
Common symbols or defined symbols with different sizes were input. A defined symbol is given priority. In the case of two common symbols, the symbol in the first file input is given priority.
- L1325 (W) Symbol attribute mismatch : "symbol": "file"**  
The attribute of **symbol** in **file** does not match the attribute of the same-name symbol in other files. Check the symbol.
- L1326 (W) Reserved symbol "symbol" is defined in "file"**  
Reserved symbol name **symbol** is defined in the **file**.
- L1327 (W) Section alignment in option "aligned\_section" is small : "section"**  
Since the boundary alignment value specified for the **aligned\_section** option is 16, which is smaller than that of **section**, the option settings made for that section are ignored.
- L1330 (W) Cpu type "CPU type 1" in "file" differ from "CPU type 2"**  
Files with different CPU types were input. Processing is continued with the CPU type assumed as H8SX.

**L1400 (W) Stack size overflow in register optimization**

During register optimization, the stack access code exceeded the stack size limit of the compiler. The register optimization specification has been ignored.

**L1401 (W) Function call nest too deep**

The number of function call nesting levels is so deep that register optimization cannot be performed.

**L1402 (W) Parentheses specified in option "start" with optimization**

Optimization is not available when parentheses "(" are specified in the **start** option. Optimization has been disabled.

**L1410 (W) Cannot optimize "file"- "section" due to multi label relocation operation**

A section having multiple label relocation operations cannot be optimized. Section **section** in file **file** has not been optimized.

**L1420 (W) "file" is newer than "profile"**

**file** was updated after **profile**. The profile information has been ignored.

**L1430 (W) Cannot generate effective bls file for compiler optimization**

An invalid **bls** file was created. This optimization is not available even if optimization of access to external variables (**map** option) is specified for compilation.

The optimization of access to external variables (**map** option) in the compiler has the following restriction. Check if this restriction is applicable and modify the section allocation.

Access to external variables cannot be optimized in some cases if a data section is allocated immediately after a program section when the **base** option is specified for compilation.

Note: The **bls** file indicates the external symbol allocation information file.

It contains the information to be used for the **map** option of the compiler.

**L1500 (W) Cannot check stack size**

There is no stack section, and so consistency of the stack size specified by the **stack** option on compiling cannot be checked. To check the consistency of the stack size on compiling, the **goptimize** option needs to be specified on compiling and assembling.

**L1501 (W) Stack size overflow : "stack size"**

The stack section size exceeded the **stack size** specified by the **stack** option on

compiling. Either change the option used on compiling, or change the program so as to reduce the use of the stack.

- L1502 (W) Stack size in "file" conflicts with that in another file**  
Different values for stack size are specified for multiple files. Check the options used on compiling.
- L1510 (W) Input file was compiled with option "smap" and option "map" is specified at linkage**  
A file was compiled with **smap** specification. The file with **smap** specification should not be compiled with the **map** option specification in the second build processing.
- P1600 (W) An error occurred during name decoding of "instance"**  
**instance** could not be decoded. The message is output using the encoding name.
- L2000 (E) Invalid option : "option"**  
**option** is not supported.
- L2001 (E) Option "option" cannot be specified on command line**  
**option** cannot be specified on the command line. Specify this option in a subcommand file.
- L2002 (E) Input option cannot be specified on command line**  
The **input** option was specified on the command line. Input file specification on the command line should be made without the **input** option.
- L2003 (E) Subcommand option cannot be specified in subcommand file**  
The **subcommand** option was specified in a subcommand file. The **subcommand** option cannot be nested.
- L2004 (E) Option "option 1" cannot be combined with option "option 2"**  
**option 1** and **option 2** cannot be specified simultaneously.
- L2005 (E) Option "option" cannot be specified while processing "process"**  
**option** cannot be specified for **process**.
- L2006 (E) Option "option 1" is ineffective without option "option 2"**  
**option 1** requires **option 2** be specified.
- L2010 (E) Option "option" requires parameter**  
**option** requires a parameter to be specified.

**L2011 (E) Invalid parameter specified in option "option" : "parameter"**

An invalid parameter was specified for **option**.

**L2012 (E) Invalid number specified in option "option" : "value"**

An invalid value was specified for **option**. Check the range of valid values.

**L2013 (E) Invalid address value specified in option "option" : "address"**

The address **address** specified in **option** is invalid. A hexadecimal address between 0 and FFFFFFFF should be specified.

**L2014 (E) Illegal symbol/section name specified in "option" : "name"**

The section or symbol name specified in **option** uses an illegal character. Only alphanumeric characters, the underscore (\_), and the dollar sign (\$) may be used in section/symbol names (the leading character cannot be a number).

**L2016 (E) Invalid alignment value specified in option "option" : "alignment value"**

The **alignment value** specified in **option** is invalid. 1, 2, 4, 8, 16, or 32 should be specified.

**L2017 (E) Cannot output "section" specified in option "option"**

Part of the code in **section** specified by **option** cannot be output. Part of the instruction code in **section** has been swapped with instruction code in another section due to endian conversion. Check the **section** address range with respect to 4-byte boundaries in the linkage list and find which section code is swapped with the target **section** code.

Note: The endian conversion function is available only in the RX Family CPU.

**L2020 (E) Duplicate file specified in option "option" : "file"**

The same file was specified twice in **option**.

**L2021 (E) Duplicate symbol/section specified in option "option" : "name"**

The same symbol name or section name was specified twice in **option**.

**L2022 (E) Address ranges overlap in option "option" : "address range"**

Address ranges **address range** specified in **option** overlap.

**L2100 (E) Invalid address specified in cpu option : "address"**

An invalid address was specified in the **cpu** option.

**L2101 (E) Invalid address specified in option "option" : "address"**

The **address** specified in **option** exceeds the address range that can be specified by the **cpu** or the range specified by the **cpu** option.

- L2110 (E) Section size of second parameter in rom option is not 0 : "section"**  
section whose size is not zero was specified in the second parameter of the **rom** option.
- L2111 (E) Absolute section cannot be specified in "option" option : "section"**  
An absolute address section was specified in **option**.
- L2112 (E) "section 1" and "section 2" cannot mapped as ROM/RAM in "file"**  
section 1 and section 2 specified in the name of **file** are not ROM/RAM-mapped.
- L2113 (E) Option "rom" and internal information in the file are conflicted**  
Specification of the **rom** option conflicts with the internal information.
- L2120 (E) Library "file" without module name specified as input file**  
A library file without a module name was specified as the input file.
- L2121 (E) Input file is not library file : "file (module)"**  
The file specified by **file (module)** as the input file is not a library file.
- L2130 (E) Cannot find file specified in option "option" : "file"**  
The file specified in **option** could not be found.
- L2131 (E) Cannot find module specified in option "option" : "module"**  
The module specified in **option** could not be found.
- L2132 (E) Cannot find "name" specified in option "option"**  
The symbol or section specified in **option** does not exist.
- L2133 (E) Cannot find defined symbol "name" in option "option"**  
The externally defined symbol specified in **option** does not exist.
- L2140 (E) Symbol/section "name" redefined in option "option"**  
The symbol or section specified in **option** has already been defined.
- L2141 (E) Module "module" redefined in option "option"**  
The module specified in **option** has already been defined.
- L2142 (E) Interrupt number "vector number" of "section" has multiple definition**  
Vector number definition was made multiple times in vector table **section**. Only one address can be specified for a vector number. Check and correct the code in the source file.



- L2143 (E) Invalid vector number specified: "number"**  
The vector number indicated by **number** is not allowed.  
Check and correct the vector number specified with **#pragma special**.
- L2200\* (E) Illegal object file : "file"**  
A format other than ELF format was input.  
\* The error number will be shown as P2200.
- L2201 (E) Illegal library file : "file"**  
**file** is not a library file.
- L2202 (E) Illegal cpu information file : "file"**  
**file** is not a cpu information file.
- L2203 (E) Illegal profile information file : "file"**  
**file** is not a profile information file.
- L2210 (E) Invalid input file type specified for option "option" : "file (type)"**  
When specifying **option**, a **file (type)** that cannot be processed was input.
- L2211 (E) Invalid input file type specified while processing "process" : "file (type)"**  
A **file (type)** that cannot be processed was input during processing **process**.
- L2212 (E) "option" cannot be specified for inter-module optimization information in "file"**  
The option **option** cannot be used because **file** includes inter-module optimization information. Do not specify the **goptimize** option at compilation or assembly.
- L2220 (E) Illegal mode type "mode type" in "file"**  
A file with a different **mode type** was input.
- L2221 (E) Section type mismatch : "section"**  
Sections with the same name but different attributes (whether initial values present or not) were input.
- L2223 (E) Cpu type "CPU type 1" in "file" is incompatible with "CPU type 2"**  
A different CPU type was input.  
Since these types are incompatible in part of the specifications, even if the file is linked, correct operation cannot be guaranteed.
- L2300 (E) Duplicate symbol "symbol" in "file"**  
There are duplicate occurrences of **symbol**.

- L2301 (E) Duplicate module "module" in "file"**  
There are duplicate occurrences of **module**.
- L2310 (E) Undefined external symbol "symbol" referenced in "file"**  
An undefined symbol **symbol** was referenced in **file**.
- L2311 (E) Section "section 1" cannot refer to overlaid section : "section 2"-"symbol"**  
A symbol defined in **section 1** was referenced in **section 2** that is allocated to the same address as **section 1** overlaid. **section 1** and **section 2** must not be allocated to the same address.
- L2320 (E) Section address overflowed out of range : "section"**  
The address of **section** exceeds the usable address range.
- L2321 (E) Section "section 1" overlaps section "section 2"**  
The addresses of **section 1** and **section 2** overlap. Change the address specified by the **start** option.
- L2322 (E) Section size too large: "section"**  
The size of **section** is too large. The size of a **\$TBR** section must be 1024 bytes or less.
- L2323 (E) Section "section 1 (address range)" overlaps with section "section 2 (address range)" in physical space**  
**section 1** overlaps with **section 2** in the physical memory. Check the addresses of the sections.  
<address range>: <section start address> - <section end address>
- L2330 (E) Relocation size overflow : "file"-"section"-"offset"**  
The result of the relocation operation exceeded the relocation size. Possible causes include inaccessibility of a branch destination, and referencing of a symbol which must be located at a specific address. Ensure that the referenced symbol at the **offset** position of **section** in the source list is placed at the correct position.
- L2331 (E) Division by zero in relocation value calculation : "file"-"section"-"offset"**  
Division by zero occurred during a relocation operation. Check for problems in calculation of the position at **offset** in **section** in the source list.
- L2332 (E) Relocation value is odd number : "file"-"section"-"offset"**  
The result of the relocation operation is an odd number. Check for problems in calculation of the position at **offset** in **section** in the source list.

**L2340 (E) Symbol name "file"- "section"- "symbol..." is too long**

The number of characters comprising **symbol** in **section** exceeds the translation limit of the assembler.

When outputting a symbol address file, make sure that the number of characters comprising the symbol name does not exceed the translation limit of the assembler.

**L2400 (E) Global register in "file" conflicts : "symbol", "register"**

Another symbol has already been allocated to a global register specified in **file**.

**L2401 (E) near8, near16 symbol "symbol" is outside near memory area**

**symbol** is not allocated in the **near8** or **near16** range. Either change the **start** specification, or remove the **near** specifier at compilation, so that correct address calculations can be made.

**L2402 (E) Number of register parameter conflicts with that in another file : "function"**

Different numbers of register parameters are specified for **function** in multiple files.

**L2403 (E) Fast interrupt register in "file" conflicts with that in another file**

The register number specified for the fast interrupt general register in **file** does not match the settings in other files. Correct the register number to match the other settings and recompile the code.

**L2404 (E) Base register "base register type" in "file" conflicts with that in another file**

The register number specified for **base register type** in **file** does not match the settings in other files. Correct the register number to match the other settings and recompile the code.

**L2405 (E) Option "compile option" conflicts with that in other files**

Specification of **compile option** is inconsistent between the input files.  
Check and correct **compile option**.

**L2410 (E) Address value specified by map file differs from one after linkage as to "symbol"**

The address of **symbol** differs between the address within the external symbol allocation information file used at compilation and the address after linkage. Check (1) to (3) below.

- (1) Do not change the program before or after the **map** option specification at compilation.

- (2) **optlnk** optimization may cause the sequence of the symbols after the **map** option specification at compilation to differ from that before the **map** option. Disable the **map** option at compilation or disable the **optlnk** option for optimization.
- (3) When the **tbr** option or **#pragma tbr** is used, optimization by the compiler may delete symbols after the **map** option specification at compilation. Disable the **map** option at compilation or disable the **tbr** option or **#pragma tbr**.

**L2411 (E) Map file in "file" conflicts with that in another file**

Different external symbol allocation information files were used by the input files at compilation.

**L2412 (E) Cannot open file : "file"**

**file** (external symbol allocation information file) cannot be opened. Check whether the file name and access rights are correct.

**L2413 (E) Cannot close file : "file"**

**file** (external symbol allocation information file) cannot be closed. There may be insufficient disk space.

**L2414 (E) Cannot read file : "file"**

**file** (external symbol allocation information file) cannot be read. An empty file may have been input, or there may be insufficient disk space.

**L2415 (E) Illegal map file : "file"**

**file** (external symbol allocation information file) has an illegal format. Check whether the file name is correct.

**L2416 (E) Order of functions specified by map file differs from one after linkage as to "function name"**

The sequences of a function **function name** and those of other functions are different between the information within the external symbol allocation information file used at compilation and the location after linkage. The address of **static** within the function may be different between the external symbol allocation information file and the result after linkage.

**L2417 (E) Map file is not the newest version: "file name"**

The **.bls** file is not the latest version.

**L2420 (E) "file 1" overlap address "file 2" : "address"**

The address specified for **file 1** is the same as that specified for **file 2**.

- P2500 (E) Cannot find library file : "file"**  
file specified as a library file cannot be found.
- P2501 (E) "instance" has been referenced as both an explicit specialization and a generated instantiation**  
Instantiation has been requested of an instance already defined. For the file using **instance**, confirm that **form=relocate** has not been used to generate a relocatable object file.
- P2502 (E) "instance" assigned to "file 1" and "file 2"**  
The definition of instance is duplicated in **file 1** and **file 2**. For the file using **instance**, confirm that **form=relocate** has not been used to generate a relocatable object file.
- L3000 (F) No input file**  
There is no input file.
- L3001 (F) No module in library**  
There are no modules in the library.
- L3002 (F) Option "option 1" is ineffective without option "option 2"**  
The option **option 1** requires that the option **option 2** be specified.
- L3004 (F) Unsupported inter-module optimization information type "type" in "file"**  
The file contains an unsupported inter-module optimization information **type**. Check if the compiler and assembler versions are correct.
- P3007 (F) Cannot create instantiation request file "file"**  
Unable to create an intermediate file for the instance generation process.  
Check that the access rights of the object created folder and those beneath it are correct.
- P3008 (F) Cannot change to directory "folder"**  
Unable to move to **folder**. Check that the folder exists.
- P3009 (F) File "file" is read-only**  
**file** is read-only. Change its access right.
- L3100 (F) Section address overflow out of range : "section"**  
The address of **section** exceeded FFFFFFFF. Change the address specified by the **start** option. For details of the address space, refer to the hardware manual of the target CPU.
- L3102 (F) Section contents overlap in absolute section "section"**  
Data addresses overlap within an absolute address section. Modify the source program.

- L3110 (F) Illegal cpu type "cpu type" in "file"**  
A file with a different cpu type was input.
- L3111 (F) Illegal encode type "endian type" in "file"**  
A file with a different endian type was input.
- L3112 (F) Invalid relocation type in "file"**  
There is an unsupported relocation type in **file**. Ensure the compiler and assembler versions are correct.
- L3120 (F) Illegal size of the absolute code section : "section" in "file"**  
Absolute-addressing program section **section** in **file** has an illegal size. When the CPU type is RX Family in big endian, correct the size to a multiple of 4.
- L3200 (F) Too many sections**  
The number of sections exceeded the translation limit. It may be possible to eliminate this problem by specifying multiple file output.
- L3201 (F) Too many symbols**  
The number of symbols exceeded the translation limit. It may be possible to eliminate this problem by specifying multiple file output.
- L3202 (F) Too many modules**  
The number of modules exceeded the translation limit. Divide the library.
- L3203 (F) Reserved module name "optlnk\_generates"**  
**optlnk\_generates\_\*\*** (\*\* is a value from 01 to 99) is a reserved name used by the optimizing linkage editor. It is used as an **.obj** or **.rel** file name or a module name within a library. Modify the name if it is used as a file name or a module name within a library.
- L3300\* (F) Cannot open file : "file"**  
**file** cannot be opened. Check whether the file name and access rights are correct.  
\* The error number will be shown as P3300.
- L3301 (F) Cannot close file : "file"**  
**file** cannot be closed. There may be insufficient disk space.
- L3302 (F) Cannot write file : "file"**  
Writing to **file** is not possible. There may be insufficient disk space.
- L3303\* (F) Cannot read file : "file"**

**file** cannot be read. An empty file may have been input, or there may be insufficient disk space.

\* The error number will be shown as P3303.

**L3310\* (F) Cannot open temporary file**

A temporary file cannot be opened. Check to ensure the **HLNK\_TMP** specification is correct, or there may be insufficient disk space.

\* The error number will be shown as P3310.

**L3311 (F) Cannot close temporary file**

A temporary file cannot be closed. There may be insufficient disk space.

**L3312 (F) Cannot write temporary file**

Writing to a temporary file is not possible. There may be insufficient disk space.

**L3313 (F) Cannot read temporary file**

A temporary file cannot be read. There may be insufficient disk space.

**L3314 (F) Cannot delete temporary file**

A temporary file cannot be deleted. There may be insufficient disk space.

**L3320\* (F) Memory overflow**

There is no more space in the usable memory within the linkage editor. Increase the amount of memory available.

\* The error number will be shown as P3320.

**L3400 (F) Cannot execute "load module"**

**load module** cannot be executed. Check whether the path for **load module** is set correctly.

**L3410 (F) Interrupt by user**

An interrupt generated by (**Ctrl**) + **C** keys from a standard input terminal was detected.

**L3420 (F) Error occurred in "load module"**

An error occurred while executing the **load module**.

**P3500 (F) Bad instantiation request file -- instantiation assigned to more than one file**

An intermediate file for the instance generation process contains an error.

Recompile the files to be linked.

**P3505 (F) Corrupted template information file or instantiation request file**

An intermediate file for the template process or that for the instance generation process

contains an error.

Do not edit these files.

**L4000\* (–) Internal error : ("internal error code") "file line number" / "comment"**

An internal error occurred during processing by the optimizing linkage editor. Make a note of the internal error number, file name, line number, and comment in the message, and contact the support department of the vendor.

\* The error number will be shown as P4000.



## Section 15 Limitations

### 15.1 Limitations of the Compiler

Table 15.1 shows the limitations of the compiler. Source programs must fall within these limitations.

**Table 15.1 Limitations of the Compiler**

| Classification        | Item                                                                                                     | Limit                                           |
|-----------------------|----------------------------------------------------------------------------------------------------------|-------------------------------------------------|
| Invoking the compiler | Total number of macro names that can be specified using the <b>define</b> option                         | None (the limit depends on the memory capacity) |
|                       | Length of file name (characters)                                                                         | None (the limit depends on the OS)              |
| Source programs       | Length of one line (characters)                                                                          | 32768                                           |
|                       | Number of source program lines in one file                                                               | None (other than the memory capacity)           |
|                       | Number of source program lines that can be compiled                                                      | None (other than the memory capacity)           |
| Preprocessing         | Nesting levels of files in a <b>#include</b> directive                                                   | None (the limit depends on the memory capacity) |
|                       | Total number of macro names that can be specified in a <b>#define</b> directive                          | None (other than the memory capacity)           |
|                       | Number of parameters that can be specified using a macro definition or a macro call operation            | None (the limit depends on the memory capacity) |
|                       | Number of expansions of a macro name                                                                     | None (the limit depends on the memory capacity) |
|                       | Nesting levels of <b>#if</b> , <b>#ifdef</b> , <b>#ifndef</b> , <b>#else</b> , or <b>#elif</b> directive | None (the limit depends on the memory capacity) |

**Table 15.1 Limitation of the Compiler (cont)**

| <b>Classification</b> | <b>Item</b>                                                                                                                                                | <b>Limit</b>                                    |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|
| Preprocessing         | Total number of operators and operands that can be specified in a <b>#if</b> or <b>#elif</b> directive                                                     | None (the limit depends on the memory capacity) |
| Declarations          | Number of function definitions                                                                                                                             | None (the limit depends on the memory capacity) |
|                       | Number of external identifiers used for external linkage                                                                                                   | None (the limit depends on the memory capacity) |
|                       | Number of valid internal identifiers used in one function                                                                                                  | None (the limit depends on the memory capacity) |
|                       | Total number of pointers, arrays, and function declarators that qualify the basic type                                                                     | 16                                              |
|                       | Array dimensions                                                                                                                                           | 6                                               |
|                       | Size of arrays and structures                                                                                                                              | 2147483647 bytes                                |
| Statements            | Nesting levels of compound statements                                                                                                                      | None (the limit depends on the memory capacity) |
|                       | Nesting levels of statement in a combination of repeat ( <b>while</b> , <b>do</b> , and <b>for</b> ) and select ( <b>if</b> and <b>switch</b> ) statements | 4096                                            |
|                       | Number of <b>goto</b> labels that can be specified in one function                                                                                         | 2147483646                                      |
|                       | Number of <b>switch</b> statements                                                                                                                         | 2048                                            |
|                       | Nesting levels of <b>switch</b> statements                                                                                                                 | 2048                                            |
|                       | Number of <b>case</b> labels in a single <b>switch</b> statement                                                                                           | 2147483646                                      |
|                       | Nesting levels of <b>for</b> statements                                                                                                                    | 2048                                            |

**Table 15.1 Limitation of the Compiler (cont)**

| <b>Classification</b> | <b>Item</b>                                                                                         | <b>Limit</b> |
|-----------------------|-----------------------------------------------------------------------------------------------------|--------------|
| Expressions           | Character array length                                                                              | 32766        |
|                       | Number of parameters that can be specified using a function definition or a function call operation | 2147483646   |
|                       | Total number of operators and operands that can be specified in one expression                      | About 500    |
| Standard library      | Number of files that can be opened simultaneously in an <b>open</b> function                        | 128          |
| Sections              | Length of section name*                                                                             | 8192         |
|                       | Number of sections that can be specified in <b>#pragma section</b> in one file                      | 2045         |

Note: This limitation is applied to the length of a section name created by the compiler when generating an object. The length that can be specified in **#pragma section** or **section** option is shorter than this limitation.

## 15.2 Limitations of the Assembler

Table 15.2 shows the limitations of the assembler.

**Table 15.2 Limitations of the Compiler**

| Item                                    | Limit                                                                            |
|-----------------------------------------|----------------------------------------------------------------------------------|
| Length of one line (characters)         | 8192                                                                             |
| Character constants                     | Up to 4                                                                          |
| Symbol character arrays                 | None*                                                                            |
| Number of symbols                       | None                                                                             |
| Number of externally referenced symbols | None                                                                             |
| Number of externally defined symbols    | None                                                                             |
| Maximum size for a section              | Up to H'FFFFFFFF bytes                                                           |
| Number of sections                      | H'FEF1 (with debugging information) or<br>H'FEFA (without debugging information) |
| File include                            | Up to 30 levels of nesting                                                       |
| Character array length                  | 255                                                                              |
| Length of file name (characters)        | None (the limit depends on the OS)                                               |

Note: For a preprocessor variable name, macro name, or macro parameter name, it is limited to 32 characters.

There is no limitation on the number of characters in a replacement symbol specified in **.DEFINE**. However, the replacement string literal is limited to 255 characters, and up to 8192 characters can be specified in one line.

## Section 16 Notes on Version Upgrade

### 16.1 Notes on Version Upgrade

This section describes notes when the version is upgraded from the earlier version (SuperH RISC engine C/C++ Compiler Package Ver. 8.x or lower).

#### 16.1.1 Guaranteed Program Operation

When a program is developed with an upgraded version of the compiler, operation of the program may change. When creating the program, note the following and thoroughly test your program.

##### 1. Programs Depending on Execution Time or Timing

C/C++ language specifications do not specify the program execution time. Therefore, a version difference in the compiler may cause operation changes due to timing lag with the program execution time and peripherals such as the I/O, or processing time differences in asynchronous processing, such as in interrupts.

##### 2. Programs Including an Expression with Two or More Side Effects

Operations may change depending on the version when two or more side effects are included in one expression.

Example

```
a[i++] = b[i++];    /* increment order of i is undefined. */  
f(i++, i++);      /* Parameter value changes according to increment order. */  
                /* This results in f(3, 4) or f(4, 3) when the value of i is 3. */
```

##### 3. Programs with Overflow Results or an Illegal Operation

The value of the result is not guaranteed when an overflow occurs or an illegal operation is performed. Operations may change depending on the version.

Example

```
int a, b;  
x = (a*b) / 10;    /* This may cause an overflow depending on the value range of  
                  a and b. */
```

#### 4. No Initialization of Variables or Type Inequality

When a variable is not initialized or the parameter or return value types do not match between the calling and called functions, an illegal value is accessed. Operations may change depending on the version.

Example

file 1:

```
int f(double d)
{
    :
}
```

file 2:

```
int g(void)
{
    f(1);
}
```

The parameter of the calling function is the int type, but the parameter of the called function is the double type. Therefore, a value cannot be correctly referenced.

The information provided here does not include all cases that may occur. Please use this compiler prudently, and thoroughly test your programs keeping the differences between the versions in mind.

#### 16.1.2 Compatibility with Earlier Version

The following notes cover situations in which the compiler (Ver. 5.x or lower) is used to generate a file that is to be linked with files generated by the earlier version of the compiler or with object files or library files that have been output by the assembler (Ver. 4.x or lower) or linkage editor (Ver. 6.x or lower), or in case the debugger used with the earlier version is to be continuously used.

##### 1. Format Converter

Later versions of the compiler (Ver. 9.04 or higher) do not include the format converter. Contact our support center if you need to input object files (SYSROF) output by earlier versions of the compiler (up to Ver. 5.x) or assembler (up to Ver. 4.x) to the optimizing linkage editor.

## 2. Point of Origin for Include Files

When an include file specified with a relative directory format was searched for, in the earlier version, the search would start from the compiler's directory. In the new version, the search starts from the directory that contains the source file.

## 3. C++ Program

Since the encoding rule and execution method were changed, C++ object files created by the earlier version of the compiler cannot be linked. Be sure to recompile such files.

The name of the library function for initial/post processing of the global class object, which is used to set the execution environment, has also been changed. Refer to section 9.2.2, Execution Environment Settings, and modify the name.

## 4. Specification of Entry via .END (Assembly Program)

Only an externally defined symbol can be specified with .END.

## 5. Objects Supported by the Optimizing Linkage Editor

The optimizing linkage editor supports different compiler or assembler depending on the version. The following shows the version of the supported tool. Linkage processing for the object file that is not described is not guaranteed.

- Optimizing linker Ver. 7: Ver. 7 or lower of the compiler, Ver. 5 or lower of the assembler
- Optimizing linker Ver. 8: Ver. 8 or lower of the compiler, Ver. 6 or lower of the assembler
- Optimizing linker Ver. 9: Ver. 9 or lower of the compiler, Ver. 7 or lower of the assembler

### 16.1.3 Compatibility with Objects for Earlier Version

- (1) Specify the following option in Ver. 7 (or later) to link an object created by Ver. 7 (or later) with an object created by Ver. 6.
  - `gbr=user`
  - `pack=4` (after Ver. 8)
  - `bit_order=left` (after Ver. 8)
- (2) The following options should always be the same in compiling user files and in building libraries. If the following option is specified during compilation in Ver. 6, the same option should be specified during compilation in Ver. 7 (or later).
  - `endian=big/little` (SH-3, SH3-DSP, SH-4, SH-4A, or SH4AL-DSP)
  - `pic=0/1` (excluding SH-1)
  - `fpu=single/double` (SH-4 or SH-4A)
  - `fpscr=safe/aggressive` (SH-4 or SH-4A)

- round=zero/nearest (SH-4 or SH-4A)
- denormalize=on/off (SH-4 or SH-4A)
- double=float (excluding SH-4 or SH-4A)
- exception/noexception
- rtti=on/off
- rtnext/nortnext
- macsave

### (3) Assembly program

Conform to section 9.3.2, Function Calling Interface in the user's manual.

- Notes:
1. A compatibility regarding the version up is not guaranteed for the contents which is not written in user's manual. If assembly code depends on the order to save or restore registers, and so on, an object created by Ver. 6 cannot be linked with an object created by Ver. 7 (or later).
  2. Make contact with the sales office about linking with OS's, middleware and so on.

## 16.1.4 Command-line Interface

### 1. Rules for Assembler and Optimizing Linkage Editor Command Lines

Spaces must be inserted between file names and options.

There are no limitations on the order in which options and their associated file names are specified.

### 2. Optimizing Linkage Editor Option

Support for the interactive specification of options has been abolished.

The inter-module optimizing tool (optlnksh), linkage editor (lnk), librarian (lbr), and object converter (cnvs) of earlier versions have been integrated into an optimizing linkage editor (optlnk). Therefore, command-line specifications have changed greatly. Tables 16.1 and 16.2 is a list of changed commands.



**Table 16.1 Changed Linkage Commands**

| No. | Command Name              | Ver. 6                                                                                                                                              | Ver. 7                                                                                                          | Note                                                                                    |
|-----|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| 1   | start                     | start=section<br>(address)<br><br>Abbreviation: st                                                                                                  | start=section/<br>address<br><br>Abbreviation: star                                                             | —                                                                                       |
| 2   | rom                       | rom=(rom section,<br>ram section)                                                                                                                   | rom =rom section=<br>ram section                                                                                | —                                                                                       |
| 3   | define                    | define=external<br>name (defined<br>value)                                                                                                          | define=external<br>name=defined value                                                                           | —                                                                                       |
| 4   | rename                    | rename=<br>ed=before change<br>(after change),<br>er=before change<br>(after change),<br>un=before change<br>(after change)<br><br>Abbreviation: re | rename=<br>(before change=<br>after change),<br>(before change=<br>after change),<br>—<br><br>Abbreviation: ren | The concept of unit<br>has been abolished<br>due to change in the<br>object format.     |
| 5   | delete                    | delete=<br>ed=unit.symbol<br>un=unit                                                                                                                | delete=(symbol)<br>—                                                                                            | The concept of unit<br>has been abolished<br>due to the change in<br>the object format. |
| 6   | print/noprint             | print<br>noprint                                                                                                                                    | list<br>—                                                                                                       | File name can be<br>omitted.                                                            |
| 7   | mlist                     | mlist                                                                                                                                               | list                                                                                                            | —                                                                                       |
| 8   | information               | information                                                                                                                                         | message                                                                                                         | —                                                                                       |
| 9   | directory                 | directory                                                                                                                                           | HLNK_DIR<br>(environment<br>variable)                                                                           | —                                                                                       |
| 10  | form                      | Abbreviation: f                                                                                                                                     | Abbreviation: fo                                                                                                | —                                                                                       |
| 11  | output/nooutput           | Abbreviation: o;<br>nooutput can be<br>specified.                                                                                                   | Abbreviation: ou;<br>nooutput cannot be<br>specified.                                                           | Only output can be<br>specified.                                                        |
| 12  | cpu                       | Abbreviation: c                                                                                                                                     | Abbreviation: cp                                                                                                | Direct range can be<br>specified.                                                       |
| 13  | elf/sysrof/sysrofplu<br>s | elf/sysrof/sysrofplus                                                                                                                               | Abolished                                                                                                       | Always ELF                                                                              |
| 14  | exclude/noexclude         | exclude/noexclude                                                                                                                                   | Abolished                                                                                                       | Always exclude                                                                          |
| 15  | align_section             | align_section                                                                                                                                       | Abolished                                                                                                       | Always valid*                                                                           |

**Table 16.1 Changed Linkage Commands (cont)**

| No. | Command Name      | Ver. 6                      | Ver. 7                                                             | Note                                                                              |
|-----|-------------------|-----------------------------|--------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| 16  | check_section     | check_section               | Abolished                                                          | Always valid*                                                                     |
| 17  | cpucheck          | cpucheck                    | Abolished                                                          | Always valid*                                                                     |
| 18  | udf/noudf         | udf/noudf                   | Abolished                                                          | Always output*                                                                    |
| 19  | udfcheck          | udfcheck                    | Abolished                                                          | Always valid*                                                                     |
| 20  | echo/noecho       | echo/noecho                 | Abolished                                                          | Always disabled                                                                   |
| 21  | exchange          | exchange                    | Abolished                                                          | The conception of unit has been abolished due to the change in the object format. |
| 22  | autopage          | autopage                    | Abolished                                                          | No target cpu                                                                     |
| 23  | abort             | abort                       | Abolished                                                          | Interactive format has been abolished.                                            |
| 24  | list              | list                        | Abolished                                                          | Different from the list option for Ver. 7.                                        |
| 25  | library/nolibrary | nolibrary can be specified. | nolibrary cannot be specified.                                     | Only library can be specified.                                                    |
| 26  | exit              | Cannot be omitted.          | Can be omitted.                                                    | —                                                                                 |
| 27  | debug/nodebug     | At default: nodebug         | At default: depends on the debugging information in the input file | —                                                                                 |

Note: Invalidated by the **change\_message** option.

**Table 16.2 Changed Librarian Commands**

| No. | Command Name | Ver. 2                            | Ver. 7                                               | Note                                      |
|-----|--------------|-----------------------------------|------------------------------------------------------|-------------------------------------------|
| 1   | add          | add                               | input                                                | —                                         |
| 2   | directory    | directory                         | HLNK_DIR<br>(environment<br>variable)                | —                                         |
| 3   | slist        | slist                             | list<br>show                                         | —                                         |
| 4   | list         | list (s)                          | list<br>show                                         | —                                         |
| 5   | delete       | Abbreviation: d                   | Abbreviation: del                                    | —                                         |
| 6   | create       | create (s   u)                    | output<br>form = library (s   u)                     | —                                         |
| 7   | output       | output (s   u)<br>Abbreviation: o | output<br>form = library (s   u)<br>Abbreviation: ou | —                                         |
| 8   | replace      | Abbreviation: r                   | Abbreviation: rep                                    | —                                         |
| 9   | abort        | abort                             | Abolished                                            | Interactive format<br>has been abolished. |
| 10  | exit         | Abbreviation<br>disabled.         | Abbreviation<br>enabled.                             | —                                         |

### 16.1.5 Provided Contents

In the SuperH RISC engine C/C++ Compiler Package, the following files have been changed.

#### 1. Standard Library File

To specify any function interface or optimizing option, a standard library generator is provided instead of the conventional standard library files.

#### 2. Header File

The header file `_h_c_lib.h` newly added declares the `_INITSCT`, `_CALL_INIT`, and `_CALL_END` functions as standard libraries.

The header file `fixed.h` that defines various limitations concerning the internal representation of fixed-point numbers is also added.

## 16.1.6 List File Specification

### 1. Optimizing Linkage Editor

The formats of the conventional linkage map and library lists have been renewed.

## 16.2 Additions and Improvements

### 16.2.1 Common Additions and Improvements (Package: Ver. 6)

#### 1. Loosening Limits on Values

Limitations on source programs and command lines have been greatly loosened:

- Length of file name: 251 bytes -> unlimited
- Length of symbol: 251 bytes -> unlimited
- Number of symbols: 32,767 -> unlimited
- Number of source program lines: C/C++: 32,767, ASM: 65,535 -> unlimited
- Length of C program string literals: 512 characters -> 32,766 characters
- Length of assembly program line: 255 characters -> 8,192 characters
- Length of subcommand file line: ASM: 300 bytes, optlnk: 512 bytes -> unlimited
- Number of parameters of the optimizing linkage editor **rom** option: 64 -> unlimited

#### 2. Hyphens for Directory and File Names

A hyphen (-) can be specified for directory and file names.

#### 3. Specification of Copyright Display

Specifying the **logo/nologo** option can specify whether or not the copyright output is displayed.

#### 4. Prefix to Error Messages

To support the error-help function in the integrated development environment, a prefix has been added to error messages for the compiler and optimizing linkage editor.

### 16.2.2 Added and Improved Compiler Functions

#### Functions Added and Improved in Ver. 7

##### (a) External Variable Access Optimization Function (**map** option support)

Accesses external variables and optimizes function branch instructions based on the addresses of variables at linkage and addresses where functions are allocated.

Optimization is performed by recompiling the program with the **map** option specifying the external symbol allocation-information file output by the optimizing linkage editor when the program was compiled for the first time.

(b) Automatic Creation of Code with GBR-Relative Access Code (**gbr** option support)

When **gbr=auto** is specified, the compiler sets the GBR and automatically creates code with which GBR-relative access is used. The contents of GBR are guaranteed before and after function calls. However, the GBR related intrinsic functions cannot be used.

(c) Enhancement of the speed/size Selection Option

Provides more precise adjustment to the speed/size option by the newly added **shift**, **blockcopy**, **division**, and **approxdiv** options.

(d) Enhancement of Intrinsic Functions

- The number of intrinsic functions have been increased  
Double-precision multiplication, SWAP, LDTLB, and NOP instructions.
- The number of **#pragma** extensions has increased and some extensions have been modified  
**#pragma entry**: Specifies entry functions and sets SP  
**#pragma stacksize**: Specifies the stack size  
**#pragma interrupt**: Supports **sp=<variable>+<constant>** and **sp=&<variable>+<constant>**
- Section operators are supported  
Functions to describe the section address and the size reference in C language have been added.
- The criteria for the generation of errors by cast expressions  
Checking of the cast expression for the address-initialization of external variables has been made less strict.

(e) Improvement of Library Handling

- Reentrant library is supported  
When the **reent** option is specified to the library generator, a reentrant library is created.
- The unit of the size allocated by the malloc calls and the number of I/O files can be changed  
In the initial settings for the C/C++ library function, **\_sbrk\_size** can be used to specify the unit size of a block for use with malloc, and **\_nfiles** can be used to specify the number of I/O files. This saves RAM capacity. The default size for malloc is 1024, and the default size for the number of I/O files is 20.

- Simple I/O Support

When the **nofloat** option is specified by the library generator, a small-size I/O routine that does not support floating-point conversion will be created.

## 2. Functions Added and Improved in Ver. 7.1

### (a) Optimizing options are added

The following options are added, and enabled finer adjustment of the level of compiler optimization

- `global_volatile`
- `opt_range`
- `del_vacant_loop`
- `max_unroll`
- `infinite_loop`
- `global_alloc`
- `struct_alloc`
- `const_var_propagate`
- `const_load`
- `schedule`

## 3. Functions Added and Improved in Ver. 8

### (a) Support for New CPUs

The SH-4A and SH4AL-DSP are supported.

### (b) Extension and Change of Language Specifications

- The DSP-C language is supported.
- The data types of long long and unsigned long long are supported.

### (c) Enhancement of Intrinsic Functions

- Intrinsic functions for DSP are added.

Detection of absolute value and MSB, arithmetic shift, rounding operation, bit pattern copy, module addressing setting, module addressing cancellation, and CS bit setting

- Intrinsic functions for SH4-A and SH4AL-DSP are added.

Calculation of sine and cosine, reciprocal number of square root, invalidation of an instruction cache block, prefetch of an instruction cache block, and synchronous data operation

- **#pragma** extensions are added and changed.
  - #pragma ifunc:** Disables or enables save and restore of floating-point registers.
  - #pragma bit\_order:** Specifies the bit field order.
  - #pragma pack:** Specifies the boundary alignment value for structures, unions, and classes.
- (d) Automatic Selection of Enumeration Type Size (**auto\_enum** option support)  
Enumeration data is handled as the minimum data type with which enumeration data can fit in.
- (e) Specification of Boundary Alignment of Structure, Union, and Class Members (**pack** option support)  
Boundary alignment of structure, union, and class members can be specified.
- (f) Specification of Bit Field Order (**bit\_order** option support)  
The order of bit field members can be specified.
- (g) Change of Error Level (**change\_message** option support)  
The error level of information-level and warning-level error messages can be individually changed.
- (h) Loosening Limits on Values  
Number of switch statements: 256 -> 2048
- (i) DSP Library of Fixed-Point Type Support  
DSP library of fixed-point type is supported.

#### 4. Functions Added and Improved in Ver. 9

- (a) Support for New CPUs  
The SH-2A and SH2A-FPU are supported.  
An option and a **#pragma** extension are added to use TBR in the SH-2A and SH2A-FPU.
- (b) Extension and Change of Language Specifications
  - The following items conform to the ANSI standard.
    - Array index

```
int iarray[10], i=3;
i[iarray] = 0;    /* Same as iarray[i] = 0; */
```
    - union bit field specification enabled

```
union u {
    int a:3;
};
```

- Constant operation  
static int i=1||2/0; /\* Error is changed to warning for zero division \*/

- Addition of library and macro  
strtol, FOPEN\_MAX

- The following items conform to the ANSI standard when the **strict\_ansi** option is specified, which may cause a difference in results between Ver. 9 and former versions.
  - unsigned int and long operations
  - Associativity of floating-point operations
- The variables with register storage class specification are preferentially allocated to registers when the **enable\_register** option is specified.

(c) Enhancement of Intrinsic Functions

- Intrinsic functions for SH-2A and SH2A-FPU are added.  
Saturation operations and TBR setting and reference
- Intrinsic functions for instructions that cannot be written in C are added.  
Reference and setting of the T bit, extraction of the middle of registers connected, addition with carry, subtraction with borrow, sign inversion, 1-bit division, rotation, and shift.

(d) Loosening Limits on Values

The following limits are loosened.

- Nesting level in a combination of repeat statements (**while**, **do**, and **for**) and select statements (**if** and **switch**): 32 levels -> 4096 levels
- Number of **goto** labels allowed in one function: 511 -> 2,147,483,646
- Nesting level of **switch** statements: 16 levels -> 2048 levels
- Number of **case** labels allowed in one **switch** statement: 511 -> 2,147,483,646
- Number of parameters allowed in a function definition or function call: 63 -> 2,147,483,646
- Length of section name: 31 bytes -> 8192 bytes
- Number of sections allowed in **#pragma section** in one file: 64 -> 2045

(e) Extension of Memory Space Allocation

More detailed settings can be made for memory space allocation.

- **abs16/abs20/abs28/abs32** option
- **#pragma abs16/abs20/abs28/abs32**

(f) Specification of Absolute Address for Variables (support for **#pragma address**)

An absolute address can be specified for an external variable.



- (g) Extension of Optimization for External Variable Access (support for **smap** option)  
Optimization is applied to access to external variables defined in the file to be compiled.  
Recompilation, which is required for the **map** option, is not necessary.
- (h) Improvement in Precision of Mathematics Library  
The precision of operation using the mathematics library is improved, which may cause a difference in results between Ver. 9 and former versions.

## 5. Functions Added and Improved in Ver. 9.01

- (a) Debugging Information Output Mode Added (Support for **optimize=debug\_only** Option)  
The information on local variables can be always referenced through the **optimize=debug\_only** option setting.
- (b) Interrupt Specifications Added (SH-3, SH3-DSP, SH-4, SH-4A, and SH4AL-DSP)  
The following interrupt specifications for **#pragma interrupt** have been added so that high-performance interrupt functions can be created.
  - Interrupt specifications
    - #pragma interrupt sr\_rts** Register bank switching and RTS-instruction return
    - #pragma interrupt bank** Interrupt handling function
    - #pragma interrupt rts** RTS-instruction return
  - Intrinsic function
    - sr\_jsr()** Nested interrupt control
- (c) Function for Omitting Range Check for Conversion between Floating-Point Number and Integer (Support for **simple\_float\_conv** Option: SH-2E, SH2A-FPU, SH-4, and SH-4A)  
Through the **simple\_float\_conv** option setting, the check of the target value range for the type conversion between unsigned integers and floating-point numbers can be omitted from the output code.
- (d) Added and Modified Specifications of Existing Functions
  - The **division=cpu=inline | runtime** option can also be specified in the SH-2A and SH2A-FPU.
  - Intrinsic functions **ocbi()**, **ocbp()**, and **ocwb()**, which manipulate the cache block, can also be specified in the SH-4.
  - The function specified with **#pragma inline** is inline-expanded regardless of the **inline** option.
  - The contents of the files specified with the **subcommand** option are output to the compile listing when the **subcommand** option and **listfile** option are specified. Accordingly, the options are output to the listing file when the listing file is output through the Renesas integrated development environment.

- (e) Improvement of Mathematical Function Libraries (SH-1, SH-2, SH2-DSP, SH-2A, SH-3, SH3-DSP, and SH4AL-DSP)

The object sizes of floating-point mathematical functions **sinf**, **cosf**, **tanf**, **expf**, **logf**, **sqrtf**, and **atanf** have been reduced and their speed and precision have been improved. Note that the results of these functions may differ from those output by Ver. 9.00.

## 6. Functions Added and Improved in Ver. 9.02

- (a) Specifying the allocation of variables in the \$G0 and \$G1 sections

Variables declared with **#pragma gbr\_base** and **#pragma gbr\_base1** can be allocated according to size by using the **stuff\_gbr** option.

- (b) Alignment of branch-destination addresses with four-byte boundaries

The **align4** option and **#pragma align4** can be used to align destination addresses for branch instructions with four-byte boundaries.

- (c) Preventing inline expansion for functions with the inline specification

The **cpp\_noinline** option prevents the inline expansion of functions and member functions that have the inline specification in C++.

## 7. Functions Added and Improved in Ver. 9.03

- (a) Selection of destinations for the allocation of variables declared with the **const** and **volatile** qualifiers

The **const\_volatile** option is used to select the initialized data area or constant area for the allocation of initialized variables declared with the **const** and **volatile** specifiers.

- (b) Inclusion of intrinsic functions for bitwise processing

When compiled, the following intrinsic functions invariably employ instructions for bitwise operations of the SH-2A core for the processing of individual bits in memory.

**bset()**: The specified bit in memory is set to 1.

**bclr()**: The specified bit in memory is cleared to 0.

**bcopy()**: The value of a bit in memory is copied to another.

**bnotcopy()**: The value of a bit in memory is inverted and the result is copied to another bit.

## 8. Functions Added and Improved in Ver. 9.04

- (a) Optimization in consideration of type at locations indicated by pointers

The **alias=ansi** option can be used to select optimization in consideration of type at locations indicated by pointers in accord with the ANSI standard.

- (b) Ability to prevent the output of DIVS and DIVU instructions (for the SH-2A and SH2A-FPU)  
The `nouse_div_inst` option can be used to prevent the output of DIVS and DIVU instructions in code for SH-2A CPU cores.
- (c) Optimization of the floating-point expressions by changing the order of operations  
The `float_order` option can be used to optimize the floating-point expressions by changing the order of operations, aggressively.

### 16.2.3 Added and Improved Assembler Functions

#### 1. Functions Added and Improved in Ver. 7

- (a) Support for New CPUs  
The SH-2A and SH2A-FPU are supported.
- (b) Loosening Limits on Values  
The limitation on the number of characters in a replacement symbol specified in the `define` option or `.DEFINE` is loosened from 32 characters to unlimited.
- (c) Support for `.STACK` Directive  
The `.STACK` directive is supported, which enables the stack size of a function written in the assembly language to be reflected in the CallWalker.

### 16.2.4 Added and Improved Optimizing Linkage Editor Functions

#### 1. Functions Added and Improved in Ver. 7

- (a) Support for Wild Cards  
A wild card can be specified with a section name of an input file or for file names in start options.
- (b) Search Path  
An environment variable (`HLNK_DIR`) can be used to specify several search paths for input files or library files.
- (c) Subdividing the Output of Load Modules  
The output of an absolute load module file can be subdivided.
- (d) Changing the Error Level  
For information, warning, and error level messages, the error level or disabling/enabling the output can be individually changed.
- (e) Support for Binary and HEX  
Binary files can be input and output.  
Intel® HEX-type output can be selected.

(f) Output of Stack Amount Information

The **stack** option can output an information file for the CallWalker.

(g) Debugging Information Deletion

The **strip** option can be used to delete only debugging information from either the load module file or the library file.

(h) Debugging Information Compression

The **compress** option can be used to compress debugging information.

## 2. Functions Added and Improved in Ver. 7.1

### Output of External Symbol Allocation-Information File (**map** option support)

When the **map** option is specified, an external symbol allocation file is created for use by the compiler in optimizing accesses to external variables.

## 3. Functions Added and Improved in Ver. 8

(a) Output Specification of Empty Areas

When the **space** option is specified, the specified value can be written to an empty area.

(b) Specification of Memory Amount

The **memory** option can be used to specify the internal memory amount.

(c) Changing Error Level when a Section Address is Overlapped

When the section address is overlapped at linking, the error level was 'Fatal' in Ver. 7, which has been changed as 'Error' in Ver. 8.0. This enables continuous processing under user's responsibilities by specifying the **change\_message** option even if the section address is overlapped.

## 4. Functions Added and Improved in Ver. 9

(a) Support for New CPUs

Object files with the SH-2A or SH2A-FPU as the CPU type can be input.

(b) Alignment Value Specification for Input Section with **binary** Option

A boundary alignment value can be specified for the section specified by the **binary** option.

(c) Output of Cross-Reference Information

The cross-reference information is output to the linkage list when the **show=xreference** option is specified, which is useful to determine the location that refers to a variable or function.

(d) Notification of Unreferenced Symbol

When the **msg\_unused** option is specified, the user can be notified of unreferenced symbols even if optimization is not specified.

## 5. Functions Added and Improved in Ver. 9.01

### (a) Suppression of Optimization in Section Units

A new option (**section\_forbid**) has been added, which allows suppression of inter-module optimization in section units.

### (b) Enhanced Overlay Function

Parentheses "(" and ")" can be used in the **start** option, which enables descriptions of more complex overlay allocations than the former-version assemblers.

### (c) Notification of Same-Name Symbols in a Library

The following message is output as a warning when multiple symbols have the same name in a library file used at linkage.

```
** L1320 (W) Duplicate Symbol "symbol" in "library (module)"
```

## 6. Functions Added and Improved in Ver. 9.02

### (a) Detection of Overlapped Objects in Physical Space

A new option (**ps\_check**) has been added, which can detect overlapped objects in the physical space.

### (b) Specification of Byte Count of Data Record

A new option (**byte\_count**) has been added, which can change the maximum byte count for a data record in the Intel-Hex-type file.

### (c) Unused Area Filling with Random Numbers

The **space=random** option enables an unused area to be filled with random numbers.

### (d) Reduction of Memory Size Occupied for Library Creation

The memory occupancy reduction function (**memory=low**) can also be used for library file creation.

## 7. Functions Added and Improved in Ver. 9.03

### (a) Output of the total sizes of sections according to section types

The **total\_size** option can be used to send the total sizes of the following types of section to standard output.

Executable section

ROM allocation section

RAM allocation section

- (b) Output of the total sizes of sections to the linkage list

The **show=total\_size** option can be used for output to the linkage list of the total sizes of different types of section produced by the **total\_size** option.

## 8. Functions Added and Improved in Ver. 9.04

- (a) Placing the results of CRC calculations in memory

The **crc** option can be used to place the results of calculations for CRC operations in a specified range of code at designated locations in memory.

## 9. Functions Added and Improved in Ver. 9.05

- (a) Splitting of sections when allocation to the specified region is not possible.

In the allocation of sections to addresses, if a section does not fit in the designated range of memory, the **cpu=stride** option can be used to split sections and allocate the excess to the next section with the same type of memory.

- (b) Specifying sections as outside the scope of splitting

When the **cpu=stride** option is in effect, the **contiguous\_section** option can be used to specify sections for allocation to a given type of memory with no splitting.

- (c) Strengthened functionality for output of listings

The **show=all** option can be used to select the output of all listings with full details.

- (d) Output of linkage maps when errors are encountered

The output of linkage maps in cases of termination due to errors is specifiable.

- (e) Easier specification of input files

Binary files are specifiable as input files at the time of output of relocatable files.

## 10. Functions Added and Improved in Ver. 10.00

- (a) Multiplication of the number for alignment in setting up section sizes

The **padding** option can be used to multiply the number for alignment in setting up section sizes.

## 11. Functions Added and Improved in Ver. 10.01

- (a) Alignment on boundaries

The **aligned\_section** option can be used to change the boundary-alignment number for specified sections to 16 bytes in linkage units.

- (b) Specifying the section attributes of binary data

The **binary=<section attribute>** option can be used to specify the section attributes of binary data.



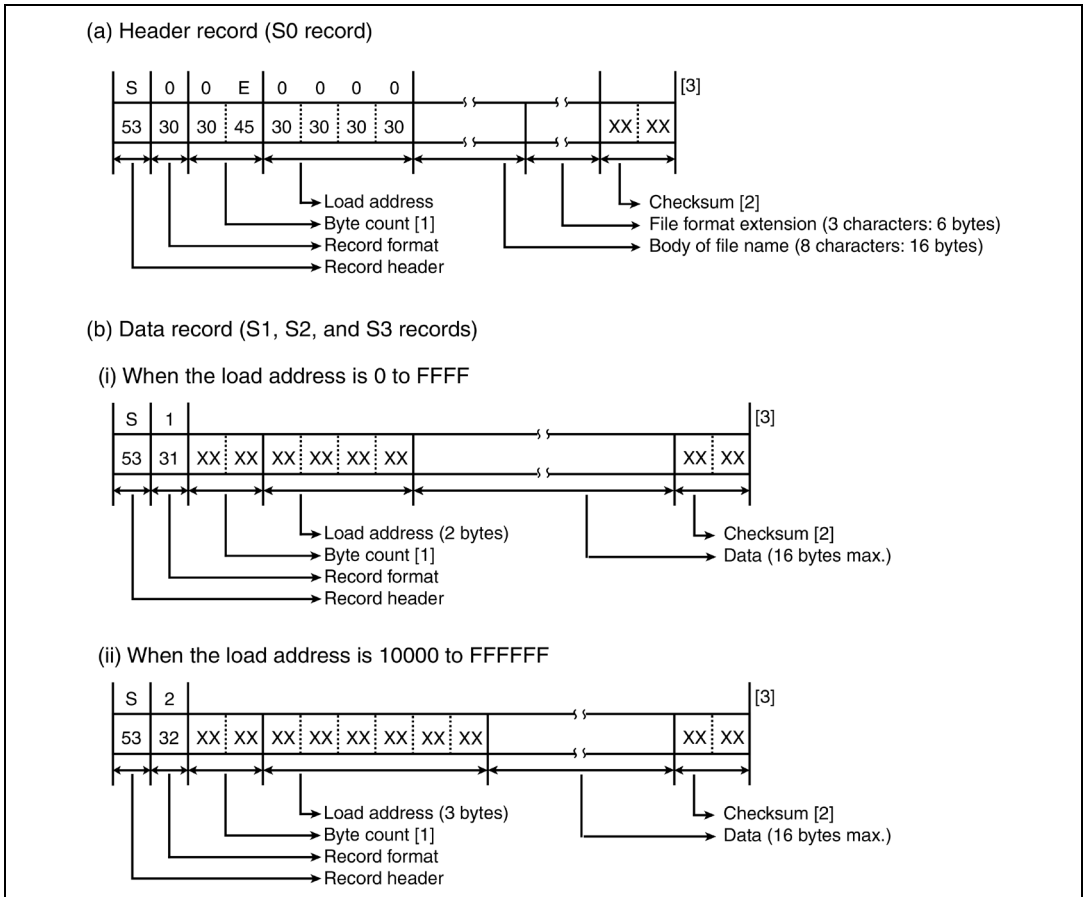


## Section 17 Appendix

### 17.1 S-Type and HEX File Format

This section describes the S-type files and HEX files that are output by the optimizing linkage editor.

#### 17.1.1 S-Type File Format



**Figure 17.1 S-Type File Format**

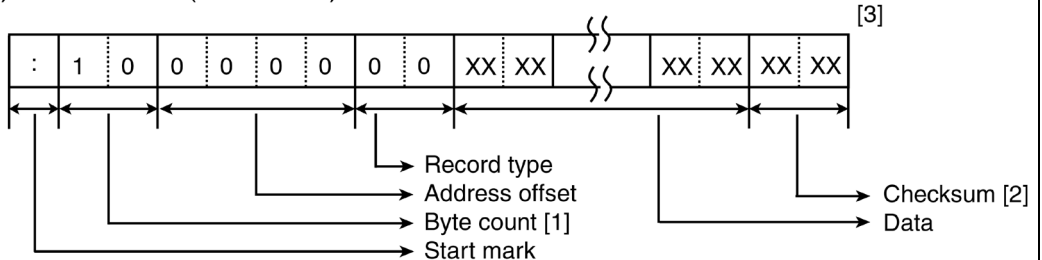


### 17.1.2 HEX File Format

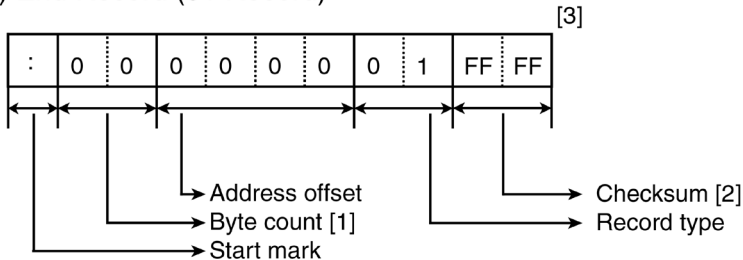
The execution address of each data record is obtained as described below.

- Segment address  
(Segment base address  $\ll 4$ ) + (Address offset of the data record)
- Linear address  
(Linear base address  $\ll 16$ ) + (Address offset of the data record)

## (a) Data Record (00 Record)



## (b) End Record (01 Record)



## (c) Expansion Segment Address Record (02 Record)

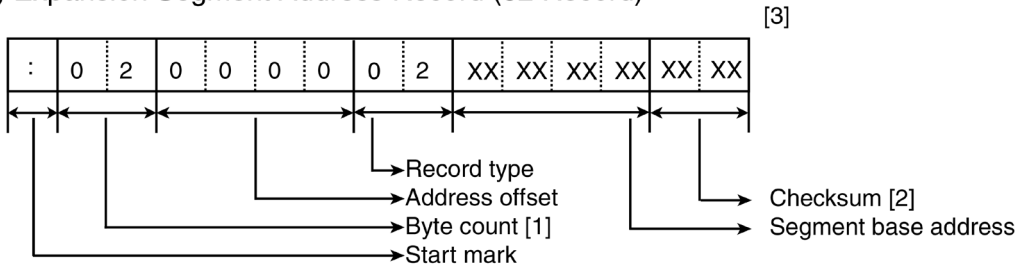
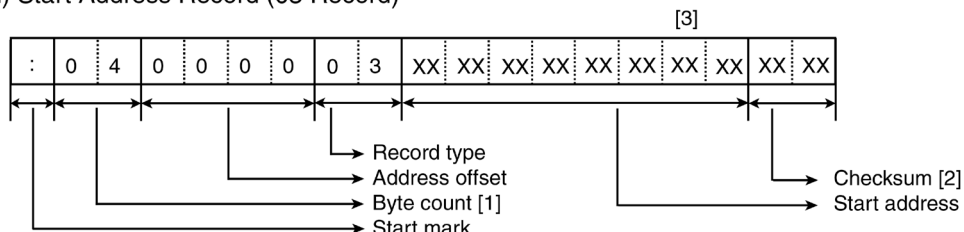
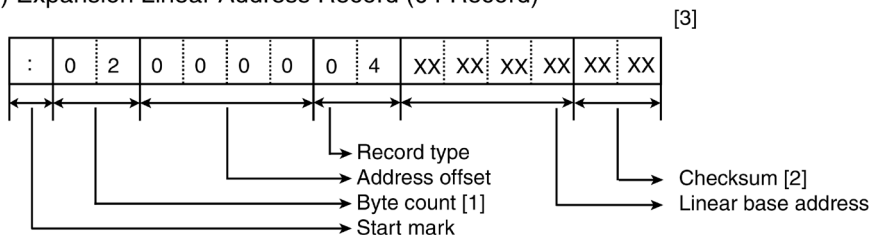


Figure 17.2 HEX File Format

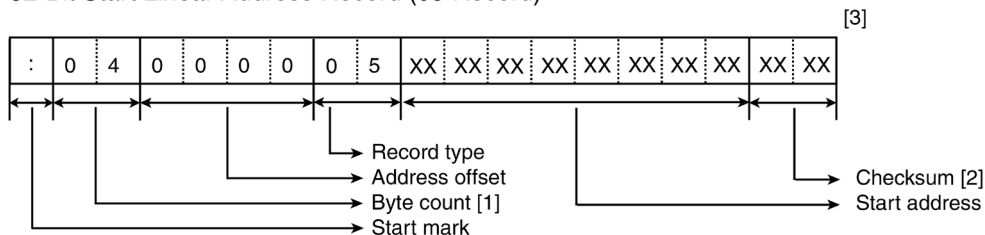
(d) Start Address Record (03 Record)



(e) Expansion Linear Address Record (04 Record)



(f) 32-Bit Start Linear Address Record (05 Record)



- Notes: [1] The number of bytes from the byte following the record type to the previous byte of the checksum.  
 [2] 2's complement of the sum of the byte count and the data between the byte count and checksum, in hexadecimal (lower 8 bits are valid).  
 [3] Line feed is added immediately after the checksum.

Figure 17.2 HEX File Format (cont)

## 17.2 ASCII Code List

Table 17.1 ASCII Code List

| Lower 4 bits | Upper 4 bits |     |    |   |   |   |   |     |
|--------------|--------------|-----|----|---|---|---|---|-----|
|              | 0            | 1   | 2  | 3 | 4 | 5 | 6 | 7   |
| 0            | NUL          | DLE | SP | 0 | @ | P | ` | p   |
| 1            | SOH          | DC1 | !  | 1 | A | Q | a | q   |
| 2            | STX          | DC2 | "  | 2 | B | R | b | r   |
| 3            | ETX          | DC3 | #  | 3 | C | S | c | s   |
| 4            | EOT          | DC4 | \$ | 4 | D | T | d | t   |
| 5            | ENQ          | NAK | %  | 5 | E | U | e | u   |
| 6            | ACK          | SYN | &  | 6 | F | V | f | v   |
| 7            | BEL          | ETB | '  | 7 | G | W | g | w   |
| 8            | BS           | CAN | (  | 8 | H | X | h | x   |
| 9            | HT           | EM  | )  | 9 | I | Y | i | y   |
| A            | LF           | SUB | *  | : | J | Z | j | z   |
| B            | VT           | ESC | +  | ; | K | [ | k | {   |
| C            | FF           | FS  | ,  | < | L | \ | l |     |
| D            | CR           | GS  | -  | = | M | ] | m | }   |
| E            | SO           | RS  | .  | > | N | ^ | n | ~   |
| F            | SI           | US  | /  | ? | O | _ | o | DEL |

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